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A Literature Survey on Green Roof Performance Management for Runoff Water Quantity

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Abstract:
The role of green roofs in urban drainage is requiring both management of water quantity and quality. Results from investigation of full scale installations as well as from laboratory models are reviewed. The following factors affecting runoff dynamics from green roofs are discussed: type of green roof and its geometrical properties (slope); soil moisture characteristics; season, weather and rainfall characteristics; age of green roof; vegetation. Design parameters as suggested by different authors are also reviewed. Factors which affect influence of a green roof on runoff water quality are discussed in general terms followed by the review of data regarding concentrations of phosphorus, nitrogen, and heavy metals in green roof runoff, its' pH, and first flush effect. Linking among fertilization, runoff pollution and vegetation development is given a particular focus. The review indicates clearly that there is a need for more research into a green roof performance in an urban environment.. The differences measured by few existing studies between the early years performance of green roofs and the later years indicate a need for long term monitoring of green roofs..

Keywords

Waste water, Run off Water, Green Roof

1. Introduction

The global population is becoming more concentrated in urban areas. The percentage of urban population worldwide is increasing. Urban areas are constantly expanding in terms of space and density. One effect of urbanization is an increase of the area of impermeable surfaces. This in turn has numerous consequences for some city infrastructure and Surrounding environment. Regarding storm water the infiltration decreases and, in effect the surface runoff and the stress on existing storm water infrastructure- true increases. Flooding from sewers in urban areas may become more frequent. Additionally studies indicate that in certain areas global warming may cause increased frequency of intense precipitation Events which will also lead to increased urban flooding.

Furthermore, new developments are often made at the expense of green areas. Fewer green areas in turn cause a decrease in canopy interception and transpiration within the city leading to increased temperature and decreased air humidity.

Green roofs have a potential for providing an attractive green space in downtown areas where the green space on the ground is limited or simply non-existing. In many countries interest in green roofs is increasing. The design of green roofs varies between different localities and depends on the roof purpose. The green roofs are often established because of aesthetic reasons. That green roofs can be appreciated pieces of art is confirmed by numerous public-cautions with photographs of outstanding examples of sky-gardens, vegetated roofs, planted rooftops, eco roofs, living roofs, green roofs and whatever they can be called. In this review the terms green roof and vegetated roof are used to name any type of soil–vegetation system established on building floors or roofs excluding the cases of pot vegetation. Some sources suggest that the particular terms refer to a particular roof type, for example eco roof describing a naturalistic green roof and roof garden referring to an area of ornamental planting on the man- made structure isolated from the natural ground However, there seems to be no consistency in the use of the terminology and the different terms are often used interchangeably.

What the development of green roofs focused so far on the roof construction, choice of soil mix and management to establish a green roof, to support vegetation, to achieve aesthetical benefits. Many of other benefits are named but so far generally the green roofs are not optimized to meet those. The performance of green roofs in urban environment towards achieving various benefits is not either well known. The more investigations are made on green roofs performance in urban environment the more research needs are identified. Green roofs need to be further developed for urban applications and their ability towards various benefits need to be optimized. The potential for improvements is large.

This review seeks a quantitative evidence of how a green roof influences urban drainage with regard to storm water quantity and quality. This paper provides a review of currently available knowledge originating from scientific research. Publications of popular/commercial character where the research methodology is not exactly explained are not included. Results from investigation of full scale installations as well as laboratory models are reviewed.

2. Fundamental Concept behind the Technology

Commonly construction of green roofs involves four layers: drainage material, filter preventing the loss of soil particles, soil substrate and vegetation. The thickness of the layer material and composition and the type of vegetation show great variation between different producers/designers. Requirements on the roof underlying the vegetated construction include waterproofing and protection against root penetration.

