Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2013.807057

52 (2014) 2717–2723
March

Taylor & Francis
Taylor & Francis Group

Effect of baffled water-holding garden system on disposal of rainwater for green building residential districts

Hong-Xiang Chai[a,*], Sui-Bing Shen[a], Xue-Bin Hu[a], Song-Ming Tan[b], Hong Wu[b]

[a]*Key Laboratory of the Three-Gorge Reservoir's Eco-Environments, Ministry of Education, Chongqing University, Chongqing, China*
Email: chaihx@126.com
[b]*Shengzhen Yuezhong Group Co., Ltd., Shenzhen, China*

Received 12 July 2012; Accepted 28 January 2013

ABSTRACT

With the acceleration of human urbanization process and the changes of hydrological cycle in cities, urban rainfall runoff pollution has become a problem and should be solved as soon as possible. Based on the concepts of enhancing infiltration rate of rainwater and reducing runoff pollutants in source area, a baffled water-holding garden system for processing rainwater in green building residential district was developed. The system was characterized as a gridized water-holding area which was composed of baffled guide walls and barrier strips. Collected rainwater overflowed into the next sub-water-holding area from the former. During the running process, rainwater was permeated into ground and retained in sub-water-holding areas; hence, rainwater energy was reduced gradually. Furthermore, runoff erosion to plant-growing area was buffered effectively. This system can effectively control runoff pollution, reduce runoff volume, and prolong the rainwater runoff confluence time to reduce downstream peak flow. The design method of baffled water-holding garden system was described through a case study. The results in this case showed that the ratio of water-holding area and confluence area was 1:48, and the reduction rate of peak flow was up to 50%. The control rate of annual rainfall runoff volume can reach 83.7% in case area, correspondingly, the removal efficiency of TSS of annual runoff was estimated by more than 83.7%.

Keywords: Green building; Rainwater; Low-impact development; Baffled water-holding garden; Design method

1. Introduction

With the acceleration of human urbanization process, natural watershed has been greatly affected, and the land use pattern has been changed to a large extent [1]. Urban commercial and industrial areas, residential areas, concrete constructions, asphalt pavements, plazas, parking lots, and other impervious surface areas are increasing, resulting in the increase in urban surface runoff and advancing of stormwater peak flow [2,3]. Due to the urban natural hydrological

*Corresponding author.

Presented at the Second International Conference on Water Resources Management and Engineering (ICWRME 2012) Zhengzhou, China, 14–16 August 2012

cycle changing caused by human activity, urban waterlogging risk is exacerbated by rainfall runoff, [4] the groundwater level is decreasing [5] and pollutants carried in rainfall runoff causes serious surface water pollution [6–8]. Nowadays, urban runoff pollution as the second largest non-point source pollution is increasingly affecting the sustainable development of cities [9,10].

In the past 20 years, rainwater ecological treatment and utilization, which was used as one of the most important ways of alleviating water shortage problems in cities and rehabilitating of urban natural hydrological cycle [11,12], were studied by many countries such as the USA, Australia, France, Germany, Italy, and Japan. In 1990s, the US stormwater management experts developed a micro-multi-point rainstorm control strategy, namely, low-impact development (LID). This system was based on the concept of rainfall runoff pollution control in source areas, to simulate the principle of the natural hydrological conditions [13,14]. LID focuses on local conditions. The quantity and quality of urban rainfall runoff is controlled through a series of ecological treatment measures such as protectable design, bio-retention, filter penetration, and runoff storage, etc. [15].

At present, most of the cities in China use combined or separated sewer system. Combined sewer system collects rainwater and sewage together to discharge into the wastewater treatment plant, while the separated sewer system collects rainwater and sewage separately and the collected rainwater is discharged into natural water bodies. But both the two traditional systems ignore the collection and utilization of rainwater or penetration in source region to reduce urban rainfall runoff [16]. Currently, some advanced stormwater management concepts and measures are available as reference for China, so the rainwater ecological treatment and utilization in China have potential good opportunities for development. LID techniques are widely adopted in Australia, the USA, and other countries [17–19], and application in China is rapidly rising.

