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Urban Wetland Systems: Green Infrastructure for Sustainable Water Management

As cities expand and become densely populated, there is a respectively growing demand for improved sanitary and ecological conditions and a more intelligent way to exploit urban space.

By Dr. Alexandros Stefanakis

GREEN INFRASTRUCTURE (GI) is today a modern approach to the urban environment and an attractive alternative to traditional infrastructure made of concrete (often called grey infrastructure). GI initially referred to open urban green areas, usually connected to each other to provide various services and/or to create a new ecosystem. Typical applications of GI solutions are the urban runoff and stormwater management, reducing the effects of urban heat islands, improving air quality etc. However, the content of that term has been expanded to include, e.g., provision of ecosystem services, the creation of new wildlife habitat and reduction of greenhouse gas emissions. GI represents today a wide set of solutions aimed at increasing the resilience of urban environments to deal with the increasing risks that modern cities face due to the frequent appearance and intensity of extreme events. Today, it is realized that ecosystem services, i.e., all services and goods that nature provides to humans, represent a tremendous value, which should not be neglected. Thus, GI is strongly related to sustainability.

Rapid urbanization and continuous expansion of modern cities are only a few of the challenges that local authorities and governments face related to urban runoff and stormwater management. Current problems have to do with the aging of existing infrastructure, shifts in precipitation patterns with more frequent and intense storm events, watershed deforestation, degradation of natural wetlands, extensive use of impervious surfaces (e.g., roadways, parking lots) that result in urban floods and pollution of water sources. As climate change is expected to further enhance these phenomena, adoption of GI could make a more beneficial use of the multiple ecosystems services and could help in impact mitigation. As cities expand and become densely populated, there is a respectively growing demand for improved sanitary and ecological conditions and a more intelligent way to exploit urban space.

One of the main fields where GI can play an important role is water management, mainly stormwater management and wastewater treatment services. Stormwater runoff management is a major issue in modern cities. Often, stormwater contributes to combined sewer overflow in cities, where domestic/ municipal wastewater, urban runoff, and stormwater are collected in the same pipe network that routes the collected volume to an end-of-the-pipe centralized wastewater treatment plant. The occurring overflow volume can be higher than the capacity of the treatment plants, which means that the excess wastewater volume is discharged into surface water bodies (streams, rivers, lakes or see) to avoid overloading of the existing treatment plants and creates flood incidents in urban areas. Another consequence is further contamination of surface waters and damage of the receiving ecosystem, considering that during flood events water from the first flush of roads and concrete surfaces, sewer washout and sanitary wastewater carries high loads of organics, nutrients, and suspended solids. Management of this water volume is important to prevent any damages to public infrastructure and private properties and to protect human health and the health status of the ecosystems.

Another example where GI can be beneficial is wastewater treatment within the urban and peri-urban environment. The established solution today is the centralized approach, i.e., the implementation of large end-of-the-pipe centralized treatment plants using conventional wastewater treatment technologies. However, these facilities are not environmentally friendly since they are heavy installations made of non-renewable materials (e.g., concrete, steel), consume large amounts of energy and have high operational and maintenance costs. In the urban environment, installing a conventional wastewater treatment plant usually downgrades the surrounding area as it is not a place where people want to live. Hence, an alternative eco-friendly solution, what would combine effective treatment with added ecological values, is desirable.

It is clear that there is the necessity for new infrastruc-

ture that will meet the requirements for effective treatment and sanitation of the generated water streams and, at the same time, create green spaces in the urban environment, which could also partially compensate the lack of sufficient green areas. The eco-friendly technology of Constructed Wetlands (CWs) is an attractive solution with added values to ecosystem services. It is known that wetlands are able to remove and/or transform various pollutants (organics, nutrients, trace elements, etc.) through a series of natural, biological, and chemical processes, and therefore improving water quality. Human-made wetland ecosystems exploit these purifying functions of natural wetlands, which have been used for the disposal and treatment of secondary and tertiary wastewater effluents for many years. Nowadays, the use of natural wetlands for treatment purposes is not allowed, since this could cause irreversible damage. The basic concept of CWs is to replicate the various wetland processes under controlled conditions for a beneficial outcome. This means that CWs are designed in such a way to mimic and enhance the functions of natural wetlands. Although CWs offer in general the same values and functions with natural wetlands, they appear as a more ecologically endowed system. It has been shown that CWs possess a higher value in terms of flood and stormwater control, water quality improvement and biodiversity restoration. Their nature makes them more easily adopted and integrated into the built environment by urban planners, engineers, and landscape architects. The main functions of CWs are flood protection, water storage, and water quality improvement.

