Constructed Wetlands on Roofs as a Module of Sanitary Environmental Engeneering to Improve Urban Climate and Benefit of the On Site Thermal Effects

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Research Projects and own research show high potential of Roof Gardens for water retention, water purification ability and on Site Thermal effects. Constructed wetlands as a part of sanitarty environmental management help to balance intense rainfalls and improve insulation of buildings while increasing air humidity and lowering air temperature in dense Urban areas.
Key words: roof garden, storm- and rainwater management, sustainable water use, Urban climate.

Mokslinių tyrimų projektai ir nuosavas tyrimas rodo, kad stogų sodai turi didelį šiluminį efektą bei potencialą vandenį sulaikyti (kaupti) ir jį valyti. Apželdinti stogai yra ekologinės aplinkos valdymo dalis, jie padeda balansuoti intensyvias liūtis ir pagerinti pastatų izoliaciją didinant oro drėgnumą ir mažinant oro temperatūrą tankiai gyvenamuose miesto rajonuose.
Reikšminiai žodžiai: stogo sodas, audrų ir lietaus vandens valdymas, miesto klimatas.

Introduction

Climate change, Green house effect, ozone hole and smog are global problems but they affect local spheres, the towns in which we live. In bigger cities the steadily rising concentration of buildings and traffic are causing additional problems. In cities, spacious greenbelts and aisles can improve air exchange. However, at current land prices building density increases and green areas become insufficient for modulating urban climates. Roof gardens have therefore been recognized as one of the best means to reduce air pollution and counter smog and urban heat island effects. (Fischer, Francesco, Tuiello, Van Velthuitzen, David, Wiberg, 2006).

The continual expansion of cities, the reduction of green spaces, global warming and the increase in energy costs will contribute to the instantaneous expansion and establishment of green roofs and green walls throughout the world during the upcoming years. Because of new requirements, engineers and architects a number of cities will have to include green roofs in their building concepts. Teams comprised of architects, landscape designers, and horticulturists are being organized to expand green roof technology (Trepanier, Boivin, Lany and Dansereau, 2009).

Alternative, decentralized purifications systems like plant purification systems demand a lot of space. While generally in urban areas, there is not enough space for storm water management facilities, water retention can be achieved by flat roofs, which could host roof gardens (Pearlmutter, 2009).

Research projects concerned with the thermal effects of green roofs show that installing and maintaining decentralized grey water purification systems on roofs and benefiting of the thermal benefit for the houses seems to be possible (Thon, Kircher, Pesch, Schmidt, Thon, 2009; Kircher, 2007).

Methods of the Research

Information about the green roofs, thermal impact on buildings and the effect on urban climate were researched using following scientific database:

Science direct Biological Abstracts (BIOSIS), FSTA, AGRIS, Biological Preview.

Researching in reviewed articles found in the databases, following aspects were investigated:

– the possibility of green roofs as water retention systems

- green roofs as locations of grey water purification
- existing systems for decentralized grey water treatment
- impact of vegetation in urban areas
- influence of green roofs on the microclimate and people
- research of the thermal effects of vegetated roofs

Following research projects or pilot facilities were investigated:

- pilot facility on a cow barn in Braunschweig
- pilot facility for Industrial Halls benefiting of thermal effects
- research project of wet constructed wetlands as rooftop greenery as a marginal filter for swimming ponds

Personal experience from long year working in landscape construction and active participation in research projects led to first ideas concerning possibilities of construction, technical aspects, planting design and hydraulics of the vegetated roofs for grey water treatment.

Results

Water retention systems are to regulate the ratio between rainwater retained on site and rainwater piped to the sewage centers. While usually, perticipation falls on sealed roofs and the water is directly piped to the drainage systems, vegetated roofs offer chances to retain water on site. The vegetation intercepts rain and the water velocity is limited. The substrates and the vegetation can collect rainwater. Roof greening can be one opportunity to reduce the water flow and store rainwater in a decentralized way (Endlicher, Jendritzky, Fischer & Redlich, 2006; Marzluff, Shulenberger, Endlicher, Alberti, Bradley, Ryan, Simon, Zumbrunnen (Eds.) 2008; Moriske & Turowski, 1998, FF.).

Installing an additional layer of substrate and vegetation on top of the sealing of the roof will increase the durability of the house sealing by reducing the temperature, UV radiation and thus minimizing the impact of aging of the roof surface. A green roof protects the roof from ultraviolet rays and studies have shown that it can extend the life span of membranes by 20 years or more (Trepanier, Boivin, Lany and Dansereau, 2009).

