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Best Management Practices for Pathogen Control in Manure Management Systems

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INTRODUCTION

Livestock waste contains many microorganisms such as bacteria, viruses, and protozoa. Some of these microorganisms do not cause sickness in animals or humans. However, some others are pathogens, meaning they are capable of causing disease in animals and/or humans. Irrespective of the size of their farms, all livestock producers have an important role in limiting pathogen movement from their operation to the environment. The purpose of this bulletin is to provide livestock producers with tools to help control pathogens in their production system. The best management practices (BMPs) addressed in this paper will focus on animal management and housing, dietary modifications, production management, land application of manure, and the chemical and biological treatment of stored manure. The number and types of pathogens present in livestock waste varies with animal species, feedstuff sources, health status of the animals, and characteristics of the manure and manure storage facilities. Not all pathogens are the same. Some are able to survive for long periods of time in manure. Others are susceptible to temperature extremes and manure processing. Therefore, adequate control of pathogens may require multiple management interventions to achieve significant reduction of pathogens in a manure management system.

PATHOGENS AND HUMAN HEALTH

Pathogens can be transmitted to humans directly throught contact with animals and animal waste or indirectly through contaminated water or food. Examples of human illness and death caused by exposure to livestock manure are found in Table 1. Water can become contaminated by runoff either from livestock facilities or from excessive land application of manure. Pathogens can contaminate food products during meat and milk processing. This bulletin will focus on BMPs to reduce exposure of food and water to pathogens in livestock waste.

Simply coming into contact with a pathogenic organism does not necessary mean that an individual will become sick. Some pathogens are highly virulent, meaning that exposure to even a few microorganisms can result in sickness. Others are less virulent. Healthy people exposed to low doses of less virulent pathogens likely will not become ill. However, elderly, young, or other susceptible individuals may become sick when exposed to even low levels of less virulent pathogens. Because it is impossible to know who will come into contact with pathogens from a livestock production area, it is a good management practice to reduce all potential exposures by controlling pathogens in livestock systems.

Some of the most commonly recognized pathogens from livestock include bacteria such as Shiga-toxin producing *Escherichia coli* (*E. coli*), *Salmonella*, *Campylobacter*, and *Yersinia*. Most bacteria can survive and even multiply in environments outside of the animal such as livestock manure. These bacteria can cause fever, diarrhea, vomiting, nausea, and abdominal pain in humans who are directly or indirectly exposed to contaminated manure.

Protozoa from livestock waste can also cause disease in exposed humans. *Giardia* and *Cryptosporidia* are considered to be the two most important waterborne protozoa of livestock origin. These protozoa are important because they are present in animal manure and are not easily destroyed except by filtration.

Although not as common as bacteria and protozoa, viruses can be present in animal manure. *Rotavirus* is the most commonly recognized pathogenic virus in animal manure. Viruses can not multiply outside of the animal, but are capable of surviving for long periods of time in the environment depending on environmental conditions. One study found that *rotavirus* could survive in a manure storage facility for more than six months.[1]

What can producers do to reduce potential contamination of surrounding surface and ground water from their livestock or poultry operations? There are three basic points in the manure management cycle where producers can implement practices to reduce pathogens: (1) in the animal, (2)

Table 1. Examples of human illness and death caused by exposure to livestock manure

Location	Year	Pathogen(s)	# of people ill	# of people died	Source of outbreak
Walkerton, Ontario, Canada	2000	*E. coli* O157:H7 *Campylobacter*	2,300	7	Drinking water contaminated when heavy rainfall caused cattle manure to enter groundwater supply through fractured limestone
Washington Co, NY	1999	*E. coli* O157:H7	781	2	Shallow, unchlorinated well at fairgrounds contaminated with drainage from manure storage area was used to prepare beverages
Springfield, IL	1998	*Leptospira*	98	0	Triathlon swimmers exposed to horse, sheep, and cattle manure that had washed into lake during heavy rains
Indiana	1996	*Cryptosporidium*	63	0	Swimmers exposed when heavy rains washed cattle manure into lake

Adapted from LPELC webcast series Outbreaks or illnesses due to livestock manure - case studies by Sheridan K. Haack, Nov 17, 2006. Available at: http://lpe.unl.edu/archive2.html

during manure collection and storage, and (3) during land application of manure. A good pathogen reduction program will include BMPs at each of these three points.

