Scientific and Technical Report Series No. 27

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

IWA PUBLISHING

Published by **IWA Publishing**
Alliance House
12 Caxton Street
London SW1H 0QS, UK
Telephone: +44 (0)20 7654 5500
Fax: +44 (0)20 7654 5555
Email: publications@iwap.co.uk
Web: www.iwapublishing.com

First published 2019

British Library Cataloguing in Publication Data
A CIP catalogue record for this book is available from the British Library

ISBN: 9781789060164 (Paperback)
ISBN: 9781789060171 (eBook)
ISBN: 9781789060188 (ePub)

This eBook was made Open Access in January 2020.

4.5 AGRICULTURAL DRAINAGE WATER

Stevo Lavrnić and Attilio Toscano

Department of Agricultural and Food Sciences, Alma Mater Studiorum – University of Bologna, Viale Giuseppe Fanin 50, Bologna 40127, Italy

4.5.1 Design objectives

Agricultural practices have been reported to cause pollution of surface water bodies in different parts of the world (Blankenberg *et al.*, 2008; Díaz *et al.*, 2012; Dunne *et al.*, 2005; Lenhart *et al.*, 2016; Mendes *et al.*, 2018). For example, nitrate has been recognised by the European Commission as one of the major agricultural pollutants and the Nitrate directive issued in 1991 aims to reduce such a pollution in the EU (EEC, 1991).

Nitrate losses from agriculture can be reduced through in-field (e.g., lowering usage of fertilisers or improving fertiliser uptake by crops) or edge-of field methods (e.g., treatment of agricultural drainage water) (Groh *et al.*, 2015). Natural wetlands, small natural streams and vegetated stream banks have a certain capacity to purify water, but the loss of these systems has caused a drop in the quality of surface water bodies receiving agricultural drainage (Borin & Tocchetto, 2007). Therefore, there is a need for a more systematic approach to this problem. For example, grass strips were reported to be capable of successful treatment of agricultural drainage water, but their capacity for it is limited and is considerably lowered when the soil is saturated (Tournebize *et al.,* 2017). On the other hand, TWs are known to be able to treat wastewater through a technology that is sustainable and low cost (Li *et al.*, 2018), can also successfully treat agricultural drainage water (Groh *et al.*, 2015; Kasak *et al.*, 2018; Vymazal & Březinová, 2015), and are more cost-effective for reducing non-point source pollution than other methods (Lavrnić *et al.*, 2018). Their additional advantage lies in the fact that TWs can also provide several ecosystem services if managed well (Tournebize *et al.*, 2017), an approach that lead to a development of the concept of integrated TWs, systems that combine water quality control and biodiversity enhancement (Scholz *et al.*, 2007).

TWs for treatment of agricultural drainage water can be either on-stream or off-stream depending on whether they are located at the flow of drainage water or outside of it (Kasak *et al.*, 2018). The first option is more suitable for nitrate removal, since concentration of nitrate is usually comparable during different periods. On the other hand, off-stream TWs are applied in cases when pesticide removal is a priority, since concentration of these substances is the highest in the first flow after their application. Therefore, the flow can be diverted towards TW only after pesticides application in order to increase HRT of the system and enable higher pesticide removal (Tournebize *et al.*, 2017). Most of the TWs treating diffuse pollution are off-stream since in-stream systems cannot treat all drainage water or the area needed for them is too big (Kasak *et al.*, 2018).

4.5.2 Processes required and type to be used

The type of TWs that is most often used for the treatment of agricultural drainage water is the FWS wetland (Dal Ferro *et al.*, 2018; Vymazal & Dvořáková Březinová, 2018). Its advantage compared to other TW types is that it can cope with pulse flows and changing water levels (Kadlec & Wallace, 2009), both conditions typical in drainage water treatment. Except for wastewater treatment, FWS wetlands can also be used for flood attenuation, water retention and biodiversity enhancement (Dal Ferro *et al.*, 2018; Díaz *et al.*, 2012).

Although the removal performances vary, the majority of the studies that reported efficiency of TW systems treating agricultural drainage water showed improvement of water quality (Díaz *et al.*, 2012). For example, these systems exhibit average removal of 1175 kg TN/ha/yr and 157 kg TP/ha/yr, the values that are comparable with those for various kinds of TWs treating different types of inflow (Vymazal & Dvořáková Březinová, 2018). However, most of the authors that deal with this topic focused on systems that were in operation for a short period of time, and not many report long-term effectiveness (Groh *et al.*, 2015). Therefore, results obtained during the first few years should be taken with caution. It was suggested that TWs treating agricultural drainage water will achieve their maximum TN removal after a certain transition period (Borin & Tocchetto, 2007; Dal Ferro *et al.*, 2018), which could be especially long in areas with cold climate since the vegetation period there is short (Kasak *et al.*, 2018). On the other hand, TP removal might diminish over the years due to the saturation of the sorption sites and biomass storage (Dal Ferro *et al.*, 2018). However, TWs could also be a long-term solution.

Hydraulic efficiency is an important characteristic of these systems and it affects pollutant removal processes. Structures such as dams or stones can increase hydraulic efficiency but can also improve aesthetics of the system and its attractiveness for a variety of wildlife (Braskerud, 2002; Kasak *et al.*, 2018). Moreover, meanders or sinuous water paths can increase retention time, a factor that affects removal (Lenhart *et al.*, 2016; Mendes *et al.*, 2018).

