

Avoiding Residues: More than Meat and Milk

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Introduction

This paper will focus on aspects of manure management related to the fate and transport of pharmaceuticals to the environment. The intent of this summary is to bring awareness of the potential impact of manure on the environment, and practices which can minimize that risk. We have chosen to use selected publications that will highlight the complexity of addressing management of pharmaceuticals

Fate and Transport of Pharmaceuticals

Manure is a biologically active material which hosts and supports many microorganisms, and thus can seldom be considered “pathogen free”. Certain manure handling techniques and methods however can limit the production and multiplication of such pathogens. In addition, common antibiotics and hormones have also been documented in animal manures. Awareness and risk assessments must be considered in developing best management practices and policy related to manure handling.

Antibiotics. The fate of antibiotics used at concentrated animal feeding operations (CAFOs) has gained recent attention by the regulatory community. Watanabe et al. (2010) reported the occurrence of antibiotics in the environment on two dairies. Samples were collected at the points of use of antibiotics and subsequent points of manure handling. They observed that although antibiotics had been used for decades on these two dairy farms, the antibiotics seemed to be detected within farm boundaries. Antibiotics were most frequently detected at lagoons, hospital pens, and calf hutches. Some evidence of sulfonamides was found in shallow ground water, while tetracyclines were identified in soils. Each of these antibiotics has distinct physiochemical properties. Sulfonamides are known to weakly sorb to soils, while tetracyclines have a higher sorption, thus explaining the

difference in location of detection. Lincomycin was found in ground water at one dairy, but not in the lagoon water at that same dairy. The authors suggest that due to Lincomycin's environmental persistence could explain the observation since it has photochemical and microbial stability. Evaluation of field surface samples demonstrated the presence of antibiotics on fields where manure had been applied, but not in the sandy subsoil.

Davis et al. (2006) studied the potential of seven antibiotics (tetracycline, chlortetracycline, sulfathiazole, sulfamethazine, and erythromycin, tylosin, and monensin) to appear in runoff water and sediment. The seven antibiotics were applied to land that had been prepared for corn production and then exposed to simulated rainfall. They observed that monensin had the highest concentration in runoff, while erythromycin had the highest concentration in sediment. Tetracycline and chlortetracycline had the lowest aqueous concentrations, and lowest absolute losses. The results suggest that erosion control practices would minimize the loss of tetracycline, erythromycin, and tylosin; while other methods would be needed to reduce off-site transport of the other four antibiotics.

The environmental occurrence and shallow ground water detection of monensin was studied by Watanabe et al. (2008). Monensin is expected to persist in the environment since hydrolysis and photolysis is limited (cited by Watanabe et al., 2008). In addition, monensin is expected to be more mobile than tetracyclines and of similar mobility to sulfamethazine (cited by Watanabe et al., 2008). Monensin was detected in one of eight shallow ground water wells at dairy I and three of eight wells (2 – 5 meters) at dairy II. The wells affected were associated with the lagoons, but not fields where manure was applied. The lagoons at both dairies were > 30 years old, were lined with 10% clay, but had previously been identified as leaking. The authors suggest that anoxic conditions near the lagoons (lack of oxygen) may promote the stability of monensin, while aerobic field conditions would promote degradation of monensin.

Antibiotic Resistance. Resistance of bacteria to antibiotics continues to be a concern of medical health professionals and veterinarians alike. Reducing the effectiveness of proven antibiotics would be costly for meat, milk, and egg production; and, potentially increasing the risk for bacterial infections insensitive to common antibiotics in humans. West et al., (2010) documented the presence of antibiotic resistant bacteria in samples from waterways in close proximity to waste-water treatment plants and CAFOs. From 830 environmental bacterial isolates, 77.1% were resistant to only ampicillin, while 21.2% were resistant to combinations of antibiotics including ampicillin (A), kanamycin (K), chlorotetracycline (C), oxytetracycline (O), and streptomycin (S). Multi-drug-resistant bacteria were significantly more common at sites close to CAFO farms.