PATHOGEN REDUCTION -- THE ANIMAL

Animal management and housing

The more pathogens present in the animal, the greater the risk that food or water will be contaminated by the manure from the infected animal. Sick or stressed animals are more likely to shed pathogens in their manure than healthy, comfortable animals. Some animals appear healthy but are "carriers," meaning they have previously been exposed to disease-causing microorganisms and can shed pathogens in their manure when they feel stressed or uncomfortable. In addition, some animals shed pathogens even when they appear perfectly healthy. Therefore, simple management practices such as vaccinations, adequate access to feed and water, appropriate space allowance, temperature and ventilation control, on-farm sanitation and biosecurity measures (Figure 1), and good animal husbandry practices can be an easy first step for producers to reduce pathogens in their manure management system. For more information on specific BMPs for animal management, producers should call their local Extension Educator or a State Extension Specialist.

The type of animal housing facility can also influence presence of pathogens. For example, the use of slotted floors can decrease Salmonella compared to other floor types such as concrete or dirt lots for swine.[2] This is likely due to the fact that animals housed on solid floors are repeatedly exposed to contaminated feces, while the contaminated feces from animals in a slotted-floor barn fall to the underground pit.

Cattle are often raised in pasture systems instead of confinement facilities. How does this influence the prevalence of pathogens in livestock waste? Raising cattle on pasture does not appear to affect the strains of pathogenic *E. coli* most commonly associated with severe foodborne illness in humans, including the well-known *E. coli* O157:H7. Research has shown that there is no difference in the prevalence of *E. coli* O157:H7 in manure from cattle raised on pasture compared to those raised in confinement.[3]

Figure 1: Biosecurity sign to restrict transport of pathogens. Credit: Minnesota Pork Board

Fly and vermin control in livestock facilities may also reduce the spread and subsequent infection of other animals with pathogenic bacteria. Flies and bird fecal samples from cattle farms in the U.S. have tested positive for *E. coli* O157.[4] Numerous studies indicate that *Salmonella* can survive for at least several days, and for as long as nine months, on insects, rodents, and surfaces of building materials such as wood, concrete, iron, steel, and brick.[5] *Salmonella* can survive in rodent feces for up to five months, which underlines the need for adequate rodent control, and frequent and thorough cleaning of animal facilities.[6]

Producers may or may not have a choice in the type of housing facility that is available for their operation. However, implementation of BMPs that are consistent with good animal husbandry to reduce animal stress is an easy first step for reducing pathogens in any livestock operation. It is likely that the small economic expense of implementing these BMPs will be recovered with increased animal performance.

Diet modifications

Diet selection to decrease pathogen excretion in feces can reduce pathogen levels in manure. Fecal shedding of bacterial pathogens can be reduced through the addition of antimicrobials to livestock diets.[7] Antimicrobials have been used for growth promotion and to treat specific diseases. Recently, public concern has increased over the routine use of antimicrobials as growth promoters in livestock feeds, especially antimicrobials that are similar to or the same as those used in human medicine. Some researchers have proposed that the use of growth promoting antimicrobials in livestock feeds has resulted in increased incidence of infections in humans that are resistant to antimicrobials.[8,9] Therefore, if antimicrobials are to be used for pathogen control on a livestock operation, producers should use antimicrobials only to treat specific diseases rather than routinely adding them to livestock diets for growth promotion.

