



Measurement and conceptual modelling of herbicide transport to field drains in a heavy clay soil with implications for catchment-scale water quality management

A. Tediosi^{a,b}, M.J. Whelan^{a,*}, K.R. Rushton^a, T.R.E. Thompson^a, C. Gandolfi^b, S.P. Pullan^a

^a Environmental Science and Technology Department, School of Applied Sciences, Cranfield University, College Road, Cranfield, Bedfordshire, MK43 0AL, UK

^b Dipartimento di Ingegneria Agraria, Università degli Studi di Milano, via Celoria 2, 20133 Milano, Italy

HIGHLIGHTS

- The transport of propyzamide and carbetamide to field drains was monitored.
- Both herbicides were transported rapidly in events following application.
- Observed data were explained with the help of a simple conceptual model.
- Drainflow seems to be the dominant herbicide transport pathway in this catchment.

ARTICLE INFO

Article history:

Received 23 May 2012

Received in revised form 5 August 2012

Accepted 8 August 2012

Available online 11 September 2012

Keywords:

Carbetamide
Propyzamide
Field drain
Leaching
Pesticide

ABSTRACT

Propyzamide and carbetamide are essential for blackgrass control in oilseed rape production. However, both of these compounds can contaminate surface waters and pose compliance problems for water utilities. The transport of propyzamide and carbetamide to an instrumented field drain in a small clay headwater tributary of the Upper Cherwell catchment was monitored over a winter season. Despite having very different sorption and dissipation properties, both herbicides were transported rapidly to the drain outlet in the first storm event after application, although carbetamide was leached more readily than propyzamide. A simple conceptual model was constructed to represent solute displacement from mobile pore water and preferential flow to drains. The model was able to reproduce the timing and magnitude of herbicide losses well, lending support to its conceptual basis. Measured losses in drainflow in the month following application were 1.1 and 8.1%, respectively, for propyzamide and carbetamide. Differences were due to a combination of differences in herbicide mobility and due to the fact that the monitoring period for carbetamide was hydrologically more active. For both compounds, losses were greater than those typically reported elsewhere for other herbicides. The data suggest that drainflow is the dominant pathway for the transfer of these herbicides to the catchment outlet, where water is abstracted for municipal supply. This imposes considerable constraints on the management options available to reduce surface water concentrations of herbicides in this catchment.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

Pesticides are an important tool in modern conventional agriculture, helping to maintain high and consistent yields in the face of a wide range threats from weeds, fungal diseases and insect pests. However, some pesticides can be transported from land to ground and surface waters (e.g. Brown et al., 2001; Holman et al., 2004; Edwards et al., 2008) where they may pose problems for water supply companies, which need to comply with drinking water quality regulations (e.g. the EU Drinking Water Directive: 98/83/EC). Due to a combination of their widespread use and their physico-chemical properties, herbicides are often detected in surface and ground waters in agricultural catchments

in the UK (Holman et al., 2004). Two active ingredients which are commonly used for blackgrass (*Alopecurus myosuroides*) control in oil seed rape (OSR: *Brassica napus*) and winter beans (*Vicia faba*) are propyzamide (3,5-dichloro-N-(1,1-dimethylprop-2-ynyl)benzamide) and carbetamide ((R)-1-(ethylcarbamoyl)ethyl carbanilate). Both chemicals are frequently measured at relatively high concentrations (occasionally > 10 µg/L) in arable-dominated surface water catchments in the UK during the winter time (e.g. Evans, 2009). Although such concentrations are unlikely to result in ecological impacts (the lowest no observed effect concentrations reported for aquatic species in PPDB (2011) are 600 µg/L and 140 µg/L for propyzamide and carbetamide, respectively), they may pose compliance problems for water companies if treatment processes fail to reduce concentrations below the EU maximum admissible concentration for drinking water of 0.1 µg/L before water is piped to consumers. Key properties of propyzamide and carbetamide pertinent to their environmental behaviour are shown in Table 1.

* Corresponding author at: Department of Geography, University of Leicester, Leicester, LE1 7RH, UK. Tel.: +44 1234 752975.

E-mail address: m.j.whelan@cranfield.ac.uk (M.J. Whelan).

Table 1

Properties of propyzamide and carbetamide pertinent to the potential for leaching loss (www.eu-footprint.org [accessed 8 January 2012]). DT_{50} is the median field-based dissipation time in soil, K_{OC} is the organic carbon to water partition coefficient, Solubility is aqueous solubility and GUS is the Groundwater Ubiquity Score (Gustafson, 1989). Also shown are data for IPU for comparison. Note that for carbetamide and IPU, the K_{OC} given is the Freundlich K_{foc} .

	Propyzamide	Carbetamide	Isoproturon
Molar mass [g/mol]	256	236	206
DT_{50} [days]	56	8	23
K_{OC} [L/kg]	840	89	122
Solubility [mg/L]	9	3270	70
GUS	1.80	2.24	2.07

