

Mini Review

Treatment wetlands in decentralised approaches for linking sanitation to energy and food security

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ABSTRACT

Treatment wetlands (TWs) are engineered systems that mimic the processes in natural wetlands with the purpose of treating contaminated water. Being a simple and robust technology, TWs are applied worldwide to treat various types of water. Besides treated water for reuse, TWs can be used in resources-oriented sanitation systems for recovering nutrients and carbon, as well as for growing biomass for energy production. Additionally, TWs provide a large number of ecosystem services. Integrating green infrastructure into urban developments can thus facilitate circular economy approaches and has positive impacts on environment, economy and health.

Key words | biomass, green infrastructure, resources recovery, treatment wetlands, water reuse

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Treatment wetlands (TWs), also known as constructed wetlands, are wetlands created specifically for the remediation of contaminated water. Currently, tens of thousands of TWs successfully treat water from a variety of sources including municipal waste, mining and industrial outflows, urban and rural runoff, and groundwater (García *et al.* 2010; Dotro *et al.* 2017; Langergraber & Weissenbacher 2017). However, continued misperceptions of appropriate applications and performance efficacy by scientists, engineers and especially regulators responsible for water quality permitting has impeded greater acceptance of this technology and limited usage in many political jurisdictions. The relative youth of wetlands as a treatment technology coupled with the rapid advancement in scientific understanding of underlying processes, physical configuration options and design options is a major contributor to limited but quickly expanding acceptance. Although being a simple and robust low-cost solution for wastewater (WW) treatment, TWs need to be properly designed and operated to function well. The worldwide lack of treatment for domestic wastewater can be reasonably resolved with the integration of this low-cost technology with the production of biomasses, energy and food, transforming in this way the treatment itself from a cost to an economic occasion, especially for low-income countries (e.g. Zhang *et al.* 2014).

In resource recovery solutions, segregation and separate collection of the effluents at households is usually applied (Ronteltap & Langergraber 2016). For TWs, this means that different

treatment targets apply (compared to treating domestic wastewater). A very interesting factor is that there are specific configurations of wetland systems and combinations of wetland with other technologies available that can better perform or be more efficient in economic terms than others. For example, when energy production is integrated in the water cycle, wetlands can offer great opportunities: a simple first stage French vertical flow (VF) wetland (Dotro *et al.* 2017) that treats raw wastewater can for instance produce compost and also a nutrient rich effluent that can be directly used for fertigation on a short rotation plantation (SRP). Especially in warm climates, the yields in obtained biomass can be extremely interesting.

Avellan *et al.* (2017) investigated how biomass from TWs can be utilized in the water-soil-waste nexus. From the plants most commonly used in TWs, *Phragmites* and *Typha* have fast growth rates. Less commonly used, but also fast growing, is *Arundo donax*. At the smaller scales that are now in operation for TWs in most countries, direct combustion and biogas production are the most promising technologies for developing countries. Direct combustion of dry biomass harvested from treatment wetlands can provide more than 10% of the cooking energy needs of a small village.

The integration of nature based retention systems in the urban tissue is enormously enlarging the potential number of applications of wetlands. TWs in future schemes of smart cities will have to be designed following new goals such as (Masi *et al.* 2017).

- Water reuse:
 - Greywater treatment (outdoor, indoor) for local reuse and recreational purposes, possibly as only liquid treatment, while excreta are collected and processed separately;
 - Rainwater (including first flush) treatment and storage;
 - Treatment of persistent organic molecules in low concentrations for water reuse;
 - Polishing of secondary treated WW, as long as these still exist, for reuse.
- Nutrient and carbon recovery:
 - TWs as pre-treatment for fertigation (disease vector reduction, separation of liquid and solid phase);
 - Biomass and fertilizer production from waste activated sludge (as long as such sludge is still produced), digestate or primary sludge in sludge treatment wetlands.
- Energy production:
 - Anaerobic reactors for biogas production plus TWs as polishing stage;
 - TWs for production of energy crops.
- Ecosystem services:
 - Multi-purpose TWs for rainwater storage, recreation and wetland ecosystems;
 - Re-adaptation of ornamental green area in terms of ecosystem services (green roofs, green walls, indoor green areas and walls, parks, permaculture productive areas) comprising organic food production in integrated habitats.

CONCLUSIONS

It can be concluded that:

- the integration of green infrastructure into urban developments is a relevant opportunity for generating circular economy approaches and several positive impacts on environment, economy and health;
- this intergration process must include the strict collaboration amongst different professions, as engineers, chemists, biologists, agronomists, architects and interior designers, urban planners and traffic experts, climatologists, habitat and species biodiversity experts, economists and sociologists.

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