Green roofs are typically divided into two main engineering categories: intensive and extensive. Intensive green roofs are established with deep soil layers; they can support larger plants and bushes and typically require maintenance in the form of weeding, fertilizing, and watering. Extensive vegetated roofs are established with thin soil layers. They are planted with smaller plants which in the final stage are expected to provide full coverage of the vegetated roof. Extensive vegetated roofs are most commonly aimed to be maintenance free, but some fertilization is often recommended for the commercial products. Extensive vegetated roofs may be established in various ways: through prefabricated vegetation mats, shot planting, seed sowing, and spontaneous self-established vegetation. Few references identify a third category of green roofs: simple-intensive (semi-intensive) which are vegetated with lawns and ground covering plants. These roofs require frequent maintenance including cutting, watering, and fertilization.

There is no agreement between different sources regarding the thickness of the soil for various roof types; A green roof with a substrate depth of 110–150 mm can be regarded by different authors as intensive or extensive. Therefore caution is needed while comparing green roofs performance towards obtaining benefits which depend on the soil layer thick- ness. A green roof changes storm water runoff compared with that from a hard roof through lowering and delaying the peak runoff (there is a time lag between the peak from a hard roof and a green roof for the same rain event). This is because a certain water volume is detained in a green roof. A portion of the detained water will drain and a portion corresponding to field capacity will be retained. The retained water will evaporate or be used by plants and parts of it will transpire. It is the evaporated and transpired water that explains the observed runoff volume reduction from green roofs.

Factors which influence green roof water retention capacity and runoff dynamics depend on:

- Green roof characteristic: number of layers and type of materials, soil thickness, soil type, vegetation cover, type of vegetation, roof geometry: slope/length of slope, roof position, roof age;
- Weather conditions: length of

proceeding dry
Period

The soil properties as well as moisture conditions before rain event are crucial for how much water will be detained and finally which portion of runoff will be reduced. Water content in the soil is given as % of volume or % of weight. When all pores are filled with water the soil is in saturated conditions. Field capacity describes the water content after free drainage. The volume of drained water is called specific yield or gravitational water.

The numerical values describing green roofs performance towards water management cannot be directly compared as factors concerning the green roof performance are seldom the same in different studies. Therefore the review discusses the similarities and differences in performance patterns as found by different studies.

3. Factors affecting green roof water

A green roof changes storm water runoff compared with that from a hard roof through lowering (attenuation) and delaying the peak runoff (there is a time lag between the peak from a hard roof and a green roof for the same rain event). This is because a certain water volume is detained in a green roof. A portion of the detained water will drain and a portion corresponding to field capacity will be retained. The retained water will evaporate or be used by plants and parts of it will transpire. It is the evaporated and transpired water that explains the observed runoff volume reduction from green roofs.

Factors which influence green roof water retention capacity and runoff dynamics depend on:

- green roof characteristic: number of layers and type of materials, soil thickness, soil type, vegetation cover, type of vegetation, roof geometry: slope/length of slope, roof position (e.g. shadowed or not, faced direction), roof age;
- weather conditions: length of proceeding dry period, sea-son/climate (air temperature, wind conditions, humidity), characteristics of rain event (intensity and duration).

The numerical values describing green roofs performance towards water management cannot be directly compared as fac- tors concerning the green roof performance are seldom the same in different studies. Therefore the review discusses the similari-ties and differences in performance patterns as found by different studies.

4. Rainfall–runoff relationship

All reviewed studies show that the green roofs have an effect on stormwater runoff reduction. How large this effect is depends on the thickness of the soil substrate, its water content, size of pre-cipitation event or precipitation distribution during study periods. It also may depend on the roof age, vegetation cover, and slope as discussed later. Exact values of runoff reduction (presented as a % of precipitation) can hardly be compared between different studies due to different conditions in which studies were performed (e.g. weather) and different number of events (length of study period) which were included to calculate the presented retention values.