Rainwater garden is a rainwater ecological treatment facilities based on the concept of LID [20] and is also a rainwater bio-retention and purification engineering facilities located in low-lying green region. Species of shrubs, flowers and even trees and other plants are planted in rainwater garden. Soil and plants in this garden play the main role of filtering and decomposing pollutants carried in rainwater runoff. At the same time, collected rainwater is temporarily stranded and then slowly penetrates into the soil to reduce runoff volume [21–23]. The rain garden includes two types: one is to mainly control runoff pollution, and the other is to mainly control volume of rainwater runoff. However, both of the two types are failed to effectively control water quantity and water quality of rainwater.

On the basis of the researches of LID technology for rainwater ecological treatment and the traditional design methods of rainwater garden [24,25], a new baffled water-holding garden system was developed to both strengthen rainwater penetration and reduce runoff pollution, and finally, to achieve the purpose of effective and synchronous control for rainwater runoff volume and quality in the whole rainfall source areas.

2. Structure of the baffled water-holding garden system

The structure of baffled water-holding garden system is shown in Fig. 1. This system is mainly composed of annular gap-catchment sink and gridized water-holding area. The gridized water-holding area is composed of baffled guide walls, barrier strips, and plant-growing areas, etc. The baffled water-holding garden system is built in the lower-lying green area or the district of low elevation greenbelt of green building residential districts and close to the collecting port of municipal storm sewer system or rainwater utilization system. At the same time, the whole environmental coordination between the system and the residential district should be taken into account, and the spacing of the system should not be larger than 3 m from the basis of the surrounding buildings [26].

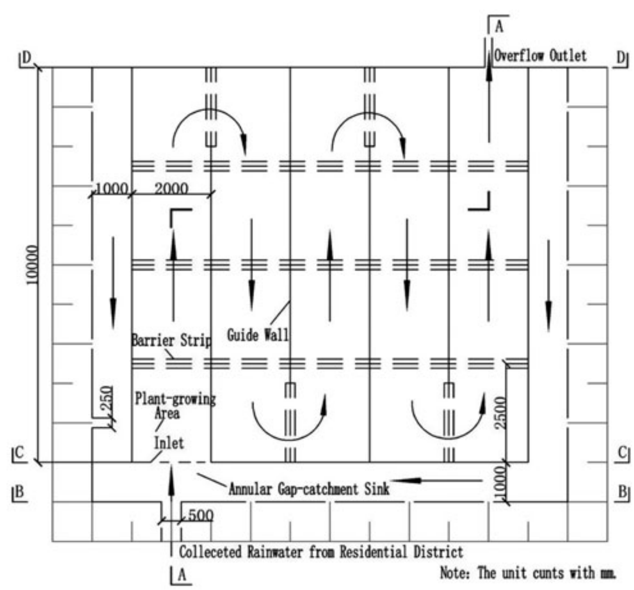

Fig. 1. Schematic of the structure of baffled water-holding garden system.

2.1. Annular gap-catchment sink

For rainfall runoff fully or timely flowing into the baffled water-holding garden, an annular gap-catchment sink is set outside the baffled water-holding area. There are many gaps in the shape of inverted equilateral trapezoid on the outside retaining wall of the sink, as shown in B-B profile in Fig. 2, and these gaps are equidistant with each other. Rainwater collected from residential districts flows into the catchment sink across a special gap, which is close to the inlet of baffled water-holding area. And the rainfall runoff of other confluence areas is collected by low elevation greenbelt and finally flows into the annular gap-catchment sink across other normal gaps. The bottom of the annular gap-catchment sink is paved with pebbles, and it also has a certain amount capacities of rainwater infiltration. Owing to the annular structure of the catchment sink, collected runoff can be buffered effectively, furthermore, to ensure the collected rainwater flows into baffled water-holding area uniformly and continuously.

2.2. Baffled water-holding area

The entire water-holding area of the system is divided into several corridors by parallel and staggered guide walls, and water flowing path in the water-holding area along the corridors is in the shape of "*S*".