There are a number of potential sources for pesticides in surface waters. Some of these may be non-agricultural, such as the use of herbicides for weed control along roads and railways (e.g. Ramwell et al., 2002, 2004a). In agricultural catchments, some chemical can be transferred directly to ditches and streams via spray drift (e.g. Holt, 2000; Felsot et al., 2011) and can be washed off hard standings in farm yards if spills occur during tank filling and sprayer washdown operations (Mason et al., 1999; Fait et al., 2007; Neumann et al., 2002; Edwards et al., 2008; Kreuger, 1998; Ramwell et al., 2004b). In addition, pesticides can be transferred from soils to surface waters via overland flow, throughflow (also known as interflow or shallow groundwater flow: Ng and Clegg, 1997) or via artificial field drains (e.g. Johnson et al., 1994; Haria et al., 1994; Brown and van Beinum, 2009), if present. Clearly a range of different sources and a range of processes may operate together in any catchment and may have differing importance at different times, depending on agronomic practices, soil type, topography, soil moisture content and storm event characteristics. In order to manage herbicide losses from agricultural uses effectively, it is important to understand the relative role of the different sources and pathways, so that actions can be targeted. For example, improving handling practices on hard surfaces (to reduce spills during filling and wash down operations) and installing biobeds (biological filters: e.g. Fogg et al., 2003) have been proposed to reduce concentrations in runoff from hard standings. However, these measures may not have a major impact at the catchment scale, even if they are important locally, if concentration peaks resulting from localised short duration “spills” during storm events diminish significantly due to dilution and to hydrodynamic dispersion in the channel network (cf. Gandolfi et al., 2001). Similarly, installing buffer zones between field edges and water courses to reduce chemical transfers in overland flow (e.g. Patty et al., 1997; Syversen and Bechmann, 2004; Patzold et al., 2007) will be ineffective if the dominant runoff pathways are subsurface. Of course, no-spray zones adjacent to water courses will affect spray drift, which is important for reducing local in-channel ecological exposure. However, the extent to which spray drift reduction can mitigate concentrations at the catchment outlet will depend on how much contemporaneous spraying is performed close to contributing water courses. In cases where the dominant contributors to pesticide exposure at the catchment outlet are diffuse in nature, management is often challenging because it is influenced by numerous interacting factors including soil properties (fixed and variable), weather, pesticide properties, and agricultural management practiced by multiple actors (Leonard, 1990; Klavivko et al., 2001; Leu et al., 2004).

The presence of artificial drainage can have a significant impact on pesticide transport by increasing infiltration rates and decreasing the frequency and magnitude of overland flow, along with the transport of particulates and sorbed compounds (Klavivko et al., 2001). However, reducing surface runoff does not necessarily mean that pesticide transport to surface waters is reduced. There is considerable evidence that pesticides have the potential to move very quickly to field drains and then to the surface water network (e.g. Czapar et al., 1994; Johnson et al., 1996; Stone and Wilson, 2006; Branger et al., 2009; Jarvis et al.,

2009). According to Johnson et al. (1996) the vast majority (75–90%) of isoproturon losses in a small drained clay catchment in Oxfordshire, UK, occurred via the artificial drainage network; volumes of water moved by overland flow were low, although concentrations in overland flow and in drain flow were similar. Harris and Catt (1999) and Haria et al. (1994) also concluded that rapid movement to sub-surface drains was a major pathway for pesticide transport to surface waters in heavy clay soils.

This paper presents the results of field investigations which were carried out in a heavy clay, artificially drained soil in the Upper Cherwell catchment, UK, which is used to gather water for drinking water supply to the town of Banbury (Fig. 1). The abstracted water at Banbury is often contaminated with herbicides, posing compliance challenges for the local water company (e.g. Evans, 2009). In addition to the requirements of the Drinking Water Directive, Article 7 of the EU Water Framework Directive (98/83/EC) makes special provision for catchments used for water supply (designated as Drinking Water Protected Areas in England and Wales). In such catchments, EU Member States are obliged to ensure that the level of treatment required to meet drinking water standards in supplied water is adequate and does not need to be augmented as a consequence of water quality deterioration. Recent attention has been directed towards carbetamide and propyzamide which exhibit periodically high concentrations (Thames Water, *personal communication*). However, despite their widespread use and associated potential issues, relatively little has been published on their behaviour in soils and their transport to surface water. The main objective of this work was to investigate the importance of field drains as conduits for the transport of these compounds to the river Cherwell, although the findings are also relevant more widely. We also attempt to interpret the phenomena observed in terms of a conceptual model of solute displacement to artificial drains.

2. Materials and methods

2.1. Catchment characteristics

The Upper Cherwell catchment (area 199 km²) is situated in Oxfordshire and Northamptonshire in central England (e.g. Neal et al., 2006). Mean annual rainfall is approximately 686 mm/y and mean annual runoff is approximately 220 mm/y for the Cherwell at Enslow Mill (Marsh and Lees, 2003). The soils of the catchment are predominantly seasonally waterlogged clays of the Denchworth, Wickham and Ragdale 2 soil associations (Ragg et al., 1984), although there are also lighter and freely drained sandy loam soils of the Banbury soil association, which are mostly developed on the Northampton Sandstone which is generally found on hill tops. These lighter soils occupy approximately 15% of the catchment but may underlie up to 30% of the arable land. Most of the heavier soils in agricultural use are artificially drained. Land drainage in the area is likely to date back to the 18th century and there are a range of drain types present (i.e. clay and plastic with different designs and dimensions). The majority of the field drainage system was probably installed by the 1970s, when the UK Government stopped the land drainage grant. The catchment is predominantly rural and approximately 50% of the agricultural land is considered to be suitable for oilseed rape production (unpublished data supplied by the Environment Agency of England and Wales), although not all of this area will be in oilseed rape in any single year. Many arable fields are currently under a three year rotation consisting of two cereal crops followed by oilseed rape. Typically oil seed rape occupies about 10% of the catchment area in any one year.

2.2. Experimental sub-catchment

Field drain monitoring was carried out in a small headwater sub-catchment in the northeast of the Upper Cherwell catchment (Fig. 1). The sub-catchment is dominated by a single 8.6 ha arable field (referred to subsequently as the experimental field) which ranges in altitude

Download English Version:

<https://daneshyari.com/en/article/6333570>

Download Persian Version:

<https://daneshyari.com/article/6333570>

[Daneshyari.com](https://daneshyari.com)