Agricultural drainage water usually has a low C/N ratio and high concentration of nitrates (Li *et al.*, 2018). Since denitrification is the dominant nitrate removal path in FWS wetlands (Groh *et al.*, 2015; Tournebize *et al.*, 2017), TN removal can be limited due to shortage of carbon. This problem could be overcome by addition of an extra carbon source that can be in liquid or solid form. Liquid carbon source has to be added constantly and could cause secondary pollution, difficulties that do not exist if a solid carbon source is used (Li *et al.*, 2018). On the other hand, it has been reported that the retention of nitrogen in a FWS wetlands can be increased through addition of straw (Blankenberg *et al.*, 2008) or non-removal of harvested biomass (Tournebize *et al.*, 2017).

Apart from the cases when organic matter content is not enough to enable denitrification, TN removal through this process can be low when the system receives a medium–low yearly load, or when flooding and anaerobic conditions inside the system occur only for short periods of time (Borin & Tocchetto, 2007). Moreover, since denitrification decreases at low temperatures there is a certain variability in removal efficiency between different seasons (Tournebize *et al.*, 2017), and it can be particularly low during the winter (Borin & Tocchetto, 2007). TN removal can also be hindered by stagnant water conditions, since oxygen can be depleted and therefore prevent complete nitrification (Díaz *et al.*, 2012).

An especially important process in FWS wetlands is sedimentation of soil particles since phosphorus and other pollutants are generally attached to them (Braskerud, 2002). For that reason, the usual design of these systems is a deeper inflow section to facilitate sedimentation (1–2 m deep), followed by a vegetated bed (0.1–0.5 m deep) (Vymazal & Dvořáková Březinová, 2018). Factors that affect retention of soil particles are sedimentation velocity, flow rate and surface area. Since the soil particle concentration is high in the beginning of the rainfall event and the flow rate is low, sedimentation usually does not represent a problem in this phase. Resuspension of soil particles is undesirable, which can be mitigated by vegetation presence (Braskerud, 2002; Kasak *et al.*, 2018). Moreover, vegetation in FWS wetlands can also improve removal efficiencies due to the provision of a carbon source for denitrification or passive transfer of oxygen from the atmosphere into the soil (Kasak *et al.*, 2018).

Wetlands can remove phosphorus through biological (plant and microbial uptake), physical (sedimentation) and chemical pathways (sorption and precipitation) (Dunne *et al.*, 2005), out of which the first two are the primary ones (Lenhart *et al.*, 2016). The physicochemical characteristics of wetland soils and sediments are one of the main factors in these processes, since they affect inorganic P sorption dynamics (Dunne *et al*., 2005). Moreover, anaerobic conditions might cause release of phosphorus from the sediments and therefore the system should be in an oxic state (Kasak *et al*., 2018). Other factors that can affect long-term stability of phosphorus bound in the sediments are supply of phosphorus sorbents, sediment redox conditions and Fe_{tot}: P molar ratios (Mendes *et al*., 2018). FWS wetlands can experience a decrease in TP removal after a certain time due to the fact that sorption sites are saturated, and that initial vegetation growth has stabilised. Therefore, it is important to perform appropriate vegetation management and removal of sediments in order to enable the same or similar level of TP removal (Díaz *et al*., 2012).

Although pathogen concentration in agricultural drainage water is low unless there are animal farms in the catchment, it is still important to consider this parameter since TWs can act as their source, rather than a sink when inflow concentration of pathogens is relatively low ($\sim$100 CFU 100 mL^{-1} of faecal coliforms) (Beutel *et al*., 2013). For example, *Escherichia coli* removal might be lower in FWS wetlands that do not have a constant water flow and are often characterised by longer periods when water is in stagnant conditions. Stagnant water can have different environmental conditions (chemical and thermal properties) in the water column that can favour development of certain bacteria. Those conditions are often prevented by the constant water mixing that exists in systems with a constant flow (Díaz *et al*., 2012). Moreover, coliform bacteria could also be introduced into the systems by warm-blooded animals such as mammals or birds (Beutel *et al*., 2013; Díaz *et al*., 2012).

Similar phenomenon can also inhibit removal of pesticides, since they can be found accumulated in biofilm (Tournebize *et al*., 2017) and sedimentation is an important mechanism for pesticide removal (Díaz *et al*., 2012). Removal of pesticides therefore depends on the sediment characteristics (i.e., organic content, particle size, hydraulic conductivity), but also on the properties of pesticide itself (i.e., half-life, solubility, octanol–water partition coefficient, and distribution or sorption coefficient) (Mahabali & Spanoghe, 2014). Vegetation in the system can contribute to pesticide removal either by their uptake (Mahabali & Spanoghe, 2014) or by enabling development of biofilm in which pesticide biodegradation can occur (Tournebize *et al*., 2017).

4.5.3 Specific considerations during design and for construction

For wetlands treating agricultural drainage, specific considerations during design and for construction are:

- Predicted runoff should be taken into consideration when planning a TW in order to adjust the depth. This is particularly important when the area is limited (Blankenberg *et al*., 2008).
- Soil texture should be estimated before construction of a FWS wetland since infiltration can present an important component of water balance of non-waterproofed systems, and can cause high water losses to infiltration (Lavrnić *et al*., 2018).
- Systems should be designed to facilitate harvesting, a process that can increase permanent phosphorus removal and prevent its release (Lenhart *et al*., 2016).
- TW to catchment ratio is an important parameter to be considered during the design phase and to enable a HRT that is long enough to allow sufficient drainage water treatment; it should be at least 1%, or even higher in regions with cold climate (Tournebize *et al*., 2017).
- Sediment resuspension could be kept at minimal level if vegetation cover is approximately 50%. Therefore, plant requirements for optimal growth should be taken into account when designing the system (Braskerud, 2002).
- Existence of dead zones and short circuits should be avoided by a proper positioning of inlet and outlet points and by creation of dykes (Tournebize *et al*., 2017).
- Vegetation development should be encouraged before the system starts operation, since water level management can be controlled in that period and it can affect proper vegetation establishment (Lenhart *et al*., 2016).