There has been uncertainty as to when and, therefore, in what location that bacteria gain their ability to be antibiotic resistant? Does it occur in the animal's gut or in the environment? Two recent publications (Subbiah et al., 2012; and Subbiah et al., 2011) have provided some insight. Subbiah et al. (2011) evaluated 10 different antibiotics for their ability to be bioactive in soil. When ampicillin,

cephalothin, cefoxitin, ceftiofur, florfenicol, neomycin, tetracycline, and ciproflaxin were tested in soil-water slurries. It was observed that supernatants from soil-water slurries of ampicillin, cephalothin, cefoxitin, ceftiofur, florfenicol inhibited bacterial growth. In contrast, supernatants of soil-water slurries from neomycin, tetracycline, and ciproflaxin soil-water slurries did not inhibit bacterial growth. This study suggests that some antibiotics are not bioactive after contact with soil. A more recent report by Subbiah et al. (2012) suggests that urine containing ceftiofur metabolites is degraded more readily in warm soil (23 degrees C) but persists at 4 degrees C. The persistence under cool temperatures could provide a $> 1 \log_{10}$ advantage to cef^R resistant *E.coli* populations.

Hormones. Numerous studies have documented the presence of hormones in manure and their subsequent fate when manure is stored in manure lagoons or applied to crop land (Dutta et al., 2010; Khanal et al., 2006; Lorenzen et al., 2004; Raman, et al., 2004; Hansleman et al., 2003; Arnon et al., 2008; and Zhao et al., 2008). The general concern is the endocrine disrupting effects on wildlife and aquatic life when these hormones or conjugates are transported to ground and surface water. Endogenously (naturally) produced hormones excreted by humans and livestock, along with a host of compounds in human personal care products (ibuprofen, pigments, soaps), can disrupt endocrine system and have been linked with developmental, reproductive, neural, immune, and other problems in wildlife and laboratory animals.

Zheng et al. (2008) characterized the concentration of three endogenous hormones (17 alpha-estradiol, 17 beta-estradiol, and estrone) in dairy waste water and lagoon water. The concentration of total steroid hormones in the sequential lagoons was $\sim 1 - 3$ orders of magnitude less than in fresh dairy wastewaters. The same relationship was observed for steroid hormones in manure solids. Bartlett-Hunt et al. (2011) studied the occurrence of thirteen steroid hormones and seventeen veterinary pharmaceuticals at operating swine and beef cattle facilities. The facilities had lagoons that were known from prior studies to have direct infiltration of waste water into shallow ground water and represent a worst case scenario. Steroid hormones were detected less frequently than pharmaceuticals.

Treatment of manure via anaerobic digestion or composting can decrease the amount of estrogens detected in manure (Zhao et al., 2008). While there is still much to be learned, it is apparent that hormones or their conjugates have an ability to persist in the environment. This persistence can in part be explained by the lipophilic nature of hormones as they are poorly soluble in water and therefore would be absorbed onto sediment particles (Arnon, et al., 2008).

Best Management Practices

A number of currently used management practices serve to ameliorate the movement of pharmaceuticals from the point of excretion by the cow to the intersect of surface and ground water.

Grass Filter Strips. Nichols et al (1997) demonstrated that grass filter strips were effective in reducing the concentration of estradiol originating from poultry litter by 58%, 81%, and 94% after transport through filters of 6.1 meters, 12.2 meters, and 18.3 meters.

Composting. Windrow composting of poultry manure for 139 days resulted in a 84% decrease in 17beta-estradiol content and a 90% decrease in testosterone content (Haak et al., 2005).

Identify Readily Available Alternatives. One of the standard practices when producing ethanol from grain has been the use of antibiotics to control the fermentation. When antibiotics are added to fermentation vessels it allows for more efficient conversion of starch to ethanol. The ethanol industry has shifted toward use of non-antibiotic antimicrobial products to avoid the issue of antibiotic residues in distillers grains (Olmstead, 2012).

Anaerobic Digestion. Anaerobic digestion of manure (Zhao et al., 2008) and sewage sludge has been shown to result in reductions in pharmaceuticals.

Education Resources

The following webcasts and websites are recommended for further understanding of the factors related to pathogens and pharmaceuticals in manure.

- http://www.extension.org/pages/Potential_Routes_for_Pathogen_Transport_to_Water
- Animal Science Societies (FASS) hosted a webinar titled "Antibiotics in Animals and People" on October 20, 2010. http://www.fass.org/policy_webinar.asp
- <http://www.waterbornepathogens.org/>
- http://www.extension.org/pages/Manure_Pathogen_Articles
- Webinar – Antibiotics and Hormones: Occurrence in Water, Fate and Transport, and Best Management Practices.
http://www.extension.org/pages/Antibiotics_and_Hormones:_Occurrence_in_Water,_Fate_and_Transport,_and_Best_Management_Practices
- Veterinary Medicines in the Environment - http://toxics.usgs.gov/highlights/vet_meds.html

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