The setting of baffled guide walls plays an important role in effectively increasing rainwater flowing time and decreasing rainwater velocity in the water-holding area, and thus, sharply prolongs the rainwater confluence time as a whole to reduce the downstream peak flow volume. The baffled guide walls, esthetics of which should be taken into account at the same time, are made of permeable concrete or permeable bricks to enhance rainwater infiltration capacities.

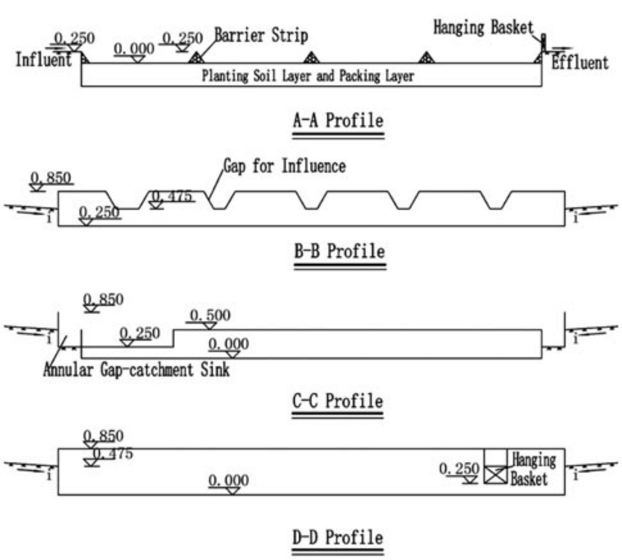

Fig. 2. Profiles of baffled water-holding garden system.

2.3. Barrier strips

By setting several equidistant barrier strips within each corridor, the corridor is divided into several sub-water-holding areas. Only the front sub-water-holding areas being full of water, the excess rainwater will overflow barrier strips into the next sub-water-holding area.

The barrier strips are composed of different gradations of rocks or pebbles. And the middle part of the barrier strips is made of different gradations of smaller pebbles and ended with larger volume of rocks. The barrier strip profile, one side of which borders on the ground, is in the shape of equilateral triangle, as shown in A-A profile in Fig. 2. Because the whole structure of the barrier strip maintains the triangle stability, it effectively resisted the impact of rainstorm runoff and plays an important role in runoff energy dissipation and water retention. Runoff energy dissipation is useful for decreasing rainwater velocity and sedimentation of particles in water. At the same time, its porous structure could intercept and adsorb pollutants in water effectively. Besides, the baffled guide wall should be higher than the barrier strips with a certain height, and the height from 200 to 250 mm is appropriate.

The whole system is characterized as a gridized water-holding area which is divided by baffled guide wall and barrier strips. During runoff overflowing the sub-water-holding areas, water is stored in each sub-water-holding area and runoff is blocked by barrier strips. Thus, collected rainwater runoff is retained, permeated effectively, and energy-dissipated gradually.

2.4. Planting soil layer and packing layer

The planting soil layer uses modified soil composed of about 55% sand, 15% topsoil, and 30% complex soil, and the water minimum permeability coefficient is not less than 13 mm/h. If planting trees, planting soil thickness is not less than 1 m. Packing layer under the planting soil layer is composed of cinder, blast furnace slag, gravel, etc, and its water minimum permeability coefficient should not be less than 10^{-5} m/s. The packing layer has a good effect on filtration and adsorption of pollutants.

2.5. Plants in water-holding area

The choosing of species of plants grew in water-holding area should give priority to native plants, and these kinds of plants should have resistance abilities against both flood and drought, so more developed root systems are essential for them. Plant-growing area has strong pollutant purification ability. Large particle contaminants are intercepted in the plant-growing area, and contaminants such as nitrogenous compounds, phosphorus compounds, heavy metals are decomposed or absorbed by plants. Besides, plants of high ornamental value or fragrant flowers deserve recommendation for plant-growing area.

