Animal Agriculture and the Environment

Water Quality

In an effort to remain profitable, livestock farms are consolidating and expanding in size. Along with expansion come larger facilities, more management responsibility, greater visibility in the community and a greater potential for adverse effects on the environment. Perhaps the greatest uncertainty regarding potential risk to the community and impacts on water quality from agricultural operations is related to manure management. Manure land application has long been important in the process of building soil quality and fertility for profitable crop production. Land application is also important in manure treatment and pathogen remediation.

This fact sheet helps answer frequently asked questions about potential impacts from livestock farming systems on surface water and groundwater quality.

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What are some specific negative environmental impacts of nutrient loading due to manure runoff in drainage ditches? Specifically, affects from: nitrogen, phosphorus and biochemical oxygen demand (BOD).

Nitrogen (N) and phosphorus (P) are major plant nutrients applied to cropland to maintain optimal yields. These nutrients are frequently applied as commercial fertilizer, but livestock manure is an important source of N, P, organic matter and micronutrients. Dissolved oxygen (DO) is a measure of the volume of oxygen in water. Michigan water quality standards specify that surface waters designated as cold-water fisheries meet a minimum DO standard of 7 mg/l, and that warm-water fisheries meet a minimum DO of 5 mg/l. Prolonged exposure to DO concentrations of less than 2 mg/l will kill most aquatic life.

Biochemical oxygen demand (BOD) is a measure of the oxygen (O_2) consumed in the microbial breakdown of organic compounds. The greater the BOD, the more rapidly O_2 is removed from the water supply and the less O_2 is available for aquatic life. Because agricultural land is nutrient-rich, runoff from farmland can carry organic matter and soluble and particulate-bound N and P to surface waters. If nutrient-rich runoff from a farm field enters a stream or river, the excess nutrients stimulate aquatic plant growth and accelerate the process of eutrophication, whereby an increase in algae and small aquatic plants increases turbidity (cloudiness) and reduces sunlight for beneficial aquatic vegetation. When the plant material decays, it increases the BOD and the O_2 level declines. As the aquatic habitat is depleted, desirable fish and other species are displaced by less desirable species. Because manure contains organic matter and has a high BOD, in extreme cases such as a manure spill or highly contaminated runoff emptying into a waterway, ammonia toxicity and a rapid drop in DO can cause a fish kill.

Manure and nutrient-rich runoff are not the only sources of BOD in the watershed. Other common sources include decaying vegetation, urban storm water runoff, the discharge from combined sewer overflows (CSO_S), sanitary sewer overflows (SSO_S) and improperly functioning septic systems that bypass the soil treatment process.

Is manure runoff in surface water an unavoidable risk related to livestock operations?

Manure-tainted runoff water is avoidable. Contaminated runoff water can originate from pastures, open lots, lanes and other areas. The NRCS can provide guidance in the placement, construction and management of structures for the diversion and containment of tainted runoff water at the farmstead. Runoff from fields after manure land application is also a potential source of tainted runoff, but many effective management options exist for soil and nutrient stabilization.

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Many crop producers have adopted low-disturbance tillage and no-till cropping practices that protect water quality by minimizing runoff, erosion and sedimentation of streams and waterways. When combined with vegetative filter strips, grassed waterways, cover crops and other soil conservation techniques, these cropping practices are very effective in mitigating overland flow and runoff from farm fields. Manure land application plans should be custom designed on a field-by-field basis whereby sensitive areas are identified and protected with setbacks — areas where no manure is applied — and vegetated buffers that filter contaminants if runoff does occur. Examples of sensitive areas include lakes, streams and wetlands; areas prone to flooding; ditches; grass waterways; and areas that drain to surface waters.

Runoff may occur from even well-managed fields during storms of uncommon intensity or duration; for instance, storms with an expected 5- or 10-year frequency. Management and attention to details are key components of environmentally sensitive livestock-based cropping systems.

In the past, when manure contaminated surface water, was that event the result of inappropriate manure application, manure storage structure failure, a breach of the manure storage facility or other mismanagement?

