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Wetland Technology

Practical Information on the Design and Application of Treatment Wetlands

Edited by Günter Langergraber, Gabriela Dotro, Jaime Nivala, Anacleto Rizzo and Otto R. Stein

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5.4 HF WETLANDS

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5.4.1 Introduction

Horizontal-flow wetlands have been used for a number of decades around the world. Current design, operation and maintenance guidelines have been summarised by Dotro *et al.* (2017). Many reviews exist in the literature on performance of these systems for treating municipal sewage, agricultural wastewater, industrial effluent, mine drainage, landfill leachate, polluted river and lake water, urban and highway runoff (Vymazal & Kröpfelová, 2008) The use of horizontal-flow wetlands has also been developed in various climate conditions such as cold climate (Wang *et al.* 2006) and tropical climate (Zhang *et al.* 2014). HF wetlands are most effective for removal of organic matter (measured as BOD and COD) and total suspended solids (TSS).

5.4.2 Design considerations

Most guidelines include recommendations on the main factors affecting the treatment performance of HF wetlands. This section summarises the rationale behind the recommendations made.

- *Filter material*. The selection of substrate is a key design parameter because it provides the area for biofilm attachment, rooting medium for the emergent plants, adequate hydraulic retention time and, if required, can react with specific pollutants such as phosphorus or metals. The hydraulic conductivity of the media is considered in current sizing criteria to balance the risk of clogging and contact time between the wastewater and the media (biofilm). Whilst media can be natural, industrial by-products or engineered products, typical material is gravel with sizes of 8–16 mm for the main layer and 50–200 mm for the inlet and outlet zones. Soil has proven to have too low a hydraulic conductivity for the loading rates typically applied and as such is no longer recommended. Whilst checking grading on delivery of media to site can be done with sieves, in reality this is not performed as the range of gravel sizing recommended is broad enough to be less critical if deviations occur, and easy to visually detect.
- *Distribution of wastewater*. Systems are typically loaded along the width of the bed, either with subsurface pipes (secondary treatment) or surface troughs (tertiary treatment). Cleaning access needs to be provided to either type of flow distribution structure as flow velocities from the upstream processes can vary daily and settling can occur within the pipes or troughs. Coarse stones are used to help flow distribution in depth.
- *Upstream treatment processes and loading rates*. The pollutant loads (g/m^2 d) are typically expressed in terms of plan area ($L \times W$), although for clogging considerations the cross-sectional area ($W \times D$) is a critical parameter. Rule of thumb sizing approaches assume typical influent quality and therefore loads applied. For example, areal loading rates of less than 10 g BOD m^{-2} d^{-1},

20 g COD m^{-2} d^{-1}, and 10 g TSS m^{-2} d^{-1} have been shown to enable secondary HF wetlands to operate without surface water ponding for 15 years of operation (Vymazal, 2018). Kadlec and Wallace (2009) suggested key design parameter for HF wetlands a design limit for the cross-sectional loading rate 250 g $BOD_5/m^2/d$. In tertiary systems, similar BOD and TSS areal loading rates have been employed in tertiary systems resulting in refurbishment intervals between 8 and 15 years. The main difference is the quantity of water that passes through the system as tertiary systems with hydraulic loading rates of 0.2–0.4 m/d, as opposed to 0.02–0.05 m/d in secondary systems (Knowles *et al.,* 2011). The capital and operational costs associated with sizing tertiary systems at these high hydraulic loading rates accept the fact that it will result in increased refurbishment intervals, as it is still a lower whole-life cost solution than building a significantly larger system that lasts longer between refurbishments (Dotro & Chazarenc, 2014).

Influent water quality can also affect the predominant wetland processes and require additional management allowed for in the design stage. Strongly anaerobic wetlands like secondary HF beds can generate sulphide and associated odours and a white discharge that will need management. Tertiary HF systems can be carbon limited for denitrification, resulting in low nitrate removal rates.

5.4.3 Potential design and operational issues

As HF systems are inherently passive (no mechanical parts for operation) and the media is fully saturated with water, they are less susceptible to critical failure than other wetland systems. Where systems have encountered major issues these are typically due to poor O&M or significant deviation from design guidelines. Experience from over twenty years of HF systems for secondary and tertiary treatment suggests, as well as following design guidelines (Dotro *et al.*, 2017), a few steps are recommended for operation. These include the protection of plant establishment in the first year of operation and management of preferential flow paths in mature systems.

Plant establishment may need to be protected based on site (region) specific risks. The most common strategies for protecting plant establishment from rodents that feed on reed plantings have included temporary flooding and temporary rabbit fencing. Flooding has resulted in unintentional incorrect operation of HF beds, with operators forgetting to lower the water level once plants have established. Fencing requires additional investment and can have a negative visual impact on the overall system. In many instances, no protection has been employed and the plants successfully established. Therefore, the risk of rodent access and damaging effects should be assessed during the design phase.

Preferential flow paths in mature systems will form as a result of accumulation of inert organics and the decay of biofilm within the bed media, as well as in the surface of HF systems that are surface loaded (Knowles *et al.*, 2011). Management strategies have included resting of HF beds (i.e., draining the water and leaving it to dry for a number of weeks) and altering the operational water level in the beds. Both of these solutions have implications for sites with only one operational bed as the ability of the system to continue to provide treatment is impaired during intervention.

Water quality standards across the world are being re-written to promote healthier ecosystems, ensure safe potable water sources, increased biodiversity, and enhanced ecological functions. Treatment wetlands are used for treating a variety of pollutant waters, including municipal wastewater, agricultural and urban runoff, industrial effluents, and combined sewer overflows, among others. Treatment wetlands are particularly well-suited for sustainable water management because they can cope with variable influent loads, can be constructed of local materials, have low operations and maintenance requirements compared to other treatment technologies, and they can provide additional ecosystem services. The technology has been successfully implemented in both developed and developing countries.

The first IWA Scientific and Technical Report (STR) on Wetland Technology was published in 2000. With the exponential development of the technology since then, the generation of a new STR was facilitated by the IWA Task Group on Mainstreaming Wetland Technology. This STR was conceptualized and written by leading experts in the field. The new report presents the latest technology applications within an innovative planning framework of multi-purpose wetland design. It also includes practical design information collected from over twenty years of experience from practitioners and academics, covering experiments at laboratory and pilot-scale up to full-scale applications.

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