Organic acids have been successfully used in poultry diets to reduce the level of *Campylobacter* and *Salmonella* but produce variable results when used in swine diets.[10,11] Direct-fed microbials, or feed additives containing “good bacteria,” have been used to reduce *Salmonella* and *E. coli* in swine manure[12,13] and to reduce some pathogenic strains of *E. coli* in calves,[14,15] feedlot cattle,[16] and sheep.[17] The addition of yeast extracts to swine diets can reduce *E. coli* and *Salmonella* in young pigs and chicks.[18,19]

Abruptly switching a high-grain diet to a high-quality hay-based diet in cattle has been reported to reduce acid-resistant *E. coli*[20] and *E. coli* O157:H7.[21] However, due to the complex nature of the cattle digestive systems, this response has been inconsistent. [22-24]

Physical form of feed can also affect bacterial levels in manure. Pigs fed finely ground diets (1/16 inch screen) were more likely to test positive for Salmonella compared to pigs fed coarsely ground diets (5/32 inch screen).[25,26] Pigs fed pelleted feed were 3.3 times more likely to test positive for *Salmonella* compared to growing-finishing pigs fed a meal diet.[26] Therefore, producers wishing to decrease *Salmonella* in swine manure should feed coarsely ground meal diets instead of finely ground pelleted diets.

The use of dietary modifications can be a relatively simple management tool to use for reduction of pathogen excretion from a livestock operation. Producers should work with their herd veterinarian to determine which pathogens are present and if the pathogen level is high enough to justify a dietary modification. Because results have been inconsistent, producers need to consider the economical and performance impacts of a diet change and any necessary adjustments to management that will result from the diet change relative to the benefits of reducing pathogens in their operation. Each livestock operation is unique and results may vary from farm to farm.

PATHOGEN REDUCTION -- MANURE COLLECTION AND STORAGE

Production management

Use of vegetative filter strips. Runoff and erosion from open feedlots and manured fields can be routed through grass filter strips to remove sediment, nutrients, and bacteria. The effectiveness of vegetative filters at removing pollutants and microorganisms depends upon site characteristics such as slope, amount of runoff, type of wastes, and presence or absence of concentrated flows. Time of year is also important. The vegetative filter strips will be less effective during springtime snowmelt when the filter strips may still be frozen or not actively growing. One study has shown that grass filter strips (15 to 30 feet in length) remove 75 to 91% of fecal coliforms and 68 to 74% of fecal *streptococci* from runoff obtained from manured plots.[27] Animal confinement areas should have a 66 to 99 foot vegetative filter strip between animals and surface water in order to minimize contamination.[28]

Control runoff and leaching from stockpiled manure. Some livestock operations need to stockpile manure before land application. If manure must be stockpiled, producers should follow all regulations set by the state regulatory authority, which, in Minnesota, is the Pollution Control Agency. Minnesota rules require that stockpiles be located, constructed, and operated so that manure-contaminated runoff from the site does not discharge into waters of the state. Permanent stockpiles must be placed on a concrete pad or clay base and have at least two feet of separa-

Figure 2: Newly constructed catch basin below an open lot. Credit: Dale Walz, Stearns Co. MN

Figure 3: Newly constructed filter strip to receive effluent from open lot catch basin. Credit: Dale Walz, Steans Co. MN

tion distance between the base of the stockpile and the seasonal high-water table. Catch basins can be used to prevent runoff from permanently stockpiled manure from reaching surface water.

Control runoff and leaching from open lots. Catch basins can be used to contain manure-contaminated water from an open lot. The water collected in catch basins can be land-applied or further treated by running through vegetative filter strips (Figures 2 and 3)

Install clean-water diversion. Berms and ditches can be used to divert up-slope runoff and rain water from buildings away from open lots or other areas where manure may accumulate. Preventing this excess water from entering the lot or manure stockpile area will not only reduce pollution potential, but will also help keep these areas drier. Drier facilities can improve animal health, which in turn lowers pathogen levels in manure.

Eliminate or reduce livestock access to streams, rivers, lakes, or ponds. Fencing livestock away from open water is an effective method of improving water quality (Figure 4). Keeping animals away from open water will prevent urination and defecation in the stream which can lead to bacterial pollution. Animal health may also be improved through reduced exposure to water-transmitted diseases and foot rot. Alternative livestock water systems can replace direct, uncontrolled livestock access to streams, ponds, and lakes (Figure 5). These systems are described in the UM Extension bulletin BU-07606, Grazing Systems Planning Guide, available in paper or in electronic form at *www.extension.umn.edu*.