Because manure handling, storage and land application methods vary greatly from farm to farm, there have been many causes of manure pollution of surface waters. In rare cases, storage structures have failed. Hoorman et al. (2005) evaluated 98 documented cases of manure contamination of surface waters in Ohio from 2000 through 2003. Most cases occurred on midsized swine (42 cases, average of 2,355 head) or dairy (37 cases, average 556 head) farms with at least 1 million gallons of manure storage. Fourteen farms (14 percent) accounted for 43 (44 percent) of the violations. Most of the farms (58) did not have an approved manure management plan, and of the 39 farms that had a management plans, 28 (72 percent) were not following them.

Hoorman et al. reported that application timing, rate and method were important. Of the 98 violations, 72 followed liquid manure application to cropland (55 after surface applications, 17 after subsoil injection). Irrigation was the most common surface application method (31) followed by the slurry tank (16) and dragline (8). The average reported application rate was 16,300 gallons per acre (GPA); the range was from 1,400 to 47,000 GPA. No tillage or incorporation was used in 57 cases; 17 used incorporation, and 24 cases were unknown. When tillage was used, overapplication, heavy rainfall or saturated soils were often cited as having contributed to the discharge.

In the Ohio study, manure contamination was linked to a combination of events. For instance, insufficient storage capacity may have led to a storage failure, an excessive application rate or application to saturated soil. The No. 1 cause (41 cases) was heavy rain after application or application on saturated soil, but in 66 cases, rain or wet soil were contributing factors.

Hoorman et al. cited poor management in more than 75 percent of the Ohio violations. Clearly, careful attention to those factors under the control of the farm manager can greatly reduce or eliminate the frequency and severity of runoff events.

With current technology, is one management system and size of production environmentally superior to another management system or size — i.e., comparing pasture, totally housed and bedded housing with an open lot?

We are not aware of research directly comparing the environmental effects of various livestock management systems. We do know that livestock farms are consolidating and expanding in size, and along with larger facilities come more management responsibility, greater visibility in the community and a greater potential for adverse impacts on the environment. However, our observations suggest that farm management that reflects a determination to mitigate potential adverse environmental effects appears to be more important than farm size or type of operation. Well-managed pasture-based systems that maintain a dense vegetative cover, observe setbacks, and restrict animal access to streams and other environmentally sensitive areas can be a community asset with minimal adverse impacts. On the other hand, just a few horses or cows on a few poorly managed acres can cause serious streambank erosion, sedimentation and manure contamination of surface waters.

There is little potential for tainted runoff from animal holding areas with total confinement housing because the livestock are under a roof. Many of these large farms operate under manure and nutrient management guidelines outlined in a farm-specific Comprehensive Nutrient Management Plan (CNMP) that specifies the timing, location and amount of manure that can be applied to the land. In addition, on-farm implementation of CNMPs raises the awareness of farm managers and their employees of the potential for manure contamination of surface and groundwaters.

Properly managed, a large livestock operation may have less impact on water quality than a small pasture-based farm, a few animals on a few poorly managed acres, or an improperly connected residential septic system.

What are some specific negative impacts of manure runoff in drainage ditches related to pathogenic microbes such as *E. coli*, viruses and parasites?

Negative human health impacts are associated with exposure — contact, ingestion and aerosol exposure — to pathogens that cause disease. **We measure the potential risk through indicators**. Fecal indicator bacteria are bacteria that are generally harmless themselves but are found in high densities in the guts of humans and other warm-blooded animals, are excreted in fecal wastes, and are found in sewage, septage, biosolids, septic tank effluent and animal waste. Examples of fecal indicator bacteria historically used for monitoring of sewage, recreational, ground- and drinking waters include the coliform group (total and fecal), *E. coli* and enterococci. The presence of these fecal indicators may signal the presence of other, more harmful pathogenic microorganisms.

