Veterinary pharmaceuticals in the environment: an introduction

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Abstract
The production of swine, cattle, and poultry raised for human consumption represents a significant portion of the U.S. agricultural economy. To maximize production, livestock producers regularly use pharmaceuticals and hormones as supplements in animal feed and water to increase rates of weight gain, and prevent or treat diseases among their livestock. For example, in swine it is estimated that antibiotics are used for disease prevention and growth promotion in more than 90% of starter feeds, 75% of grower feeds, 50% of finishing feeds, and 20% of sow feeds. Equally relevant numbers are seen in beef cattle production (1-4). It has been well documented that measurable quantities of pharmaceuticals are excreted, often in original form, in feces and urine of livestock. Livestock waste, containing pharmaceuticals and hormones, is often used as fertilizer for farm fields or pastures and may result in nonpoint source pollution of ground or surface waters (5). Field

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Chapter 2

Veterinary pharmaceuticals in the environment: an introduction

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The production of swine, cattle, and poultry raised for human consumption represents a significant portion of the U.S. agricultural economy. To maximize production, livestock producers regularly use pharmaceuticals and hormones as supplements in animal feed and water to increase rates of weight gain, and prevent or treat diseases among their livestock. For example, in swine it is estimated that antibiotics are used for disease prevention and growth promotion in more than 90% of starter feeds, 75% of grower feeds, 50% of finishing feeds, and 20% of sow feeds. Equally relevant numbers are seen in beef cattle production (1-4). It has been well documented that measurable quantities of pharmaceuticals are excreted, often in original form, in feces and urine of livestock. Livestock waste, containing pharmaceuticals and hormones, is often used as fertilizer for farm fields or pastures and may result in nonpoint source pollution of ground or surface waters (5). Field application of manure often involves injection or incorporation of the waste, which may bring nutrients, hormones, and pharmaceutical residues spatially closer to tile drainage systems. These drainage systems often flow directly into nearby streams, rivers, or other waterways, and may therefore act as a source of waterway contamination. A national reconnaissance study performed by Kolpin and colleagues (6) was among the first to bring widespread attention to the issue of pharmaceuticals in the environment. Many studies have examined environmental chemistry and ecotoxicology of human drugs, however fewer have examined veterinary pharmaceuticals.

Although pharmaceutical residues have been studied extensively in tissues and excrement, relatively little is known about the environmental fate of pharmaceuticals, hormones, and their metabolites once the excreta reaches soil and water environments (7,8). Sorption of chemicals onto solid phases, such as soil or sediment, or degradation is extremely important because it could affect the fate and impact of these substances in that environment.

Recently, veterinary pharmaceuticals were found in 48% of 139 stream waters tested in 30 states, according to the United States Geological Survey (6). Recent sediment monitoring studies by Kim and Carlson (9,10) detected
extractable antibiotic residues up to 0.1 mg/kg in sediment from an impacted river; typical concentrations were 0.001 to 0.03 mg/kg. The significance of low concentrations of veterinary pharmaceuticals in lagoon water, soil, and surface water ecosystems is not well understood, particularly when so few data are available regarding sorption and bioavailability of hormones and pharmaceuticals in environmental matrices. Simply detecting the compounds does not provide adequate information on the ecological significance. These concentrations appear to be too low for significant activity; however ecotoxicity data exist for only a small number of compounds. Low or transient concentrations of pharmaceuticals could have several effects; in addition to the obvious potential effects based on mode of action, they may have secondary modes of action causing harm to non-target populations in aquatic and terrestrial habitats.

Even at low environmental concentrations, hormones and pharmaceuticals and their metabolites may be biologically active in environmental matrices; these compounds are designed to elicit specific effects, and while those effects may not lead to mortality, the may significantly alter physiology or behavior, thus impacting organismal fitness. For example, antibiotics entering the environment could potentially alter bacterial populations and their activity in soil, sediment, and water, thus affecting biodegradation, nutrient cycling, and water quality. In addition, there is concern that antibiotics in the environment may induce antibiotic resistance, resulting in adverse human health effects. Certainly, there is significant evidence for development of antibiotic resistance within animals and in the excretion of antibiotic-resistant bacteria in manure (11-13). Much less is known about the ability of low concentrations of antibiotics to induce resistance in the environmental microbial population or to provide selective pressure for maintenance of antibiotic resistance genes among microorganisms, although the transfer of antibiotic-resistance from agricultural settings to humans has been reported (14). Similarly, low concentrations of hormones have also demonstrated potential biological activity (15-20).

There are concerns over potential direct and indirect effects of pharmaceuticals on non-target eukaryotic organisms in important habitats found across agricultural landscapes. In particular, small ponds and wetlands that serve as key breeding sites for amphibians and support invertebrate communities that provide food for migrating birds (21) can receive significant amounts of contaminated agricultural runoff, which could contain pharmaceutical residues (22,23). The aquatic risk of these chemicals has not been extensively characterized (24,25); even less is known about potential implications for terrestrial habitats.

Studies on the fate, bioavailability, and effects of veterinary pharmaceuticals in terrestrial and aquatic systems will lead to improved management practices through the understanding of the potential for risk to the environment. Studies presented in this book provide information that is essential to understanding the environmental mobility and degradation of veterinary pharmaceuticals and hormones. Bioavailability studies serve as a crucial link to understanding the likelihood of environmental residues impacting species or microbial communities in a negative way. Published reports have confirmed that very low levels of residues are detected in water and sediment
monitoring studies (6,9,10,26,27), but the significance of those residues will depend, to a great extent, on their biological availability. Ecotoxicological studies herein point to possible impacts of pharmaceutical and hormone residues on wildlife and plants; these studies are put in a risk assessment context, and importantly suggest unique considerations for ecological risk assessments of pharmaceuticals. The synthesis of these data into this book will provide a more comprehensive evaluation of the fate and potential effects of these contaminants in the environment, leading to more informed management decisions.

The purpose of this symposium was to bring together scientists from academia, government, and industry to discuss and present data relevant to the potential significance of veterinary pharmaceuticals and hormones in the environment. Topics presented in the subsequent chapters include fate studies examining sorption, mobility, degradation, and persistence in soil and aquatic systems, bioavailability in aqueous systems, ecotoxicological studies, and recommendations for risk assessment of veterinary pharmaceuticals.

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References