2.6. Overflow outlet

If rainwater received in baffled water-holding garden system goes beyond the water-holding design capacity of the whole system, water can be discharged from overflow outlet. The front opening of overflow outlet is provided with a hanging basket for intercepting pollutants. Because rainfall runoff collected from confluence areas has been used and treated well by baffled water-holding garden system, and rainwater volume has been reduced sharply, the excess water overflowed from the outlet is clean enough to be recycled. This part of excess rainwater can be collected by a rainwater storage tank for use or discharged into municipal storm sewer system.

To sum-up, during the running process in the system, pollutants carried in rainfall runoff such as oil, salt, nitrogen, phosphorus, toxic substances, and garbage are reduced effectively through interception, infiltration, sedimentation, and absorption, and the quality of excess water discharged from overflow outlet improves largely as well. In addition, owing to the gridized structure of water-holding area which is composed of baffled guide walls and barrier strips, rainfall runoff collected from confluence areas can be buffered effectively. During the running process, runoff energy is gradually dissipated and runoff velocity is decreased, which prolongs the rainwater runoff confluence time as a whole to reduce the downstream peak flow volume. At the same time, collected rainwater within design return period is retained and permeated completely, which contributes to reducing the downstream peak flow volume as well. Therefore, the baffled water-holding garden can achieve the purpose of the effective and synchronous control of rainwater runoff volume and quality in the whole rainfall source areas.

3. Design method of baffled water-holding garden system and case analysis

3.1. Design method of the water-holding area

In order to achieve the purpose of the synchronously effective control of rainwater quantity and quality in green building residential district, a basic design method was adopted based on the current design codes or standards in China [27]. Combined with case analysis, design as follows:

Roof and ground rainwater collected from a green building residential district in Western China was ecological processed with the baffled water-holding garden system, and the system was located in low elevation greenbelt. According to the complete water balance method [25], factors of the infiltrating capacity of the system, influences of plants in water-holding area, water storage capacity of interspaces were considered comprehensively, and the calculation formula of rainwater confluence area was as follows:

$$A_{\mathrm{d}} = \frac{A_{\mathrm{f}}[60KT(d_{\mathrm{f}} + h) + h_{\mathrm{m}}(1 - f_{\mathrm{v}})d_{\mathrm{f}} + nd_{\mathrm{f}}^2]}{H\varphi d_{\mathrm{f}}} \tag{1}$$

where A_{f} = water-holding area (m^2); A_{d} = confluence area (m^2); H = design rainfall (mm), which is equivalent to the control of runoff volume generated by 90% of annual rainfall events, the value depends on the relationship between design rainfall and removal efficiency of rainfall runoff pollutants and taken as 29.1 mm according to hydrological data and specific requirements for runoff pollutant control in case area [28]; φ = runoff coefficient was estimated to 0.64 according to the weighted average calculation on different surface types in case area; d_{f} = rainwater garden depth (m), generally including planting soil layer and packing layer, taken 1.25 m (considering planting trees, the planting soil layer thickness took 1.0 m; packing layer thickness took 0.25 m); K = planting soil permeability coefficient, taken 4.2×10^{-5} m/s according to permeability of selected soil in case area; T = rainfall duration, taken 120 min; h_{m} = the maximum depth of water-holding layer (m), taken 0.25 m; h = mean design depth of water-holding layer, 1/2 of its maximum depth (h_{m}) was appropriate, taken 0.125 m; f_{v} = proportion of plant cross sectional area accounting for surface of water-holding area, taken 20%; n = voidage, the average of planting soil layer and packing layer, taken 0.3 generally.

For a water-holding area of $A_{\mathrm{f}} = 100\mathrm{m}^2$, as shown in Fig. 1 and it was calculated that the confluence area was $A_{\mathrm{d}} = 4873.5\mathrm{m}^2$, that is, the ratio of rainwater confluence area/water-holding area was about 48.7. Setting five baffled guide walls equidistantly in water-holding area, and the length of each corridor was 10 m and the distance between walls was $B_1 = 2$ m, and the height of baffled guide wall took 0.5 m and the width was 120 mm. Setting three barrier strips equidistantly in each corridor and the distance between strips was 4.25 m, and the height of barrier strips took

0.25 m and the length was 2 m. In addition, the baffled guide walls were made of permeable concrete or permeable bricks.

