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Transport of veterinary antibiotics in overland flow following the application of slurry to arable land

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Abstract

The environment may be exposed to veterinary medicines administered to livestock due to the application of organic fertilisers to land. Slurry is often spread on to fields following the harvest of the previous crop. Despite recommendations to do so, the slurry may not be ploughed into the soil for some time. If precipitation occurs before incorporation then it is likely that the slurry and any antibiotic residues in the slurry will be transported towards surface waters in overland flow. This phenomenon has been investigated in a plot study and transport via 'tramlines' has been compared to that through crop stubble. Three veterinary antibiotics, from the tetracycline, sulphonamide and macrolide groups, were applied to the plots in pig slurry. Twenty four hours after the application the plots were irrigated. Following this the plots received natural rainfall. Sulphachloropyridazine was detected in runoff from the tramline plot at a peak concentration of 703.2 $\mu g\,l^{-1}$ and oxytetracycline at 71.7 $\mu g\,l^{-1}$. Peak concentrations from the plot that did not contain a tramline were lower at 415.5 and 32 $\mu g\,l^{-1}$, respectively. In contrast, tylosin was not detected at all. Mass losses of the compounds were also greater from the tramline plot due to greater runoff generation. These did not exceed 0.42% for sulphachloropyridazine and 0.07% for oxytetracycline however.

Keywords: Veterinary antibiotics; Overland flow; Tramlines; Slurry

1. Introduction

Veterinary medicines are used in agriculture to prevent disease in livestock and treat illness. Following administration, quantities of these drugs may be excreted as the parent compound and/or metabolites and enter the environment due to the spreading of manure and slurry on agricultural land, or due to direct deposition by grazing livestock (Halling-Sørensen et al., 1998).

The presence of veterinary medicines in the environment may be a cause for concern as they are designed to have a biological effect (Halling-Sørensen et al., 1998). These chemicals may affect terrestrial and aquatic organisms (Wollenberger et al., 2000) as well as play a role in the development of antimicrobial resistance (Chee-Sanford et al., 2001). Data exist which show that residues may be present in manure and slurry applied to land (Haller et al., 2002). Although it is recommended that slurry be incorporated into the soil within 24 h of application, and within 4 if possible (Chambers et al., undated), this is often not the case (ADAS, 1997a,b, 1998a,b). Thus it has been found that precipitation

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may occur between slurry application and incorporation (Jarvis et al., 1987; Edwards and Daniel, 1993; Kay et al., 2004). Antibiotic residues in the slurry may therefore be transported to surface waters in overland flow. This phenomenon may help to explain detections of veterinary medicines in surface water monitoring studies (Hirsch et al., 1999; Meyer et al., 2000; Campagnolo et al., 2002).

Only one study has investigated the transport of veterinary medicines in overland flow (Nessel et al., 1989) and none has studied antibiotics, the most used class of veterinary medicine (VMD, 2002) in particular. The contribution of the dissolved and particulate phases to chemical concentrations in surface runoff are also unknown, even for pesticides which have been studied in much greater detail than veterinary medicines (Frink, 1991; Soileau et al., 1994). Pesticides in overland flow have been detected at concentrations up to 1403 $\mu g\, l^{-1}$ showing how important this hydrological pathway may be, particularly as veterinary antibiotics have been found to behave in a very similar fashion to veterinary antibiotics in the environment (Kay et al., 2004). Previous investigations have also found overland flow to be responsible for the transport of nutrients (e.g. Fraser et al., 1999; McDowell and Sharpley, 2003) and slurry itself (e.g. Quinton et al., 2003; Tyrrel and Quinton, 2003).

It is perceived that this study will help to determine if transport in overland flow is a potentially important route whereby surface water pollution by veterinary antibiotics may occur. Moreover, the work will help to determine the extent to which tramlines affect the transport of veterinary medicines and the influence of not incorporating slurry into the soil before rain occurs. Provision of this information will show to what extent management strategies need to address surface runoff. These include the risk assessment process that is carried out prior to chemical registration (CVMP, 1997) and agricultural codes of practise (MAFF, 1998).

2. Materials and methods

2.1. Study compounds

The test substances investigated in the study were chosen as they are commonly used in veterinary medicine (VMD, 2002), have a range of sorption and degradation characteristics (e.g. Rabølle and Spliid, 2000; Ingerslev et al., 2001) and are largely excreted as the parent molecule (Parfitt, 1999). They comprised three antibiotics (Table 1), which are used in greater quantities than other classes of veterinary medicine (Boxall et al., 2002; Koschorreck et al., 2002). These were oxytetracycline (OTC) (BioChemika grade, Fluka, Gillingham, Dorset, UK), sulphachloropyridazine (SCP) (Vetranal® grade, Riedel-de Haën, Gillingham, Dorset, UK) and tylosin (TYL) (BioChemika grade, Fluka, Gillingham, Dorset, UK).

2.2. Surface runoff plots

Two plots measuring 5×2 m were established on a field in Leicestershire, UK, covered with the stubble from the previous year's wheat crop (Fig. 1). The soil was a clay loam (Salop series). The angle of slope averaged 6°, varying between 4.8° and 7.2°. One of the plots had a 'tramline' running down the middle created by the passage of agricultural machinery used to apply pesticides and fertilisers to the previous crop. Metal runoff traps measuring 2 m in length (Cranfield University at Silsoe, Bedfordshire, UK) were installed at the down slope end of each plot so that runoff moving through the top 5 cm of soil was intercepted. Each runoff trap had a metal lid which stopped the direct entry of precipitation into the trap. In the tramline plot it was necessary to place the trap slightly deeper as the tractor wheeling was slightly more than 5 cm deep. Each plot was hydrologically isolated to 5 cm depth by inserting a plastic strip into the soil around the edge of the plot. Three porous pot tensiometers (Soil Monitoring Engineering, Milton Keynes, UK) were installed inside each plot to measure soil moisture in the top 5 cm. These consisted of a porous ceramic pot attached to a water filled plastic pipe sealed with a screw cap and rubber septum. Changes in soil water pressure within the tensiometer due to water moving through the porous cup into the soil or vice versa, depending on soil moisture, were measured using a hand-held Thies Clima (Goettingen, Germany) pressure transducer which was inserted through the rubber septum.

2.3. Slurry and antibiotic application

Slurry from a working pig farm in Leicestershire, UK, was used in the experiment. The pigs were treated continuously with tylosin at 100 g/t of feed and the slurry had been stored for between 0 and 3 months in concrete lined pits under the houses. OTC and SCP were spiked into the slurry at concentrations predicted using the model developed by Spaepen et al. (1997). These were 18.85 $mg\, l^{-1}$ for OTC and 25.58 $mg\, l^{-1}$ for SCP (nominal concentrations). These concentrations are within the same order of magnitude as peak concentrations measured in slurry in recent studies for the sulphonamides (Campagnolo et al., 2002; Haller et al., 2002) and tetracyclines (Hamscher et al., 2002).

The slurry was applied at a rate of 45 000 $l\, ha^{-1}$, inline with normal agricultural practise (Kay et al., 2004). This was done using a watering can with the rose removed to allow the passage of slurry solids. Forty five litres of slurry was applied to each plot, therefore, 1.15 g