Types of indicators

Total coliforms: a group of bacteria found in animal and human feces (but also in soil). These indicators are used to assess the safety of drinking water and groundwater.

Fecal coliforms: a subgroup of the total coliform group. They originate in animal and human waste and are used for evaluating wastes, particularly wastewater discharges from sewage treatment plants.

E.coli: a particular type of fecal coliform. It is used for evaluating recreational waters because there is a relationship between swimming in waters with increasing concentrations of these bacteria and health risk — risk of diarrhea, respiratory disease, and ear, eye, and nose and throat infections. *E.coli* is also used to assess drinking water and groundwater. Special groups of pathogenic *E.coli* (e.g., *E.coli* 0157:H7, which caused the recent spinach contamination) can cause serious disease. They are found in the wastes of infected animals and humans but at lower levels than the indicator *E.coli*. (See "what is a pathogen?" below.)

Enterococci: a group of bacteria found in feces of humans and animals. Enterococci are used to assess recreational water quality. There is a relationship between swimming in waters with increasing concentrations of these bacteria and health risk (risk of diarrhea, respiratory disease, and ear, eye, and nose and throat infections).

Coliphage: viruses found in the feces of animals and humans that infect bacteria. This may become a new indicator for groundwater (EPA Ground Water Rule). Because coliphage is a virus, it can move readily through soil.

What is a pathogen?

A pathogen is a bacterium parasite or virus that can infect animals or humans and cause disease. The pathogens of concern in water are referred to as waterborne pathogens. These microbes are excreted in feces of infected organisms (not all organisms excrete pathogens as they excrete indicators). They can survive in water and infect the next person or animal they contact when that person or animal ingests the pathogen (usually through exposure to contaminated hands, food, recreational waters and drinking waters).

Key zoonotic pathogen sources/exposures/diseases

Pathogen	Sources	Types of Exposures	Diseases
Bacteria:			
Pathogenic E.coli *Campylobacter* *Salmonella*	Animal and human waste	Drinking water, recreational water, hands, contaminated surfaces	Diarrhea, Guillian-Barre, Reactive Arthritis, Hemolytic Uremic Syndrome
Parasites:			
Cryptosporidium	Animal and human waste	Drinking water, recreational water, hands, contaminated surfaces	Diarrhea

Some pathogens are *zoonotic pathogens*, microbes/pathogens that infect both humans and animals and can move from animals to humans and from humans to animals. Rotaviruses and enteroviruses often found in human waste are host-specific: they are distinct from those that infect animals and are not considered zoonotic.

Animal excreta (fecal wastes) containing zoonotic pathogens can release these pathogens into waterways directly — e.g., cattle in streams — or from populations of animals from manure or waste lagoons. If these pathogens enter waterways, they can survive for days or months and may end up at beaches or in waterways where people recreate. Exposure through touching the water, ingesting the water or inhaling any aerosols (or splashes) can occur, and then the pathogen may take hold and start an infection. Indicator organisms are also found in all these wastes at high concentrations and indicate the potential presence of the true pathogens.

There are published reports of manure entering groundwater. Were these events the result of inappropriate manure application, failure of a manure storage structure or failure of the drinking water system?

It is difficult, given our current system of determining and documenting the causes of human illness, to specify how many cases of human sickness are due to pathogen contamination of water resulting from agricultural livestock sources. Not all waterborne disease outbreaks are recognized, investigated or reported. In many cases, the pathogen causing the outbreak is not determined, and even when the pathogen is determined, by the time the outbreak environment is investigated, the source of contamination may no longer be present.

There are several records of outbreaks of human illness, and deaths, associated with contamination of water with livestock manure. In a recent book summarizing 66 drinking water outbreaks from affluent nations (Hrudey and Hrudey, 2004), 12 implicated livestock manure as the pathogen source. These included:

1. An outbreak at the 1999 Washington County Fair, New York (*E. coli* O157:H7; of 781 confirmed cases, 71 people were hospitalized, and 2 died)
2. An outbreak in Walkerton, Ontario, Canada in 2000 (*E. coli* O157:H7 and *Campylobacter jejuni*; 2,300 people were ill, 65 were hospitalized and 7 died)

In both these cases, a ground water well providing public water supply was contaminated by livestock manure following heavy rainfall. In both cases, there were problems with the well construction or maintenance that permitted the contamination to occur, and there was no plan in place for a well-head protection area — an area surrounding the well where certain activities that might contaminate the well water are prohibited — (Hrudey and Hrudey 2000).