5. Substrate soil moisture characteristics

Few studies present the soil moisture characteristics for studied green roofs, although these describe the soil water holding capacity and thus potential for storm water runoff reduction. That runoff from green roof does not occur until the soil is at field capacity. For the studied extensive vegetated roof, it was 9–10 mm of rain if rain occurred after a dry period. Regarding the runoff process it was observed for more intense rain events that the storage on the roof could increase above the max storage capacity, for studied example the storage computed as the difference between the rain intensity and runoff intensity was 12 mm.

6. Role of the age of green roof

The vegetated substrate of green roofs undergoes various chemical and physical changes with time: soil particles may be lost, dissolvable substances are washed off with water, organic content may increase, the porosity of the soil changes e.g. due to development of roots. It can thus be expected that the age of green roofs would influence runoff dynamics. Still very few studies address the changes of hydraulic performance of aging green roofs.

7. Green roofs influence on urban catchment

Three scenarios are studied: existing land cover, all roofs green, flat roofs green. Roofs accounted for 15.9% of the total land cover and 29.5% of the imper vious surfaces in the watershed. The share of roofs suitable for greening, in these study called flat roofs, was identified. In 3 of 8 studied area zones share of flat roofs was over 65%. These were commercial and university campus areas. Hydrological modeling showed that the influence from the vegetated roofs on runoff clearly depends upon the size of designed storm event. Even wide spread of green roofs would have the minimal influence on urban runoff for the storm events greater than 2 years, 24 h. Authors conclude that green roofs alone cannot be relied upon to provide complete storm water management at the watershed scale. Larger metropolitan or industrial sites may lead to different conclusion. The green roofs may be an effective tool for managing small storms in highly developed areas.

8. Conclusion

This review paper addressed the role of vegetated roofs in urban drainage considering both management of water quantity and quality with related aspects (geometrical properties, soil type and depth, vegetation and maintenance). It is found that general statements about the potential beneficial role of vegetated roofs in urban environment are common through the current literature. However, the scientific evidence of the various benefits is still insufficient. There are examples of different studies reporting contradictory results. The reason behind this is partly different study conditions and different design of green roofs and possibly partly too short study periods. Specialists doing research on green roofs tend to focus on their own field, generalizing the other aspects. However, green roofs can potentially benefit many sectors in the urban environment and decisions regarding their construction and design should be based on a number of benefits rather than roofs should be seen as a tool to solve one particular engineering problem. It becomes apparent that as for example when storm water is considered extensive green roofs alone are not an economically sound option for mitigating the runoff problems. However, green roofs used for runoff management with consideration of achieved enhanced aesthetical values followed by increased property prices and in combination with energy saving on heating/cooling the green roofs may turn into a profitable investment.

9. References

[i] Arnell, N.W., 1999. The effect of climate change on hydrological regimes in Europe: a continental perspective. Global Environ. Change 9, 5–23.

[ii]Bates, B.C., Kundzewicz, Z.W., Wu, S., Palutikof, J.P. (Eds.), 2008. Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change. IPCC Secretariat, Geneva, p. 210.

[iii] Bengtsson, L., Grahn, L., Olsson, J., 2005. Hydrological function of a thin extensive green roof in southern Sweden. Nordic Hydrol. 36 (3), 259–268.

Bengtsson, L., 2005. Peak flows from thin sedum-moss roof. Nordic Hydrol. 36 (3), 269–280.

[iv] Bliss, D.J., Neufeld, R.D., Ries, R.J., 2009. Storm water runoff mitigation using a green roof. Environ. Eng. Sci. 26 (2), 407–417.

Brenneisen, S., 2003. The benefits of biodiversity from green roofs-key design consequences. In: Conference proceedings Greening Rooftops for Sustainable Communities, 2003, Chicago.

Brenneisen, S., 2006. Space for urban wildlife: designing green roofs as habitats in Switzerland. Urban Habitats 4 (1), 27–36, www.urbanhabitats.org.