3.2. Design method of annular gap-catchment sink

The catchment sink was annular with many gaps set on the outside retaining wall, as described in 1.1.

The formula of design storm intensity in case area was as follows:

$$q = \frac{2,509(1 + 0.845\lg P)}{(t + 14.095)^{0.753}} \quad (2)$$

where P = design return period, taken 3a; t = confluence time, taken 5 min.

The formula of rainwater design flow in case area was as follows:

$$Q = \frac{1}{10,000} \times A_d \times \varphi \times \frac{2,509(1 + 0.8451\lg\ P)}{(t + 14.095)^{0.753}} \quad (3)$$

Calculation result of Eq. (3) was Q = 119.15 L/s. The effective volume of annular gap-catchment sink calculated with confluence time of 1 min, and rainwater volume was (119.15 × 60)/1,000 = 7.15 m^3. The width of gap-catchment sink took B_2 = 1 m and the length of gap-catchment sink was 31.96 m, as shown in Fig. 1. It was calculated that the depth of collected rainwater in gap-catchment sink was 0.224 m, taken 0.225 m.

The gaps on the outside retaining wall were in the shape of inverted equilateral trapezoid, and the width of trapezoid bottom was 0.25 m, and the angle of bevel edge and vertical direction was 30 degrees and the height of trapezoid was 0.375 m. There were five gaps used for influent set on the outside retaining wall of each edge of catchment sink. The bottom width of the special gap used for receiving collected rainwater from green building residential area was 0.5 m. In addition, the bottom of the annular gap-catchment sink was paved with pebbles of about 5 cm in diameter.

3.3. Control rate of stormwater peak flow

The design rainfall of water-holding area is H = 29.1 mm in case area. For a rainfall event, runoff volume within the design scale of rainfall can be cut completely by the baffled water-holding garden system [29]. Consequently, letting T be the rainfall duration, calculation formula was as follows:

$$H = \frac{60}{10,000} \times \frac{2,509(1 + 0.845\lg P)}{(T + 14.095)^{0.753}} \times T \quad (4)$$

It was calculated that T = 19.35 min. Because of the retention of the system, confluence time was extended to ($t + T$), with rainwater runoff changing to Q' (L/s).

$$Q' = \frac{1}{10,000} \times A_d \times \varphi \times \frac{2,509(1 + 0.845\lg P)}{(t + T + 14.095)^{0.753}} \quad (5)$$

It was calculated that Q' = 62.89 L/s. Supposed that excess rainwater beyond the design rainfall took T' minutes to flow out of the water-holding area.

$$V = Q'/(\Delta h \times B_1) \quad (6)$$

$$T' = L/v \quad (7)$$

In Eqs. (6) and (7), Δh (= 0.1 m) was the design height of water surface of overflow outlet, and L (= 50 m) was the total length of corridors in baffled water-holding area. The calculation results of Eqs. (6) and (7) were as follows: v = 0.32 m/s, T' = 2.6 min. And then, the peak flow volume in overflow outlet was cut to Q'':

$$Q'' = \frac{1}{10,000} \times A_d \times \varphi \times \frac{2,509(1 + 0.8451\lg P)}{(t + T + T' + 14.095)^{0.753}} \quad (8)$$

The calculation results of Eq. (8) were Q'' = 59.86 L/s. For rainfall events of design return period p = 3a, the reduction rate of peak flow in baffled water-holding area was as follows:

$$\phi = 1 - Q''/Q = 1–59.86/119.15 = 49.76\%$$

The design rainfall (H) adopted in this case was determined with pollutants control rate of rainfall runoff produced by 90% annual rainfall events in case area. According to the statistical analysis, when H took 29.1 mm in case area, the control rate of annual rainfall volume was up to 83.7% correspondingly [28].