The U.S. Centers for Disease Control (CDC; www.cdc.gov) maintains a record of the cause of all drinking water (including the water system deficiencies) and recreational water outbreaks reported since 1971 (CDC, 2004). The following zoonotic pathogens (those that can be transferred between humans and animals) were identified in drinking water outbreaks between 1991 and 2002: *Giardia* (16%), *Cryptosporidium* (7%), *E. coli* O157:H7 (5%) and *Campylobacter* (3%) (Craun et al. 2006). In most cases, the specific source of the zoonotic agent was not identified. Water treatment deficiencies contributed to 14-34% of drinking water outbreaks between 1991-2002, and water distribution deficiencies contributed to 25-50% of outbreaks in the same time period (Craun et al. 2006).

These data indicate that multiple barriers must be established to prevent drinking-water contamination, including source water protection, adequate monitoring, water treatment and sanitation (Hrudey and Hrudey, 2004; Calderon et al. 2006). In addition to these safeguards for municipal or other public water supplies, homeowners should be aware of the need for monitoring and maintenance for domestic wells.

Have antibiotics been found in surface and groundwater? If so, do they have a negative impact on those waters? How do they enter those waters?

Chemicals used every day in homes, industry and agriculture can enter the environment in wastewater. A 1999 study by the Toxic Substances Hydrology Program of the U.S. Geological Survey (USGS; http://toxics.usgs.gov/regional/emc/index.html) showed that a broad range of chemicals found in residential, industrial and agricultural wastewaters commonly occur in mixtures at low concentrations in surface waters of the United States. The chemicals included human and veterinary drugs (including antibiotics), natural and synthetic hormones, detergent metabolites, plasticizers, insecticides and fire retardants. One or more of these chemicals were found in 80 percent of the streams sampled. Fifty percent of the streams contained seven or more of these chemicals, and about one-third of the streams contained 10 or more of these chemicals. Measured concentrations were usually extremely small, and for pharmaceuticals (including antibiotics) much lower than would be consumed if a person or animal were consuming the drug. In Huron County, Michigan, a USGS study detected both human-use and veterinary-use antibiotics in stream water, but there were no detections in groundwater (Duris and Haack, 2004). Other chemicals indicating domestic, industrial and agricultural impacts on water quality were also detected. The fact that we detect these chemicals in water shows us that virtually every aspect of our collective human actions influences surface water and groundwater quality. Many of these chemicals are ones we use every day in our personal lives, or medications that we consume or give to our pets or that are required for the health and welfare of animals in agriculture. Since we have only begun to recognize the occurrence of these chemicals in the environment, we have much work to do before we can state what the consequences of their detection will be.

Are Gratiot County soils and water table suitable for livestock production and manure application?

Many locations in Gratiot County have soils and water table suitable for livestock production, manure storage and manure application to cropland. Characteristics that influence the suitability of a site for a manure storage facility include but are not limited to soil type, depth to seasonal high water table, land slope, proximity to wells and flow paths to surface water. Site suitability for land application of manure will depend on many factors, including soil type, land slope, moisture content of the manure, crop nutrient needs, manure nutrient content, soil drainage, weather conditions, crop stage, proximity to surface water and residual nutrients.

Is it possible for manure from manure storage structures and field application to enter our groundwater?

Unless the ground is underlain by solutionized bedrock such as limestone near the surface there is little to no possibility for raw manure to reach groundwater. Solutionized bedrock is not found in Gratiot County. There have been situations where manure nutrients and/or pathogens have entered groundwater and surface water, but none was associated with a structural failure when the structure was in accordance with the NRCS standard unless there was a catastrophic failure due to flooding or overfilling. One structure in another state had a foundation collapse because the subsurface investigation missed the presence of underlying solutionized bedrock.

