Chapter 2

Why use treatment wetlands?

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2.1 NEW APPROACH TO WATER MANAGEMENT

Wastewater is a historical development. Current approaches to wastewater treatment result from a combination of a need to protect public health (limiting human contact with waste) and the belief that we can dispose of things on this planet. It is also based on the idea that we can taint things and fix them later. In the case of wastewater this means mixing together whatever comes along, only to separate it at the end of a long pipe in a treatment plant, or at least separate water from everything else in order to release the water back into the natural environment, causing "limited" negative impact, where the definition of limited is entirely dependent on what is accepted at any given time and place.

This concept of disposal of treated water into the aquatic environment is the main goal of wastewater systems and, with few exceptions, all regulations have this goal in mind, even if it is not explicitly mentioned. The approach worked as long as we considered the planet as boundless for us. With the growing number of human beings and their influence on the surface of Earth this is no longer true. We are increasingly realising that we cannot get rid of substances which are not metabolised and reintegrated into natural cycles harmlessly. Simultaneously we have discovered that extracting resources and discarding them after a single use has become too inefficient for our needs and the available offer on Earth. Both aspects are illustrated by footprint or Earth overshoot day calculations, which show that our present behaviour needs more space than is available on this one Earth or, expressed in time, that the resources available per year fall far short of lasting until the end of the year at present rates of consumption. We are therefore in search of a new way to use resources, not least those related to water, which comprise water itself, plant nutrients, carbon and energy.

In a first step the conventional boundaries between different aspects of water – water supply, wastewater disposal and urban drainage – are expected to disappear. “The complex water issues are intertwined and cannot be sustainably solved by the traditional siloed water management approaches” (Ma *et al.*, 2015). Thus, for any given water need the best and most effortlessly available water source can be used. Treatments will be applied to various types of waters and for different purposes, each with its own requirements, making the particular water source fit for the next purpose.

In the future, treatment of water will always involve the definition of a further use of that water, determining the treatment needs. While all wastewater has to be treated, the reflection on the supply side will also need a water balance and an examination of all available water streams beginning at the source. To optimise the reuse potential it may be useful to segregate such streams and treat them separately. At the same time that may lead to scale considerations to find the best size of collection, treatment and distribution systems for a particular reuse option. This may result in systems of very different scales simultaneously: a water supply scheme for a metropolitan area, domestic and industrial wastewater treatments of various sizes from municipal to one particular production process down to greywater (i.e. all the wastewater except those from toilets) treatment for one building producing service water for toilet flushing, garden irrigation and even laundry in that same building. The Water Supply and Sanitation Collaborative Council postulated in 2000 at its Bellagio meeting that the household is the basic unit at which to start examining water issues, with the aim of solving every issue at the smallest possible scale, from household to entire country, optimising the possible solutions in repeated cycles. This was named the “household-centred approach” (EAWAG-SANDEC & WSSCC, 2000). It was initially conceived for developing countries, but is applicable everywhere.

In an additional step, water use optimisation will be achieved by considering the entire urban metabolism. That would mean including all water aspects and all related substances into an integrated urban material flow management. The key characteristic is to consider all material and energy flows as a system in order to optimise that system as a whole, and to proceed according to the general principles of material flow management (Figure 2.1) or the classical three Rs: Reduce, Reuse, Recycle. The shift from supply, drainage and treatment of water to a material flow management approach will open entirely new possibilities in terms of reduction, its first and most important element, far beyond conventional water saving and efficiency increases. This will be achieved by considering all water sources, but also other collection and transport options beyond water. Reduction of water use will become an integral part of a green economy, based on the three key aspects of sufficiency, i.e. what is really needed, consistency with nature of all steps involved, and efficiency as the last element, once the first two have been consecutively completed.

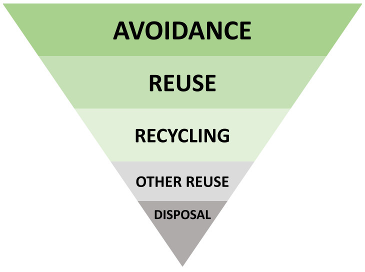

Figure 2.1 Hierarchy of measures for material flow management.

Additionally, a city does not consist of material and energy flows alone. It is built infrastructure, arranged around people and their needs. Jan Gehl therefore requests "Cities for People" (Gehl, 2010), respecting a "human scale".

Cities are complex systems of people, physical fabric and functions. While the present urban system works, neither the cities nor their inhabitants are sustainable. However, "achieving the vision of lively, safe, sustainable and healthy cities has become a general and urgent desire" (Ma *et al.*, 2015). We could add that cities have to become sustainable to thrive within the known planetary boundaries (Steffen *et al.*, 2015). This will only be achievable if the system is addressed in its complexity. The relations between its elements have to be examined and optimised, and the resource flows balanced, in a systemic approach.

With respect to water this means it has to be seen in connection with "urban green" to lead to blue–green solutions. The built environment in combination with these blue and green features should allow the characteristics of the natural water balance to be kept, in terms of infiltration, retention, evapotranspiration and run-off.

The blue–green nature-based "infrastructure" must be linked to urban space use and green infrastructure planning. Urban green will host urban food production in a future with green mobility, linking water professionals to agriculture and traffic, while at the same time providing for biodiversity and nature-based solutions (NBS) for urban services instead of grey infrastructure. Simultaneously the needs and potential of the people living in the cities and using the water and the blue and green infrastructure must be considered, which means co-development of solutions by all major actors with the assistance of sociologists and experts in participatory processes.