Best management practices to control runoff from livestock operations will not eliminate or reduce pathogens on a livestock operation. However, implementation of these BMPs will prevent pathogens from leaving the livestock operation and potentially contaminating food or water supplies.

Figure 4: Livestock exclusion fencing to protect a stream. Credit: Tim McCabe, USDA-NRCS

Figure 5: Nose pump for livestock watering away from streams, lakes, and ponds. Credit: Lynn Betts, USDA-NRCS

Most are relatively easy to install and partial funding for construction of systems to control or treat runoff may be available through the Natural Resource Conservation Service Environmental Quality Incentives Program (NRCS – EQIP) or state cost-share programs. Contact your local NRCS office or Soil and Water Conservation District to determine if your project qualifies for EQIP or other cost-share programs.

Figure 6: Compost turning. Credit: David Schmidt, University of Minnesota

Biological Treatment of Manure

Anaerobic storage. Anaerobic lagoons are widely used in southern climates for the treatment and temporary storage of swine manure but are not used in Minnesota. Deep pits, also an anaerobic storage system, located beneath animal housing facilities, are commonly used in Minnesota. In an anaerobic system, bacteria are not exposed to oxygen. Although bacteria can survive anaerobic conditions for long periods of time, most pathogens are reduced within 30 days.[29] Bacteria that do survive may be destroyed during the land application process due to exposure to UV light and the natural drying out of the bacteria if the manure is surface applied. However, it is recommended that liquid manure from these systems be injected or immediately incorporated to conserve nitrogen and avoid risk of phosphorus runoff.

Composting.Compost is an organically rich soil amendment produced by the decomposition of organic materials. During the composting process, organic materials such as animal manure and livestock carcasses are broken down by microorganisms. Active composting generates heat, carbon dioxide (CO_2) and water vapor. The end product of composting is a dark, earthy-smelling material. During composting, temperatures can reach 150°F. Most pathogens that are harmful to humans can be destroyed at 131°F or higher. The Minnesota Board of Animal Health recommends two heat cycles of greater than 131°F to ensure pathogen destruction. However, there is no evidence that composting destroys prions, the abnormal proteins believed responsible for diseases such as Bovine Spongiform Encephalopathy, Chronic Wasting Disease and Scrapie.

In order for their compost to successfully reach a temperature of 150°F, producers need to monitor the compost pile carefully. The microorganisms in the compost need certain nutrients such as carbon and nitrogen that must be provided in correct quantities. Incorrect ratios of carbon and nitrogen can cause the compost pile to either over-heat (causing a fire) or remain cold and dormant. Heat must be uniform throughout the compost pile and the composted manure must be turned and mixed on a regular basis so that all manure has sustained exposure to the pathogen-killing temperatures (Figure 6). More information about composting is available at the U of MN Extension Dairy website: *www.extension.umn.edu/dairy/dairystar/09-09-06-Spiehs.htm*

Figure 7: Aerobic digester on Minnesota farm. Credit: The Minnesota Project

Aeration. Aeration involves exposing manure to oxygen and air. Natural aeration involves storing manure in large, shallow (less than 5 ft. depth), storage structures so enough oxygen can naturally reach the bacteria. These types of structures are rare in Minnesota or other northern climates. Mechanical aeration involves pumping air into a storage structure. Aeration is especially effective against viruses in cattle and pig slurry.[30,31] The combination of supplemented heat and aeration can further reduce pathogens in manure.[30] Storage at 68°F for two to four days in an aerated system reduced infectious viral load 90%. To get the same reduction at 41°F in a non-aerated system, 300 days were required. The combination of aeration and high temperature (122°F) can destroy *Salmonella*, *E. coli*, fecal *Streptococci*, and *Cryptosporidium* oocysts in cattle manure in as little as 24 hours.[31] Due to the costly nature and the reduced effectiveness of aeration systems during cold weather they are not commonly used in Minnesota.