In the urban context, wetland technology applications are rare, mainly due to space limitations. However, continuous research and state-of-the-art designs developed over the last 10-15 years gradually close this gap between land availability and area demand. The wider use of decentralized systems offers a better management option for the generated volumes and minimizes the required quantity and size of centralized facilities. Use of constructed wetlands in urban suburbs, for example, is today feasible. In suburban areas, the land is usually cheaper, the population density is smaller and the building volumes are not that massive as in the main urban areas. The technical developments and improvements in constructed wetland design make it easier to adopt this treatment solution, even in areas with relatively limited available space. Intensified CW systems, e.g., aerated wetlands where artificial aeration is applied to further improve the oxygen availability in the bed, are an example. The increased treatment capacity of these systems is translated to reduced area demands, while the amount of energy required for the air blowers is minimum and can be covered by renewable energy sources, e.g., solar or wind energy. Hence, there is the strong potential of using of wetland technology in suburban and urban areas.

Innovative ideas can also be applied for the successful integration of CWs in the urban environment, e.g., the use of wetlands as green roofs. The concept deals with the construction of roofs with a vegetated surface. Studies have shown that this practice can regulate the temperature inside the building, reduce the urban heat-island effects, and act as a carbon sink while providing a range of ecological services.

In urban and suburban areas, the lower infiltration rate, the limited evapotranspiration due to the extended land coverage with building infrastructure, roads etc. and the limited green spaces result in significantly higher runoff volumes, up to 50% higher compared to natural land. For example, it has been estimated that 1 acre of parking lot generates 16 times higher stormwater volume than 1 acre of meadow. The modern approach of building GI takes into consideration multiple issues such as water quality improvement, resources protection, flow volume control and cost-effective long-term operation and maintenance. CWs are increasingly viewed as an ecological solution to the management of stormwater and CSO providing a series of advantages, such as reduction in runoff volumes, peak flows and duration, protection of downstream water resources, reducing the risk of flooding, water quality improvement, increase of runoff infiltration, creation of wildlife habitat and options for recreation activities.

Overall, the use of Constructed Wetlands in urban and peri-urban areas can offer multiple benefits and services to the residents. As a multi-purpose green technology, they provide a new habitat for animals and plants, while treating water, improving water quality and reducing pollution. Given that these systems are dominated by dense clusters of reeds, they act as a cooling island, regulate the microclimate of the surrounding areas and moderate the strong winds. In this way, they act as aesthetically pleasant urban green spaces, which contribute to the well-being of the community and provide options for recreational activities. It is also known that the contact with green spaces in the urban context, supports the physical and psychological health. In this frame, Wetland technology represents a key solution for the increased resilience of modern cities to existing stressors regarding water and wastewater management.

Distribution of several CWs throughout a green infrastructure network allows the usage of treated effluents to create wetlands for habitat enhancement, irrigation, and open space uses. The main advantage of large constructed wetland systems for wastewater treatment is the significantly lower operating costs and external energy use. The economic value of the ecosystem services provided by CWs justifies their construction to realize the wide range of provisioning, regulating, and cultural benefits.

When connected to urban ecological corridors, the ecosystem services provided by CWs promote the creation of large-scale multifunctional landscapes, altering this way the characteristics of urbanized development. Being one of the most productive habitats on the planet, Constructed Wetlands built for wastewater treatment or stormwater control offer a series of environmental and social benefits, enhance biodiversity and habitat, create corridors for wildlife and become part of the regional recreational network. Their integration in the urban environment supports a healthier ecological balance of existing water streams by providing clean water while protecting downstream areas of the city from flooding. The provision of additional green space with aesthetic values is a way for the community to feel connected with nature and to increase psychological well-being. In summary, the multiple benefits of Constructed wetlands should be further exploited and realized in order to include these green systems in current and future urban plans.

About the Author

Dr. Alexandros Stefanakis is a Wetlands Expert at Bauer Resources GmbH. He has graduated from the Department of Environmental Engineering, Democritus University of Thrace, Greece with the Diploma of Environmental Engineer in 2005. His Master in Science in 2007 focused on Hydraulic Engineering and the Environment. His Ph.D. (2011) focused on Ecological Engineering and Technology investigating several pilot constructed wetland units for wastewater treatment and sludge dewatering. His expertise lies in water engineering and specifically on natural waste treatment systems. He is an expert on sustainable and decentralized treatment systems, mainly Constructed Wetlands. As an Environmental Engineer, he has designed, managed and constructed wastewater treatment facilities using Wetland Technology in many countries in Europe, Middle East, USA, and Africa. Currently, Bauer Nimr LLC employs him, and he is based in Oman working on projects in the Middle East and around the world.