2.2 ROLE OF WETLANDS IN THE NEW APPROACH

Treatment wetlands are nowadays a well accepted technology for the treatment of different types of wastewater. Additionally, TWs are increasingly used for other purposes. The new approach in dealing with water, however, with respect to all the issues detailed in the preceding section, is introducing entirely new applications and new requirements for TW design. The need to produce water from any of a range of different possible sources that is fit for a particular purpose will require different treatment targets rather than just discharging a mixed treated wastewater stream into a final sink (freshwater or soil). TWs also must fit into the urban fabric and provide additional ecosystem services and benefits beyond producing water. Thus, the following main urban applications can be identified (Masi *et al.*, 2018):

- Water reuse:
    - Greywater treatment (outdoor, indoor) for local reuse and recreational purposes, possibly as the only liquid treatment, while excreta are collected and processed separately (Masi *et al.*, 2010, 2016);
    - Rainwater (including first flush) treatment and storage (Nolde, 2007) for domestic or industrial purposes, or irrigation of urban green, including food production;
    - Combined Sewer Overflow (CSO) treatment and storage, also to prevent spreading of persistent organic pollutants (Meyer *et al.*, 2013);
    - Treatment of persistent organic molecules in low concentrations for water reuse (Matamoros *et al.*, 2016; Verlicchi & Zambello, 2014);
    - Polishing of secondary treated WW, as long as these still exist, for reuse (Ayaz, 2008; Rousseau *et al.*, 2008).

- Nutrient recovery:
  - TWs as pre-treatment for fertigation (disease vector reduction, separation of liquid and solid phase);
  - Biomass production from secondary sludge (as long as such sludge is still produced), digestate or primary sludge;
  - Biomass production by harvesting TW vegetation, further used as pelletized slow-releasing soil amendment/fertiliser.
- Energy production:
  - Anaerobic reactor (biogas) + TW as polishing stage;
  - TWs as biomass production plots (Avellán & Gremillon, 2019).
- Ecosystem services:
  - Multi-purpose TWs for rainwater buffering or storage, recreation and wetland ecosystems;
  - Re-adaptation of ornamental green areas in terms of ecosystem services (green roofs, green walls, indoor green areas, roundabouts, sidewalks, parks, permaculture productive areas) comprising organic food production in integrated habitats.

A very interesting factor to be noted is that for the above-mentioned targets there are specific configurations of TW systems and combinations of TWs with other technologies available that can perform better or be more efficient in economic terms than others. This will be given particular attention in Chapters 4 and 5.

This list highlights the fact that TWs can help to close loops or at least use substances in cascades in various ways. They can treat water for a certain next purpose, e.g. domestic, industrial, irrigation of urban green or crops. They can be used to recover other substances for their further use or to extract and trap hazardous or recalcitrant substances, thus increasing the possible usages of the treated water and control of the spread of harmful substances around the planet (see global distillation theory). Finally, they are productive systems in themselves, producing biomass, providing organic matter (especially TWs for or comprising sludge treatment), cooling through evapotranspiration, providing habitats, etc.

The integration of nature-based water retention and treatment systems in the urban fabric is enormously enlarging the potential number of applications of TWs, even more so if the concept of "retention" is not only thought of in terms of flood risk reduction, but also considering the trapping of nutrients and organic compounds, in particular the emergent and more persistent and hazardous ones. This sector is the most obvious for the need to involve a large variety of competences to take optimal advantage of the multiple potential benefits of the installations. Such advantages comprise increasing the water retention capacity of a city, to locally bolster biodiversity by offering habitats for wildlife, to work as a last barrier and interface between settlements and water bodies (i.e. adsorbing persistent organic pollutants), to create enjoyable spaces and recreation areas, to reduce air pollution and to contribute to climate change adaptation or even mitigation. Other applications of TWs can offer perhaps not the full panoply but, in each case, at least some of the additional benefits of nature-based solutions, if designed properly and taking these benefits into consideration, both with regard to the necessary competences in the team involved as well as to the outcome. The concept of nature-based solutions should therefore become a core principle in every urban planning process, spreading multi-purpose green infrastructure in our cities (Liquete *et al.*, 2016; Masi *et al.*, 2018) in order to make their benefits available everywhere.

Thus, beyond the already well established designs of treatment wetlands at the downstream fringe of settlements and their wastewater pipes or CSOs, they can be implemented at many other places.

- In buildings
- On buildings (roofs, facades)
- Next to buildings in backyards or gardens,

- Along streets, as additional green areas storing and treating water
- In parks
- Along rivers and other natural features
- Downstream of agricultural areas, including urban agricultural land as buffer strips
- Integrated into existing treatment plants, as polishing stages, the main treatment stage, or for sludge treatment.

A few particular advantages of TWs are their flexibility in size, with little economy of scale, their simple maintenance requirements, demanding skills very similar to widespread irrigation systems, and the very limited to no disturbance that most applications cause in their immediate vicinity if properly designed and operated. This combination of characteristics allows a high flexibility in size, location and vicinity of their implantation and makes them particularly appropriate for urban applications.

2.3 THE NEW DESIGN APPROACH FOR WETLANDS

Based on the previous chapter, we propose that when designing a treatment wetland, the following steps shall be followed:

(1) Define the treatment objective(s).
(2) Define the processes required to reach the treatment objective.
(3) Choose the proper treatment wetland type, or a combination of different types, that allows to reach the treatment objective.

This new design approach will be elaborated in more detail in Chapter 3.