Figure 1. A smoke test was performed to demonstrate the presence of macropores between a subsurface drain tile [at about 1.2 m (4 ft) depth] and the soil surface. In this case, a 4.6-m-wide (15 ft) strip of alfalfa was sown directly over the tile drain (indicated by white flags), and annual row crops were grown on the remainder of the field. The alfalfa stand was in its second year of production. Note that the smoke emerges from highly dispersed locations, indicating how well the macropores are interconnected with the tile. This is visual confirmation that liquids, such as manure slurry, could be expected to enter the tile quickly if application rates exceed the infiltration rate of the soil.

CHAPTER 35

Manure Concerns—Pathogens, Antibiotics, and Other Chemicals

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(PHOTO BY RYAN MAHER, USDA-ARS).

Manure is a fantastic resource for farmers — brown gold, as some have called it — but its use is not without problems. These problems arise because of what the manure contains and how it is used, especially in certain field conditions.

Pathogens

Manure application to forages may enhance the spread of pathogenic organisms within a herd or, if either the forage or manure is transferred to other farms, pathogens may be spread to other herds. Many dairy operations have tested positive for the Johne's disease organism *(Mycobacterium avium* subsp. *paratuberculosis)* and to other bacteria including *Salmonella*, *Clostridium difficile*, *Campylobacter* and *Listeria* (USDA). Farmers facing the problem of herd or flock diseases need to consider a wide variety of mitigation tactics, among which is manure management.

Many pathogens excreted in feces can live for several months in the field. For example, although Johne's disease organism is an obligate parasite, surprisingly, it can survive longer than a year in soil or sediment apparently by entering a dormant state (Whittington et al. 2004). This pathogen has even been found in water leaching from the root zone and on harvested grass leaves (Salgado et al. 2011). Thus, forages contaminated with manure can transport Johne's disease organisms between animals on a farm and even between farms.

Manure enhances the survival of *Escherichia coli* in the field by providing carbon substrates for growth; the microorganism may survive for up to one month on clean plant surfaces, but organisms in a coating of manure on the soil could re-contaminate harvested forage when mowing, raking or baling weeks later (Habteselassie et al. 2010). Both antibiotic-resistant *E. coli* and non-resistant strains survived in large numbers for six months in cattle dung under field conditions (Alexander et al. 2009). The transport of manure between farms and the increasing use of manure hauling contractors may contribute to spreading pathogens even greater distances.

The risk of transfer of pathogenic organisms to animals is highest when manured forages are grazed, and is least when forages are ensiled (Thomas 2011). Forages need to be ensiled using best practices (correct moisture, rapid filling, good packing, oxygen exclusion and perhaps use of a silage inoculant). Dry hay and green-chopped forages may contain high populations of pathogens from top-dressed manure. If Johne's disease is present on the farm, the best option is to avoid top-dressing or broadcasting manure on forages and rather spread manure with shallow injectors. Forages top-dressed with manure that are properly ensiled are unlikely to transmit live Johne's organisms. Alternatively, manure contaminated with pathogens should be applied beneath the soil surface for arable crops like seed or grain crops rather than forage crops so long as there is no risk posed to humans.

Antibiotics and antibiotic-resistant bacteria

Many classes of livestock receive antibiotics prophylactically or as antimicrobial growth promoters, and 30-90% of the administered antibiotics can be excreted in manure (Kumar et al. 2005; Sarmah et al. 2006). Some of the antibiotics degrade rapidly, whereas others persist and have been found in runoff or tile drainage water (Dolliver and Gupta 2008; Song et al. 2010). Spread of antibiotics into the environment is potentially problematic if: 1) they can alter the ecological balance among microorganisms; 2) bacteria develop resistance to the antibiotics by repeated exposure to non-lethal doses (Kumar et al. 2005). Recent research has found that the presence of antibiotic resistance in bacteria is enhanced in manure (Heuer et al. 2011), and antibiotic-resistant bacteria have been transferred from manure to humans. These problems are most effectively avoided by reducing antibiotic use in livestock production, but composting and other manure treatments such as anaerobic digestion also may help to reduce risk (Storteboom et al. 2007).

Chemicals

Another concern with applying manure is transmission of pesticides. Herbicides that contaminate feed can be excreted in manure, either as the original compounds or degradation products that are phytoactive. For example, in the past few years plant damage has been reported from aminopyralid herbicide (brand names Milestone, ForeFront, Chaparral, GrazeonNext, CleanWave, and Opensight) that was applied in contaminated manure or compost from livestock pastured on or fed hay from treated fields. This herbicide is labeled for grassland to control deep-rooted perennial broadleaf plants such as thistles, ragweed and knapweed. It is effective in controlling alfalfa, also. The chemical is excreted in both urine and feces (Durkin 2007), and both manure and manure compost have reportedly damaged susceptible crops after application (USEPA 2011). Manufacturers have provided recommendations concerning the use of manure that may contain aminopyralid (Manure Matters).

Spread of naturally occurring bioactive chemicals in manure may also be a concern. Hormones and hormone mimics (chemicals that have similar effects as hormones at very low concentrations) are well known to be present in human sewage, but are also present in livestock and poultry manure. These chemicals disrupt the endocrine system in higher organisms, which regulates metabolism, growth, development and even emotional state. Pregnant animals excrete high concentrations of steroidal (fat soluble) hormones 17β-estradiol and the oxidized form, estrone. Also, different forms of 17β-estradiol are administered to growing cattle to increase muscle mass and reduce fat deposition. These compounds are known to affect development, especially sexual development, in many wildlife organisms (Colburn et al. 1993), and have been called micropollutants, because they are potentially damaging at concentrations of only a few parts per *trillion* (Thorpe et al. 2003; Thorpe et al. 2009). There is evidence that low concentrations of estradiol in irrigation water improved yields of alfalfa, although this effect was reversed at higher concentrations (Shore et al. 1992). The large boost in crop yield after application of liquid swine manure (Ceotto and Spallacci 2006) might be partially explained by the hormones contained in the manure. However, this surprising possible benefit from hormonal chemicals does not outweigh the potential for ecological disruption.

Estrone and 17β-estradiol usually do not move far in the soil matrix because they are adsorbed by organic matter and are degraded in moist topsoil, although very wet conditions slow their decomposition. Composting may be effective in reducing concentration of estrogenic compounds in manure (Hakk et al. 2005). Although movement to water is relatively rare (Stone and Casey 2009), these compounds have been found in cold-water streams in karst (fractured limestone bedrock) regions and in tile drainage water, as well as in runoff (Peterson et al. 2005; Kjær et al. 2007), posing a threat to both cold and warm water fisheries. Because a wide range of organisms are extremely sensitive to these hormones and hormone-like compounds, it is crucial to minimize the transfer of manure to water.

It is often risky to apply liquid manures with very low solids content on tile-drained soils when the tiles are discharging water. Risk of manure movement to surface water is greater with shallow tiles or mole drains compared to deeper drains (Goss and Richards 2008). Regardless of tile depth, liquid manure can move rapidly to the tiles through cracks in dry soils and macropores formed by tap-rooted crops and 'nightcrawler' earthworms (*Lumbricus terrestris*) (Fig. 1; see Ball et al. 2004 in *Advanced Silage Corn Management).* Manure loss to public waters via tile drains has resulted in litigation and large fines for manure applicators. Guidelines are available in many jurisdictions to reduce risk of manure movement to water through tile drains (Hoorman et al. 2008).

Conclusion

Manure is an asset for crop production but farmers and commercial manure applicators need to be aware of emerging concerns to minimize the impact on other farms and risk of conflict and litigation by the public.

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