Using conventional planted roofs temperature peaks on the surface of the roof sealing can be adjusted. The building and the microclimate are positively influenced by:

– Reduction of radiation heating the roof because of shading by the plants. The effect of the leaf convecting the solar radiation and convecting the global radiation can be seen in illustration 1 (Leu, 2008).

– Increased latent heat transfer by evaporation (by transpiration of 1 g water into the atmosphere, the amount of 2.450 kj will be taken of the microclimate and after condensating discharged into the atmosphere(Leu, 2008).

Vegetated roofs have a higher reflexion of short-wave radiation compared to a dark roof, thus reducing greenhouse warming (compare Image 2) (Leu, 2008). The reflection of radiation by green vegetation (solid line) escapes trapping by greenhouse gases, while heat radiations from grey brown bare surfaces are fully absorbed by greenhouse gasses.

For constructed wetlands as a special from of roof garden the evaporations rates are expected to be higher and therefore the positive influence will be stronger compared to conventional roof gardens.

Vegetation has a high value for the citizens of a town. A “green city” has positive effects on the quality of live and on urban climate.

Aesthetically pleasant roofs with aquatic macrophytes and their socialised Fauna (butterflies, birds, dragonflies) will provide high quality living space for people remote from traffic and its associated noise and pollution (Leu, 2008).

Plants have a positive influence on the air of urban areas and their compounds. Vegetation is producing oxygen by photosynthesis and stabilizes the essential content of the air.

A tree is producing about 4 litre of oxygen during a 12-hour day per m² surface of a leaf. Grassland has approximately 100m² leaf surfaces on 1 m² area. An area of 1,5 m² grassland is producing enough oxygen that one human being needs for breathing in one year (Roemert; 1996).

Particular matter and dust can be purified by vegetation. Leafs of plants can bind dust particles and reduce the deposition of particular matter in inner cities.

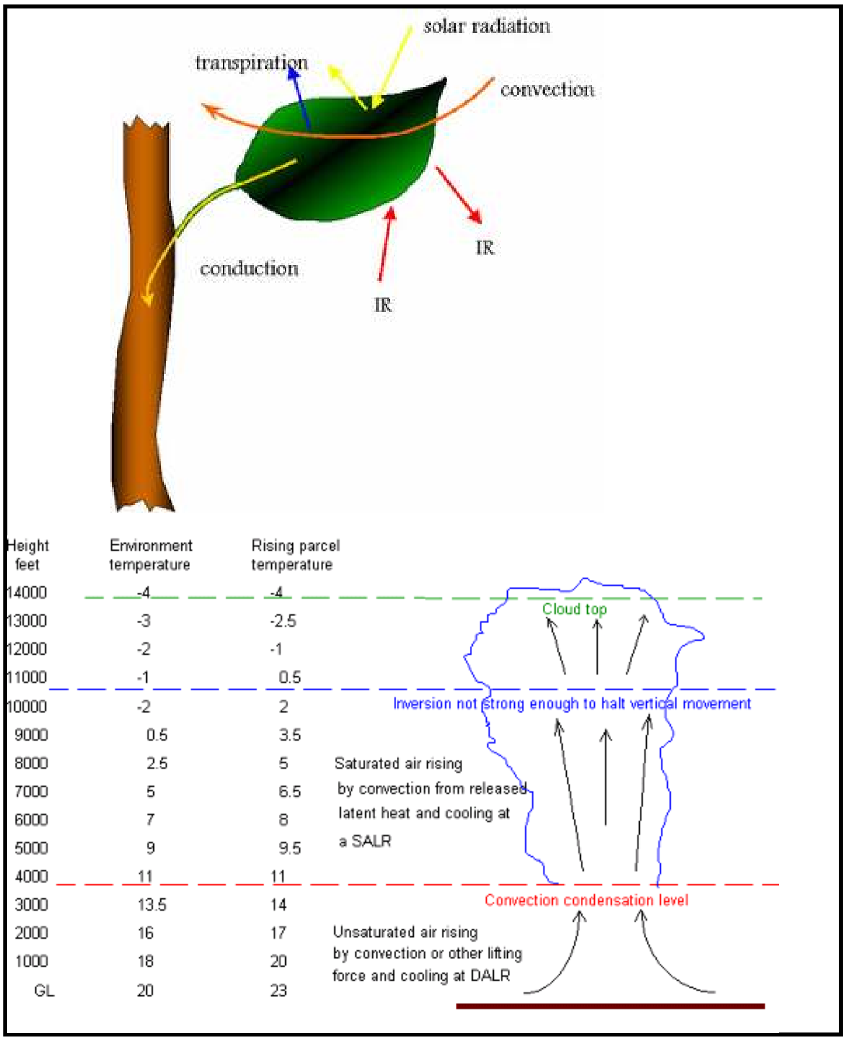

Fig.1. Thermal procedures on a leaf (Leu, 2008)
1 pav. *Lapo šiluminė apykaita* (Leu, 2008)