For those rainfall events less than the design rainfall in case area, the rainfall runoff and pollutants carried in which are completely retained and removed. Pollutants carried in runoff mainly involve TSS, while the unique structure of the baffled water-holding garden system is suitable for controlling TSS carried in runoff. If taking the average concentration of TSS of annual rainfall runoff pollutants into account, the removal efficiency of TSS of annual rainfall pollutants is equal to the control rate of annual rainfall volume. In fact, for a rainfall event, the first flush carries higher TSS, so the effective control of initial rainwater runoff means too much for an entire rainfall event. Moreover, the latter runoff in a rainfall event carries lower TSS and tends to be stable, and the control of runoff of this phase cannot contribute much more to TSS removing than the first flush for an entire rainfall event. Therefore, for the rainfall runoff control rate of 83.7%, TSS carried in an entire rainfall event can be removed to more than 83.7%.

3.4. Design method of overflow outlet

The overflow outlet adopted broad crest weir, and the design flow could be calculated according to the following formula [30]:

$$Q'' = 385b\sqrt{2g}\Delta h^{2/3} \tag{9}$$

where Q'' (L/s) was the design overflow of service area; b (m) was the width of overflow outlet; Δh (m) was the height of overflow outlet, taken 0.1 m.

It was calculated that $b = 0.163$ m, taken 0.170 m.

4. Results

Baffled water-holding garden system is a kind of technique of low-impact development, and the system is characterized as a gridized water-holding area which is composed of baffled guide walls and barrier strips. Collected rainwater overflows into the next sub-water-holding area from the former. During the running process, rainwater is permeated into ground and retained in sub-water-holding areas and its energy is dissipated gradually; furthermore, some parts of particulate pollutants are settled down or intercepted, and runoff erosion to plant-growing areas is buffered effectively. In addition, this system can effectively control runoff pollution, reduce rainfall runoff volume, and prolong the rainfall runoff confluence time as a whole to reduce the downstream peak flow volume. The results of rainwater ecological treatment for a green building residential district in Western China showed that, the ratio of water-holding area and flow concentration area was 1:48, and the reduction rate of peak flow was up to 50%. The control rate of annual rainfall volume can reach 83.7%, correspondingly, the removal efficiency of TSS of annual runoff was estimated by more than 83.7%.

Acknowledgements

The work reported here was financially supported by the State Water Pollution Control and Harnessing of the Major Projects (People's Republic of China, Grant No. 2010ZX07320-001).

