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Do constructed wetlands in grass strips reduce water contamination from drained fields?

Romain Vallée [a], Sylvie Dousset [a, *], François-Xavier Schott [b], Christelle Pallez [c], Agnès Ortar [c], Richard Cherrier [b], Jean-François Munoz [c], Marc Benoît [d]

[a] LIEC, UMR 7360 CNRS – Université de Lorraine, Bd des Aiguillettes, BP 70239, 54506 Vandœuvre-lès-Nancy, France
[b] Chambre Régionale d'Agriculture de Lorraine, 9 Rue de la Vologne, Bâtiment I, 54520 Laxou, France
[c] ANSES, Nancy Laboratory for Hydrology, Water Chemistry Department, 40 Rue Lionnois, 54000 Nancy, France
[d] INRA, unité ASTER, UR 055, 662 Avenue Louis Buffet, 88500 Mirecourt, France

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A B S T R A C T

This study evaluates the efficiency of two small constructed wetlands installed in the regulatory grass strips between a drained plot and a river. The observed nitrate removal efficiencies were independent of the season or type of constructed wetland and ranged from 5.4 to 10.9% of the inlet amounts. The pesticide mass budgets ranged from −618.5 to 100%, depending on the molecule. The negative efficiencies were attributed to runoff and remobilization. In contrast, the highest efficiencies were associated with pesticides with high K_{oc} and low DT_{50} (half-life) values, suggesting sorption and degradation. However, the effectiveness of these wetlands is limited for pesticides with low K_{oc} or high DT50 values; thus, the use of these molecules must be reduced. Increasing the number of these small, inexpensive and low-maintenance wetlands in the agricultural landscape would reduce the level of water pollution whilst preserving the extent of cultivated land, but their long-term effectiveness should be evaluated.

1. Introduction

The protection of water resource quality is a major issue for the future. However, the intensive use of pesticides in agriculture contributes to contamination of the environment (DGS, 2012). In Lorraine (eastern France, Fig. 1), approximately 20% of agricultural lands are drained (Recensement Agricole, 2010), and this ratio reaches 70% in certain watersheds. The crop management of heavy clay soils in agriculture requires artificial drainage for sustainable and profitable crop production. Furthermore, numerous studies have reported on the contribution of drainage water to the dispersion of agricultural pollutants, such as nutrients and pesticides (Accinelli et al., 2003; Brown et al., 2004; Riise et al., 2004; Schiavon and Jacquin, 1973). Two studies conducted in Lorraine have reported peak concentrations of pesticides in drainage water ranging from 5.9 to 395.3 $\mu g\ L^{-1}$, and these exports account for as much as 2.4% of the applied amount (Dousset et al., 2004; Novak et al., 2001).

In response, agricultural practices have been optimized to reduce pesticide exports in field drainage by establishing treatment periods, creating monitoring networks, utilizing non-chemical methods, and banning a number of compounds. Despite the applied measures, numerous pesticides have been detected in water bodies in France. For example, in a study conducted in 2011 (SOeS, 2013), 93% of 2552 point measurements of surface waters were reported to be affected by the presence of at least one pesticide, and 19% were affected by more than 20 pesticides. Constructed wetlands (CWs) have been presented as a potential solution for reducing these inputs of pollution and have been described as good environmental practices (JOCE, 2006). The majority of CWs are installed at the watershed scale or at the scale of several plots (Hunt et al., 2008; Rose et al., 2006; Schulz and Peall, 2001). Thus, these CWs are fairly large, consisting of several hundreds or thousands of square metres, and consequently compete for space with cultivated land. Several authors have developed a bypass system for driving the most contaminated drainage water towards these CWs (Passeport et al., 2013; Tournebize et al., 2013) which should be, in the end, managed by farmers. Thus, despite their positive effect on water quality, these CWs may present problems in terms of their acceptability to farmers. Furthermore,

* Corresponding author.
E-mail address: sylvie.dousset@univ-lorraine.fr (S. Dousset).