During a three year, trial six perfused vegetation variants showed encouraging results for an application of biological filters for private swimming ponds. Shallow horizontal filters were installed for an appliance as constructed wetlands on roofs. Purification- and transpiration rates were measured and the thermal effect compared to the surrounding temperature were investigated and analyzed.

Several plant mixtures on different substrates were tested. The air temperature underneath the roof garden models was measured. During the trials the cooling effect of pervaded roof garden vegetation was pretested and first results were encouraging. Accurate measurements and statistical analyses should help in estimating the practical use of swimming pond filters for roof insulation. The roof planting should also help cooling the buildings in summer (Kircher, Thon, 2008). Considering climate change, the installation of water bodies in urban landscape might contribute to improve life quality as well (Abromas, Grecevicius, Marcius 2007; Kucinskiene, Malakauskiene, 2007).

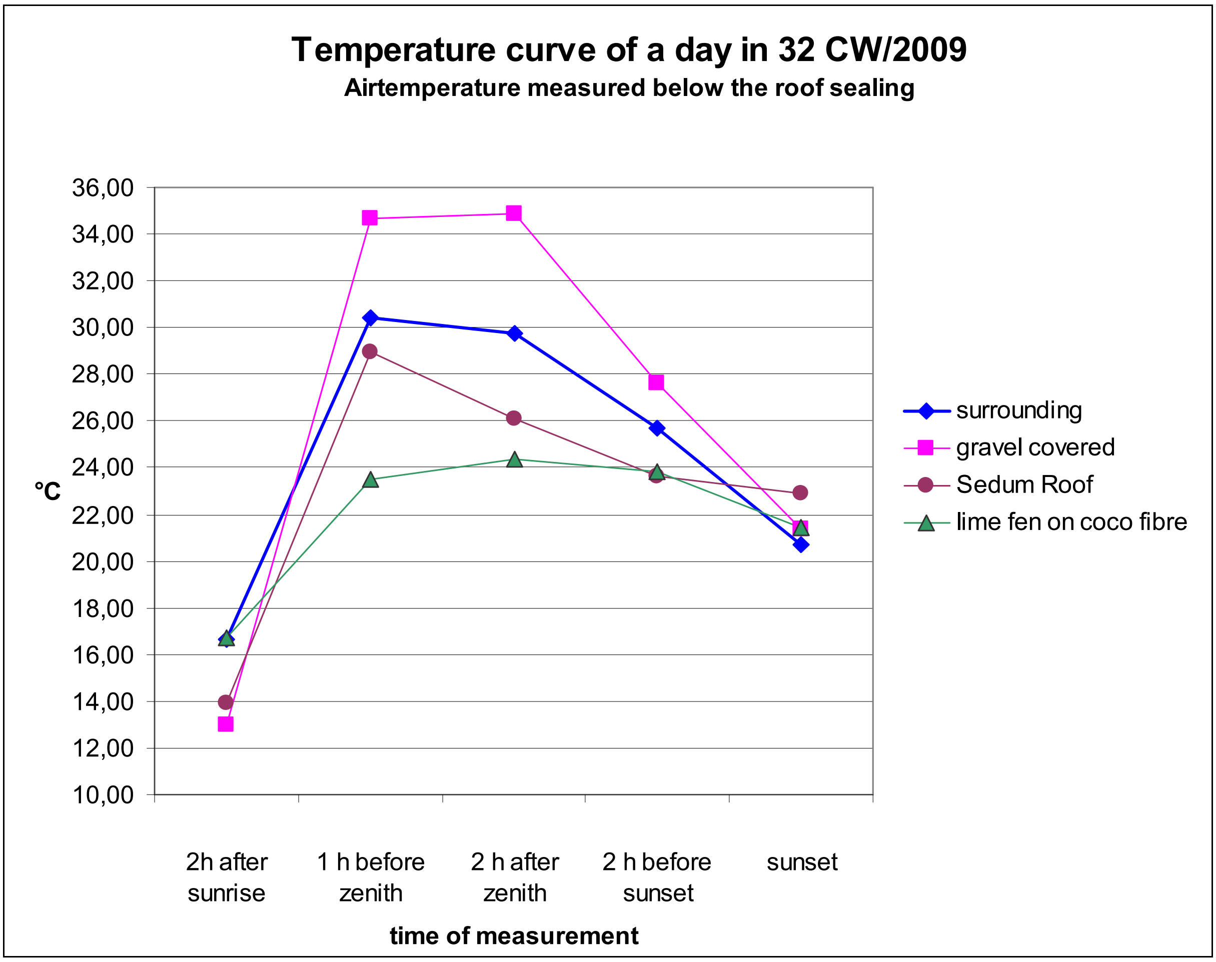

Fig.2. *Influence of different roof coverings on the temperature on buildings*
2 pav. *Skirtingos stogo dangos įtaka pastato temperatūrai*

During 2009 the air temperature underneath the miniature roof gardens was measured 5 times a day. The highest temperature differences were measured in the 32 calendar week of 2009 (Fig. 2). The air underneath the sealing of vegetated variants was lower than the surrounding temperature. The difference of the surrounding temperature and the air temperature underneath the roof sealing show the influence of the system on the temperature. The highest difference was 11°C. The importance of water and vegetation can be seen focussing the influence on the temperature of the gravel plots. The air underneath the gravel plot was higher than the surrounding air temperature. That means that coverage of a flat roof with gravel does not have an as strong influence on the temperature activity compared to flushed, vegetated variants A. Thon, W. Kircher, R. Pesch, G. Schmidt, I. Thon (2009).

The results are encouraging and show that constructed wetlands on roofs have the potential to positively effect the microclimate in dense urban areas and that on site thermal effects can help to reduce heating and cooling costs for buildings.

Discussion

To optimize the potential of rainwater retention, the system needs to cover as much space on the roof as possible to collect most of the rainfall. It needs to collect high amounts of water to buffer heavy rainfalls. This can be achieved either by dynamic water level or by a storage system to buffer changing water resources.

To optimize the positive effect of wet green roofs for urban microclimate and the inhabitancy the system need to show high evaporation rates. The higher the evaporation rate is, the more moist air will be produced. Moist air has a higher binding capacity of particular matter. By evaporation the temperature of the surrounding area will reduced.