Anaerobic digesters. Anaerobic digesters have been primarily used for manure stabilization and odor control (Figure 7). They have also been shown to reduce *E. coli*, *Salmonella typhimurium*, and *Yersinia enterocolitica* in the digester slurry. At a digester temperature of 95°F, 90% reduction in these bacteria required less than three days. Anaerobic digestion was not as effective against *Listeria monocytogenes* and *Campylobacter jejuni*.[32]

Many livestock producers, particularly those raising swine and dairy, may already be utilizing anaerobic manure treatments such as deep pits in their operation. Farms that generate solid waste can modify their operation to incorporate composting. There is growing interest in the use of anaerobic methane digesters for manure treatment. Higher capital investments will be necessary for producers wishing to utilize aeration or anaerobic digesters as a means of pathogen control, but other benefits such as odor control and the generation of alternative energy may justify the additional cost for some livestock operations.

Chemical Treatment of Manure

Chlorine. Chlorine is a method of disinfection commonly used for drinking water.Chlorine is very effective against bacteria but less effective against viruses and protozoa. Unfortunately, the high organic matter found in manure substantially inhibits the effectiveness of chlorine. The chemical reactions that occur when chlorine and organic matter are exposed to each other also produce toxic and carcinogenic by-products.

Lime stabilization. Lime stabilization of animal slurry has been used to reduce odor and pathogens before land application. The advantages include low cost of lime, easy disposal of treated slurry, and reduction in soil acidification. However, there may be some additional costs to consider such as labor to mix and haul the lime.

Ozone. Ozone is a powerful oxidizing agent and very effective at killing bacteria. *E. coli* counts were reduced by 99.9% and total coliforms decreased 90% after treatment with ozone.[33] However, organic materials found in animal waste interfere with ozonation and therefore a pretreatment such as solids separation would be needed for an effective ozonation process.

Ultraviolet light (UV) irradiation. Ultraviolet light irradiation destroys the DNA and RNA of pathogens. There are no residual compounds present after UV disinfection and the nutrient content of manure is not affected by UV exposure. Viruses are more resistant to UV treatment than bacteria and protozoa.

Pasteurization. Pasteurization of manure requires that a temperature of 158°F be maintained for 30 minutes. It is effective at reducing all pathogens but would be cost-prohibitive on most livestock operations unless it occurs as part of a composting or digesting system.

While effective in reducing pathogen levels in stored manure, most chemical treatments are not economically feasible for small to mid-sized livestock producers. Lime stabilization may be the only chemical treatment that could be implemented economically on small or mid-sized farms. However, larger producers may find chemical treatments such as ozone an attractive alternative to current manure management practices.

PATHOGEN REDUCTION -- LAND APPLICATION

Land application is a critical period in manure management. Pathogens from animal waste can threaten humans who are exposed to runoff, have direct contact with manure, or consume food or water contaminated with infectious manure. Application rate and seasonal conditions are important factors contributing to the transfer of pathogens from lands where manure has recently been applied to nearby surface water.

There is a higher risk of pathogen transfer to the food chain when fresh manure is land-applied than when stored manure is land-applied because there is no storage or treatment period to decrease pathogen numbers.[34] Typically, bacteria are highly susceptible to UV light and drying that naturally occur following surface application of manure to cropland. Cattle grazed on pasture two to three weeks after human sludge was applied to a field did not get sick but 1/3 of cattle that grazed a field immediately after sludge application became ill with Salmonella.[35] This indicates that pathogen numbers were decreased by UV exposure and natural drying of manure on the soil surface. Delaying incorporation for even one week significantly reduced pathogen survival following manure application due to exposure to UV radiation and the drying effect of the atmosphere.[36] Incorporating manure will increase the total time that manure-borne pathogens remain viable in the soil after land application.[36] But leaving manure on the soil surface increases the likelihood that pathogens can spread through flies or vermin, increases the possibility that heavy rainfall will cause surface runoff and contaminate nearby water sources, and increases odor and gas emissions from the field.[36]

