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A lysimeter experiment to investigate the leaching of veterinary antibiotics through a clay soil and comparison with field data

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This paper describes one of the first studies to investigate the fate of veterinary medicines in cracking clay soils.

Abstract

Pharmaceuticals used in livestock production may be present in manure and slurry as the parent compound and/or metabolites. The environment may therefore be exposed to these substances due to the application of organic fertilisers to agricultural land or deposition by grazing livestock. For other groups of substances that are applied to land (e.g. pesticides), preferential flow in clay soils has been identified as an extremely important mechanism by which surface water pollution can occur. This lysimeter study was therefore performed to investigate the fate of three antibiotics from the sulphonamide, tetracycline and macrolide groups in a clay soil. Only sulphachloropyridazine was detected in leachate and soil analysis at the end of the experiment showed that almost no antibiotic residues remained. These data were analysed alongside field data for the same compounds to show that soil tillage which breaks the connectivity of macropores formed over the summer months, prior to slurry application, significantly reduces chemical mobility.

Keywords: Veterinary medicines; Lysimeters; Clay soil; Leaching; Preferential flow

1. Introduction

Veterinary medicines are used in agriculture to prevent diseases in livestock and treat illness. Subsequently, the potential exists for quantities of these drugs to 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 direct deposition by grazing livestock (Halling-Sørensen et al., 1998).

Available data already show that residues may indeed be present in manure and slurry spread to land (Haller et al., 2002) and that this may subsequently lead to acute and sub-lethal effects in the environment (Holten-Lützhøft et al., 1999) including the development of antimicrobial resistance (Chee-Sanford et al., 2001). Only a limited amount of information is available, however, on concentrations of these compounds in soil (Hamscher et al., 2002), surface water and groundwater (Kolpin et al., 2002; Hirsch et al., 1999). Moreover, very few studies have looked at the processes determining the transport of veterinary medicines in the environment. It is therefore difficult to fully assess their risk to terrestrial and aquatic ecosystems and the extent to which agricultural management protocols need to address these compounds to ensure minimal adverse environmental impact.

A wealth of information exists to indicate that chemical application to under-drained clay soils poses

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a highly significant risk to the environment due to the rapid movement of runoff, solutes and sediment associated contaminants to surface waters via soil macropores and field drains (Kladivko et al., 1991; Brown et al., 1995). These studies have, however, focused on pesticides and nutrients which are somewhat different from veterinary medicines. Veterinary products have different usage patterns, are applied to land in manure and slurry and tend to have high molecular weights, many different functional groups and be polar (Boxall et al., 2002b). It may not therefore be appropriate to apply our understanding of other chemicals to veterinary medicines.

This lysimeter study was performed to complement a field investigation (Kay et al., 2004) which addressed the fate of antibiotics in an under-drained clay soil. Lysimeters have been widely used to investigate the leaching behaviour of plant protection products as they are easier to run than field experiments, less costly (Beck et al., 1995; Vink et al., 1997; Kamra et al., 2001) and are more likely to produce an accurate mass balance of chemical transport (Kamra et al., 2001; Francaviglia and Capri, 2000). In this case, the lysimeter study also made it possible to investigate the effects of incorporating the slurry into the soil immediately after application, which was not done in the field as normal agricultural practise was followed. The results of this study should help to assess the threat posed by veterinary medicines to terrestrial and aquatic organisms as well as provide an indication of potential management options that could be used to alleviate any risks.

2. Materials and methods

2.1. Lysimeters

Twelve undisturbed soil cores measuring 25 cm diameter and 60 cm depth (corresponding to the depth of soil above the tile drains in the field experiment) were extracted for the study. The soil was the same clay loam as in the field experiment (Table 1). The field from which the lysimeters were taken had been in ‘Set-Aside’ during the preceding growing season but was ploughed in the autumn, several months before the lysimeters were taken. The lysimeters were extracted by placing a metal cutting ring on the down turned end of a piece of underground drainage pipe and pushing this perpendicularly into the soil using the back actor of a JCB digger. The soil around the cores was then dug away and the lysimeters removed, with plastic caps protecting the ends of each column. The cores were transported to the laboratory in an upright position before being set up outdoors (Fig. 1). Any smearing of the soil at the base of each lysimeter, caused by contact with the plastic cap, was picked away with a hand-held trowel. Each lysimeter was then supported on a high density polyethylene funnel filled with non-calcareous rinsed pea gravel to support the soil and aid drainage. The junction between the lysimeter sleeve and the funnel was sealed using an underwater cement (Quentsplass Underwater Metal, Boston Chemical Company Ltd, Wetherby, UK). Leachate samples were collected in 1 l amber glass bottles and stored at −24 °C prior to chemical analysis. Precipitation was monitored onsite daily using a Casella raingauge.

Table 1
Soil characterisation

	Ap horizon 0–37 cm	Btg 1 horizon 37–60 cm
Sand (63 μm–2 mm), %	42.6	34.2
Silt (2 μm–63 μm), %	32.3	27.7
Clay (<2 μm), %	25.1	38.2
pH (in $CaCl_2$)	6.8	7.3
CEC, mEq/100 g	22.4	25.2
OC, %	2.2	0.7
Bulk density, g/cm^3	1.3	1.56

2.2. Study compounds

The compounds studied were chosen as they were commonly used in veterinary medicine (Veterinary Medicines Directorate, 2002), had a range of physico-chemical properties (e.g. Rabølle and Spliid, 2000; Ingerslev et al., 2001) and were largely excreted as the parent molecule (Parfitt, 1999). These comprised three antibiotics, which are used in greater quantities than other classes of veterinary medicine (Boxall et al., 2002b; Koschorreck et al., 2002). Oxytetracycline (OTC) belongs to the tetracycline group of antibiotics which

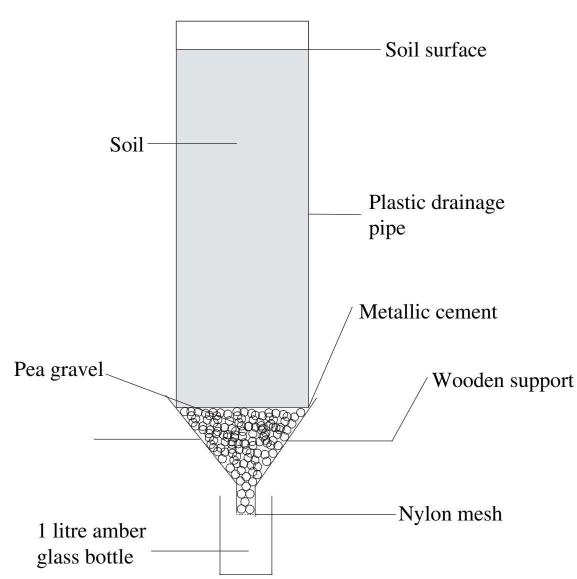

Fig. 1. Lysimeter design.