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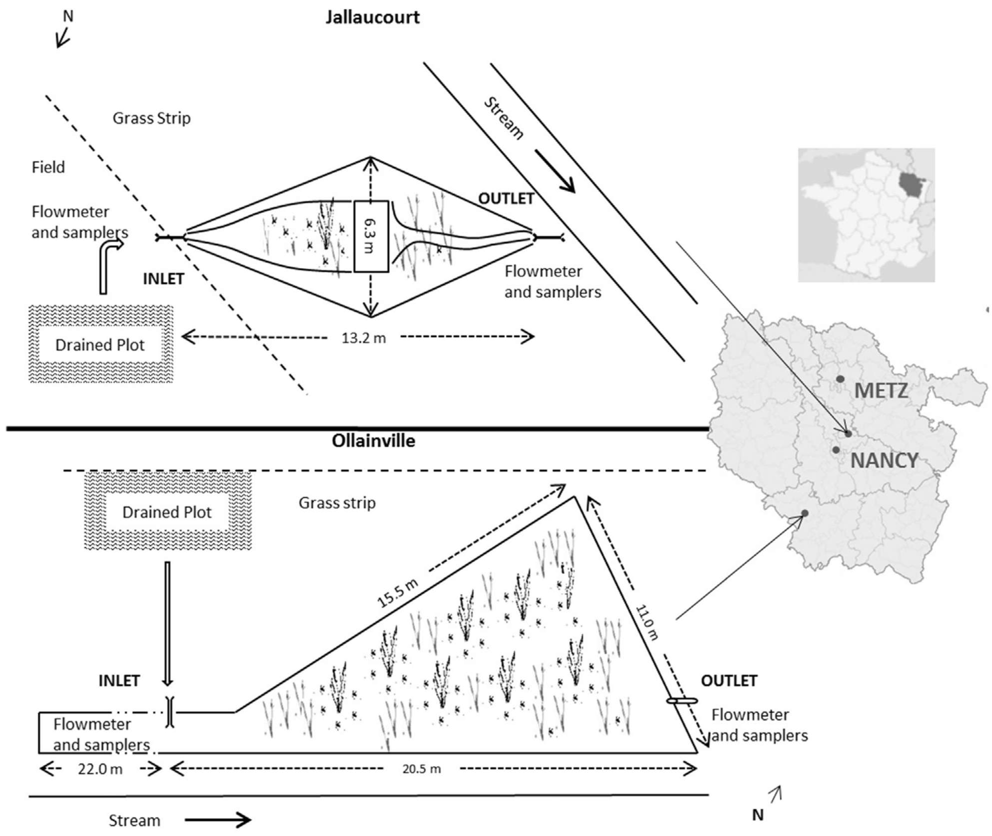

Fig. 1. Location map and schematic designs of the constructed wetlands.

these wetlands are difficult to reproduce in the agricultural landscape because of their large size requirements.

Two small CWs were established in the 5-m-wide regulatory grass strips located between a cultivated plot and a river in Europe (JOCE, 2000). The aim of this study was (*i*) to evaluate the effectiveness of these small CWs at reducing the water contamination by pesticides and nitrate and (*ii*) to understand the processes involved in determining their effectiveness. The concentrations of nitrate and pesticides in water and pesticides in substrates (straw, plants and sediments) were regularly monitored during the drainage seasons of 2012/2013 and 2013/2014.

2. Materials and methods

2.1. Site description

2.1.1. Catchment description and agricultural crops

The soils of the two research sites are gleyic cambisols (FAO, 2006). In Lorraine, the agriculture is characterized by dominant crops of winter wheat (*Triticum turgidum*), winter barley (*Hordeum vulgare*), rape (*Brassica napus* L.) and maize (*Zea mays*). The rotations for both sites were synchronized as follows: winter rape (2011–2012), winter wheat (2012/2013) and maize (2013/2014). The technical management practices adopted by the farmers were similar for each crop. The pesticide management practices are given in Table 1.

2.1.2. Constructed wetland design

The two selected CWs were implemented in grass strips between an agricultural plot and a stream (Fig. 1) during the autumn 2010. The device at Jallaucourt (Moselle, France; N48°49′42.9″ E06°22′40.6″) consisted of a 13-m-long, 6-m-wide ditch. This CW received the drainage water from a 5 ha plot with an average slope of 12.5%. A bundle of straw was placed in the middle of the CW to reduce water flow and increase the hydraulic residence time. Upstream of the bundle of straw, the water depth may reach 1 m. The water storage capacity was estimated to be 4 m^3. Spontaneous vegetation grew in the devices. In autumn 2014, the device was entirely covered by 16 species, dominated by *Juncus conglomeratus*, *Juncus inflexus*, *Ranonculus repens* and *Glyceria notata*. At the beginning of each drainage season (October), the straw bundle was replaced and pesticides were extracted from the straw. Boscalid and epoxiconazole were found at concentrations of 28.5 and 36.6 $\mu g\ kg^{-1}$, respectively, for the 2012/2013 drainage season and at 2.8 and 17.5 $\mu g\ kg^{-1}$, respectively, for 2013/2014. These low concentrations did not influence the concentration of pesticides quantified at the outlet of the CW.

The device at Ollainville (Vosges, France; N48°15′52.8″ E05°49′24.8″) consisted of a triangular pond (20.5 m × 15.5 m × 11 m) and a 22-m-long and 1-m-large oxbow-lake. This CW received the drainage water from a 9 ha plot with an average slope of 5.0%. The water depth ranged from 0.6 to 0.8 m. The water storage capacity was estimated to be 100 m^3. In autumn 2014, vegetation entirely covered the device, and 17 species were identified, including *Typha latifolia*, *Callitriche platycarpa*, *Glyceria notata*, and *J. inflexus*.

2.2. Monitoring and sampling

The flow rates were measured continuously using a Venturi flume (E1253AY, CONTRAFLUX®) and an ultra-sound flowmeter (950-US 50 Hz, SIGMA). Using an automatic sampler (SD-900