The greatest risk of pathogen transfer from manured land to surface waters is through runoff. Runoff into tile lines or surface fractures in Karst soils can contaminate ground water as well. Production practices that reduce or eliminate runoff of manure-contaminated water will ultimately reduce pathogen transfer. When it comes time to land-apply livestock manure, be sure to calibrate application equipment and apply at recommended rates based on crop nutrient needs. Manure application rate has been shown to correlate positively with indicator organisms for pathogenic viruses.[37] Higher levels of indicator organisms were found in soils where manure was applied at twice the recommended level compared to soils where manure was not applied.[36] These high levels persisted for 143 days after manure application.[37] Injection or incorporation of manure will also decrease runoff potential.[37,38] Avoid application during winter months when the ground is frozen because this increases the likelihood of manure runoff into nearby waters during spring snow melt. Pathogen survival in manure and soil is enhanced at low temperatures[39], increasing the risk of transport of viable pathogens in surface runoff from winter-applied manure.

SUMMARY

The best management practices described above can aid producers in reducing pathogen transfer from their operations. Producers need to determine which BMPs or combinations of BMPs are economically feasible for their operations.

Some of the BMPs described in this bulletin are easily implemented and economically feasible for livestock operations of all sizes. Best management practices that are consistent with good animal husbandry to reduce animal stress should be implemented on every farm. Livestock operations of all sizes need to control runoff and leaching from stockpiled manure and open lots. Many producers already use biological treatments such as anaerobic storage in deep pits and composting that significantly reduce pathogen survival in manure.

Diet modification, installation of vegetative filter strips, elimination of livestock access to open water, changes in animal housing facilities, and use of lime to treat manure may be economical for some producers and should be evaluated on a case-by-case basis. Other practices such as aeration of stored manure, anaerobic digesters, and use of chemical treatments such as chlorine, ozone, UV light, and pasteurization may not be economically feasible for small to mid-sized producers. Large-scale producers may be better able to utilize this type of BMPs. Clearly, more research is needed in this area to discover new, low-cost practices that reduce pathogen transfer from manure and to improve the BMPs mentioned in this publication.

RESOURCES FOR ADDITIONAL INFORMATION

University of Minnesota Extension Manure Management and Air Quality
www.manure.umn.edu

Livestock and Poultry Environmental Stewardship
www.lpes.org

National Livestock and Poultry Environmental Learning Center
www.lpe.unl.edu

Minnesota Pollution Control Agency
www.pca.state.mn.us

Midwest Planning Service
www.mwps.org

BEST MANAGEMENT PRACTICES CHECKLIST

- ☐ Good husbandry practices

    Vaccinations
    Adequate access to feed and water
    Adequate space allowance
    Appropriate temperature for age of animal
    Adequate ventilation
    Biosecurity protocol enforced on farm

- ☐ Animals housed on slotted floors
- ☐ Use of antimicrobials to treat disease only
- ☐ Use of antimicrobials to treat disease only
- ☐ Use of organic acids in diet
- ☐ Use of direct-fed microbials in diet
- ☐ Use of yeast extracts in diet
- ☐ Feeding coarsely ground diet
- ☐ Feeding meal diet
- ☐ Use of vegetative filter strips to treat runoff
- ☐ Runoff and leaching controlled from stockpiled manure
- ☐ Runoff and leaching controlled from open lots
- ☐ Clean water diversions installed around open lots
- ☐ Livestock access to streams, rivers, ponds, and lakes eliminated or reduced
- ☐ Anaerobic lagoon or deep pit used for manure storage or treatment
- ☐ Composting used for manure storage or treatment
- ☐ Aeration used for treatment of stored manure
- ☐ Anaerobic digestion (with or without heating) used for manure treatment
- ☐ Chlorine used for manure treatment
- ☐ Lime stabilization use for manure treatment
- ☐ Ozone used for manure treatment
- ☐ Ultraviolet light used for manure treatment
- ☐ Pasteurization used for manure treatment
- ☐ Equipment calibrated before land application of manure
- ☐ Manure applied at recommended rates for crop nutrient removal
- ☐ Manure injected or incorporated immediately following land application
- ☐ Manure not applied during winter months

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