References

[1] A. Brath, A. Montanan, G. Moretri, Assessing the effect on flood frequency of land use change via hydrological simulation (with uncertainty), J. Hydrol. 324(1–4) (2006) 141–153.
[2] J.H. Lee, K.W. Bang, L.H. Ketchum, Jr., J.S. Choe, M.J. Yu, First flush analysis of urban storm runoff, Sci. Total Environ. 293(1–3) (2002) 163–175.
[3] L. Gottschalka, R. Weingartner, Distribution of peak flow derived from a distribution of rainfall volume and runoff coefficient, and a unit hydrograph, J. Hydrol. 208(3–4) (1998) 148–162.
[4] A. Deletic, The first load of urban surface runoff, Water Res. 32(8) (1998) 2462–2470.
[5] P. Göbel, H. Stubbe, M. Weinert, J. Zimmermann, S. Fach, C. Dierkes, H. Kories, J. Messer, V. Mertsch, W.F. Geiger, W.G. Coldewey, Near-natural stormwater management and its effects on the water budget and groundwater surface in urban areas taking account of the hydrogeological conditions, J. Hydrol 299(3–4) (2004) 267–283.
[6] J.H. Lee, K.W. Bang, Characterization of urban stormwater runoff, Water Res. 34(6) (2000) 1773–1780.
[7] J.Y. Kim, J.J. Sansalone, Event-based size distributions of particulate matter transported during urban rainfall-runoff events, Water Res. 42(10–11) (2008) 2756–2768.
[8] L.-H. Kim, H.-M. Kang, W. Bae, Treatment of particulates and metals from highway stormwater runoff using zeolite filtration, Desalin. Water Treat. 19 (2010) 205–211.
[9] Y. Li, J. Ma, Z. Yang, I. Lou, Influence of non-point source pollution on water quality of Wetland Baiyangdian, China, Desalin. Water Treat. 32 (2011) 291–296.
[10] W. Che, Y. Liu, J. Q. Li, Flush model of runoff on urban non-point source pollutants and analysis, Water and Environmental Management Series, Water in China, IWA Publishing, 2003, pp. 143–150.
[11] P.J. Coombes, J.R. Argue, G. Kuczera, Figtree Place: A case study in water sensitive urban development (WSUD), Urban Water, 1999.
[12] M. Zaizen, T. Urakawa, Y. Tkai, H. Takai, The collection of rainwater from dome stadiums in Japan. Urban Water, 1999.
[13] M.E. Dietz, Low impact development practices: A review of current research and recommendations for future directions, Water Air Soil Pollut. 186(1–4) (2007) 351–363.
[14] A.H. Elliott, S.A. Trowsdale, A review of models for low impact urban stormwater drainage, Environ. Model. Softw. 22(3) (2007) 394–405.
[15] N.B. Chang, M.P. Wanielista, A. Makkeasorn, Innovative design of low impact development in support of green building initiative, Environ. Inf. Arch. 5 (2007) 66–85.
[16] J.Q. Li, W. Che, Rainwater problems and countermeasures for sustainable development in cities, Urban Environ. Urban Ecol. 18(4) (2005) 5–8.
[17] USEPA, Reducing stormwater costs through low impact development(LID) strategies and practices (2007) 08–25. Available from: http: //www.epa.gov/nps/ lid
[18] B. Rushton, Low-impact parking lot design reduces runoff and pollutant loads, J. Water Resour. Plan. Manage. 127(3) (2001) 172–179.
[19] F. Montalto, C. Behr, K. Alfredo, M. Wolf, M. Arye, M. Walsh, Rapid assessment of the cost-effectiveness of low impact development for CSO control, Landscape Urban Plan. 82(3) (2007) 117–131.
[20] C. Kloss, Green infrastructure for urban stormwater management, in: N. She, M. Cha (Eds.), Low Impact Development for Urban Ecosystem and Habitat Protection, Seattle, Washington, USA, 2008.
[21] M.E. Dietz, J.C. Clausen, A field evaluation of rain garden flow and pollutant treatment, Water Air Soil Pollut. 167(1–4) (2005) 123–138.
[22] B.C. Asleson, R.S. Nestingen, J.S. Gulliver, R.M. Hozalski, J.L. Nieber, Performance assessment of rain gardens, JAWRA 45(4) (2009) 1019–1031.
[23] H. Yang, D.C. Florence, E.L. McCoy, W.A. Dick, P.S. Grewal, Design and hydraulic characteristics of a field-scale bi-phasic bioretention rain garden system for storm water management, Water Sci. Technol. 59(9) (2009) 1863–1872.

[24] R. Bell, D. Dilollo, K. Smarz, M. Ling, C. Ambos, E. Jackson, D. Knezick, R. Pillar, T. McQuade, I. Martin, Rain garden manual for New Jersey, Office of Continuing Professional Education Cook College 102 Ryders Lane New Brunswick, New Jersey, 2005.
[25] L.L. Xiang, J.Q. Li, N. Kuang, W. Che, Y. Li, X. Liu, Discussion on the design methods of rainwater garden, Water Wastewater Eng. 34(6) (2008) 47–51.
[26] Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD), Engineering technical code for rain utilization in building and sub-district (GB50400-2006), China Architecture & Building Press, Beijing, 2006.
[27] Shanghai Urban Construction and Communications Commission, Code for Design of Outdoor Wastewater Engineering (GB50014-2006), China Planning Press, Beijing, 2011.
[28] G.Q. Pan, W. Che, J.Q. Li, H.Y. Li, Urban runoff pollution control quantity and its design rainfall in China, Chin. Water Wastewater 24(22) (2008) 25–29.
[29] J.Q. Li, W.L. Wang, J. Bian et al., Eco-technologies and case study on disposal of urban road runoff, Chin. Water Wastewater 26(16) (2010) 60–64.
[30] Architectural Design & Research Institute of Tongji University, Technical Specification for Symphonic Drainage System of Roof (CECS 183–2005), China Planning Press, Beijing, 2005.