Manure application poses little threat to surfacewater and groundwater when it is applied properly. The proper method, time, rate and placement will depend on many factors, including soil type, land slope, moisture content of the manure, crop nutrient needs, manure nutrient content, soil drainage, weather conditions, crop stage, proximity to surface water and residual nutrients. The NRCS Nutrient Management (code 590) practice standard establishes criteria for land application of manure and other sources of nutrients. To protect groundwater, all factors from nutrient form through method of application must be considered in the nutrient management plan and implemented on the cropland in accordance with the standard.

Do NRCS construction standards for manure storage facilities adequately protect ground- and surface water? What is the record of accomplishment of manure storage facilities built to NRCS standards?

A manure storage facility sited, designed, constructed, operated and maintained in accordance with NRCS standards will have no effect on surface water quality and minimal effect on groundwater quality. All steps from site selection through operation and maintenance must follow the standard. NRCS standards are based on sound science and proven experience and have a positive record of performance. The primary NRCS standard for manure storage is Waste Storage Facility (code 313). The type of manure storage appropriate for a farm depends on site-specific conditions such as animal species and how they are housed and bedded; physiographic features such as soil texture, depth to the seasonal high water table and topography; and proximity to wells and flow paths to surface water. The NRCS standards require storage capacity for all manure, wastewater, bedding and runoff, additional storage for normal precipitation plus a 25-year, 24-hour storm event (slightly over 4 inches in Gratiot County), and a freeboard of 6 to 12 inches.

The NRCS standards require a liner (e.g., compacted clay, concrete, flexible membrane) to limit exfiltration within acceptable levels. No liner is impervious. Of the accepted liners, compacted clay has the greatest coefficient of permeability at 1 x 10-7 cm/sec. In perspective, a dairy farm with

500 cows with storage for 6 months of manure and wastewater production would have a surface area of about 1 acre (215 feet square) and a storage depth of about 10 feet. At its average design depth, the compacted clay liner allows an exfiltration of less than 600 gallons per day or about 1.1 gallons per cow per day. In contrast, a conventional residential septic system will discharge at least 50 gallons per person-day into the soil. The MDEQ Groundwater Contamination Investigation Unit reported no known correlation between well contamination and manure storage structures (Concrete Criteria for Agricultural Waste Storage Facilities, unpublished multiagency task force report submitted to MDEQ and Michigan NRCS, April 2005).

The NRCS standards are in the electronic Field Office Technical Guide. The NRCS Agricultural Waste Management Field Handbook also contains technical guidance for planning, design, operation and maintenance of manure storage facilities.

Do the GAAMP guidelines adequately protect our local environment?

The GAAMPs (generally accepted agricultural management practices) for manure management and utilization help Michigan livestock producers adopt sustainable and environmentally responsible management practices. Twenty years ago, Michigan citizens were concerned about the potential environmental impact of increasingly larger livestock operations. Michigan State University assembled a transdisciplinary team of scientists to recommend management practices based on sound science that were environmentally responsible, socially acceptable and economically sustainable. The management practices focus on: control of runoff from facilities and fields receiving manure, odor reduction, construction design for manure storage and treatment facilities, and manure land application. Additionally, the GAAMPs refer producers to more technical and detailed information about runoff control, odor management, proper design and construction of manure storage facilities, and proper application of manure to land. They also encourage producers to develop a manure management system plan (MMSP) and recommend that producers keep records to document the implementation of the GAAMPs and MMSP. The MMSP focuses on two areas: management of manure nutrients and the management of manure and odor. When a livestock operation follows the GAAMPs and management plans are implemented by following the technical bulletins referenced in the GAAMPs, the risk of potential contamination of groundwater and surface waters is managed at an acceptable level.

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Additional Reading

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