High evaporation rate will increase the up streaming air. While the moist air is rising the temperature is declining. This means that the humidity wills condensate. The more humid the air is, the higher will be the rate of condensating. Condensating humidity will produce clouds. Clouds could shade the urban area and therefore reduce hot spots in the town.

Conclusion

Constructed wetlands can provide significant gains in living comfort in often monotonous, densely populated urban centers. Economic and environmental impacts of different options need to be measured and modelled to identify optimal system layout. Further research need to demonstrate the optimized application of a waste water resource for achieving significant water and energy savings under strong improvement of housing conditions and rural microclimate. The system designed will be applicable to existing flat roof buildings, but will have even higher benefits by full integration into novel structures.

Results show new Research and Demands in this working field, such like:

1. Application of the purified water in a second – independent – water system for toilet flushing and disposal, so that the same water volume is used twice. Roof cooling by the wetland itself and by irrigation of additional roof garden design elements.
2. Influence and potential for improving microclimate in rural areas by reducing air pollution and heat island effects.
3. The approach that 15–20% of heating / cooling costs can be saved.
4. Collecting the treated water in a cistern and applying it for garden irrigation.

New research projects should focus on gathering information about transpiration rates of plants. Different vegetation types needs to be established on decentralized wet roof garden purification systems. Purified grey water could be recycled and used for irrigation or toilet flushing in an independent water circulation system.

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Apželdintas stogas – kaip ekologinės aplinkos kūrimo modulis pagerinti miesto klimatą ir naudingai panaudoti šiluminį efektą

Santrauka

Darbe išnagrinėti mokslinių tyrimų projektai ir pateiktas nuosavas tyrimas, kuris rodo, kad stogų sodai turi didelį potencialą vandenį sulaikyti (kaupti), vandenį valyti ir turi vietos šiluminį efektą. Įrengti drėgnieji plotai ant stogų yra kaip ekologinės aplinkos valdymo dalis, jie padeda balansuoti dideles liūtis ir pagerinti pastatų izoliaciją didinant oro drėgnumą ir mažinant oro temperatūrą tankiai gyvenamuose miesto rajonuose. Mokslinių tyrimų projektai, susiję su žaliųjų stogų šiluminiu efektu rodo, kad decentralizuotų vandens valymo sistemų ant stogų instaliavimas ir priežiūra, naudingas šiluminio efekto panaudojimas pastatams yra įmanomas dalykas.