Carter, T., Jackson, C.R., 2007. Vegetated roofs for stormwater management at mul- tiple spatial scales. Landscape Urban Plan. 80, 84–94.

Carter, T.L., Rasmussen, T.C., 2006. Hydrologic behavior of vegetated roofs. J. Am. Water Resour. Assoc. 42 (5), 1261–1274.

Currie, B.A., Bass, B., 2008. Estimates of air pollution mitigation with green plants and green roofs using the UFORE model. Urban Ecosyst. 11, 409–422.

erndtsson, J., Emilsson, T., Bengtsson, L., 2006. The influence of extensive vegetated roofs on runoff quality. Sci. Total Environ. 355 (1–3), 48–63.

Czemiel Berndtsson, J., Bengtsson, L., Jinno, K., 2008. First flush effect from vegetated roofs during simulated rain events. Hydrol. Res. 39 (3), 171–179.

Czemiel Berndtsson, J., Bengtsson, L., Jinno, K., 2009. Runoff water quality from intensive and extensive vegetated roofs. Ecol. Eng. 30, 271–277.

DeNardo, J.C., Jarrett, A.R., Manbeck, H.B., Beattie, D.J., Berghage, R.D., 2005. Stormwater mitigation and surface temperature reduction by green roofs. Trans. ASAE 48 (4), 1491–1496.

Dunnett, N., Nagase, A., Hallam, A., 2008a. The dynamics of planted and colonis- ing species on a green roof over six growing seasons 2001–2006: influence of substrate depth. Urban Ecosyst. 11, 373–384.

Dunnett, N., Nagase, A., Booth, R., Grime, P., 2008b. Influence of vegetation compo- sition on runoff in two simulated green roof experiments. Urban Ecosyst. 11, 385–398.

Earth Pledge, 2005. Green Roofs: Ecological Design and Construction. A Shiffer Design Book, Shiffer Publishing Ltd.

Emilsson, T.U., Czemiel Berndtsson, J., Mattson, J.E., Rolf, K., 2007. Effect of using conventional and controlled release fertilizer on nutrient runoff from various vegetated roof systems. Ecol. Eng. 29, 260–271.

English Nature, 2003. Green roofs: Their existing status and potential for conserving biodiversity in urban areas. English Nature Research Reports, Report no 498, English Nature, Northminster House, Peterborough, UK.

Fang, C.-F., 2008. Evaluating the thermal reduction effect of plant layers on rooftops. Energy Build. 40, 1048–1052.

FLL, 2002. Richtlinie für die Planung, Ausführung und Pflege von Dachbegrünungen (in German) (Guidelines for planning execution and upkeep of Green roof sites). Bonn, Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau E.V.

Gedge, D., Kadas, G., 2005. Green roofs and biodiversity. Biologist 52 (3), 161–169. Getter, K.L., Rowe, D.B., Andresen, J.A., 2007. Quantifying the effect of slope on extensive green roof stormwater retention. Ecol. Eng. 31, 225–231.

Graham, P., Kim, M., 2005. Evaluating the stormwater management benefits of green roofs through water balance modeling. In: Green Roofs for Healthy Cities Con- ference, May 2005, Washington, DC.

Hilten, R.N., Lawrence, T.M., Tollner, E.W., 2008. Modeling stormwater runoff from green roofs with HYDRUS-1D. J. Hydrol. 358, 288–293.

Kosareo, L., Ries, R., 2007. Comparative environmental life cycle assessment of green roofs. Build. Environ. 42, 2606–2613.

Köhler, M., 2003. Plant survival research and biodiversity: lessons from Europe. In: Conference proceedings Greening Rooftops for Sustainable Communities, 2003, Chicago.

Köhler, M., Schmidt, M., Grimme, F.W., Laar, M., de Assunç ão Paiva, V.L., Tavares, S., 2002. Green roofs in temperate climates and in the hot-humid tropics – far beyond the aesthetics. Environ. Manage. Health 13 (4), 382–391.