

Manure and Water Quality Concerns

Management of animal manure and other byproducts to minimize water quality impact represents a substantial challenge facing the livestock and poultry industry. The following discussion briefly summarizes the components of manure that are of greatest concern, their specific impact on water quality, and their common pathways to surface and/or groundwater.

Water quality contaminants

Manure contains the following four primary contaminants that impact water quality: (1) N, (2) P, (3) pathogens, and (4) organic matter. Those contaminants, their environmental risk, and common pathway to water are summarized in Table 1-3.

Nitrogen (N). For growth and survival, all living things require N, the fundamental building block of protein. Livestock and poultry use only part of the protein in their rations for the production of meat or other animal products. The remaining protein is excreted as N in manure in the form of urea (in urine) and organic-N (in feces). Urea is quickly transformed into ammonium-N. Nitrate-N can originate from manure N.

Most N in manure exists in an ammonium or organic N form (Figure 1-2). In these forms, it is likely to be transported with surface water runoff and erosion. These forms of N are unlikely to leach through soils with the exception of macropore flow to shallow water tables or tile lines. In general, the filtering ability of soil restricts movement of organic compounds, and the negatively charged clay soil particles restrict the movement of positively charged ammonium-N (NH_4^+).

Ammonium-N in surface water also represents an environmental risk. In most natural surface waters, total ammonium-N concentrations greater than about 2 ppm exceed the chronic criteria for fish. The toxicity of ammonium-N varies with acidity and water temperature. In alkaline water at high temperatures, toxic conditions can exist down to 0.1 ppm.

The role of N in water is receiving growing scrutiny due to its contribution to harmful alga blooms in coastal waters and to nitrates in drinking water. Algae or phytoplankton are microscopic, single-celled plants. Most species of algae are not harmful and serve as the energy producers at the base of the food web, without which higher life on this planet would not exist. Occasionally, conditions allow algae to grow very fast or “bloom.” These conditions have resulted in hypoxic (low oxygen level) regions in the Gulf of Mexico, Chesapeake Bay, and other locations. The low oxygen levels inhibit aquatic life and reduce fishery production. In addition, some alga blooms produce toxins that result in fish lesions and fish kills. Pfiesteria and other related species have been identified in the estuaries of the Mid- and South

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Table 1-3. Summary of potential manure contaminants of water quality, the associated environmental risk, and most common pathway to water.

Potential pollutant	Environmental risk	Most common pathway to water
Nitrate-N	Blue baby syndrome	Leaching to groundwater
Ammonia-N	Fish kills	Surface water runoff
P	Eutrophication	Erosion and surface water runoff
Pathogens	Human health risk	Surface water runoff
Organic solids	Reduced oxygen level in water body–fish kills	Surface water runoff

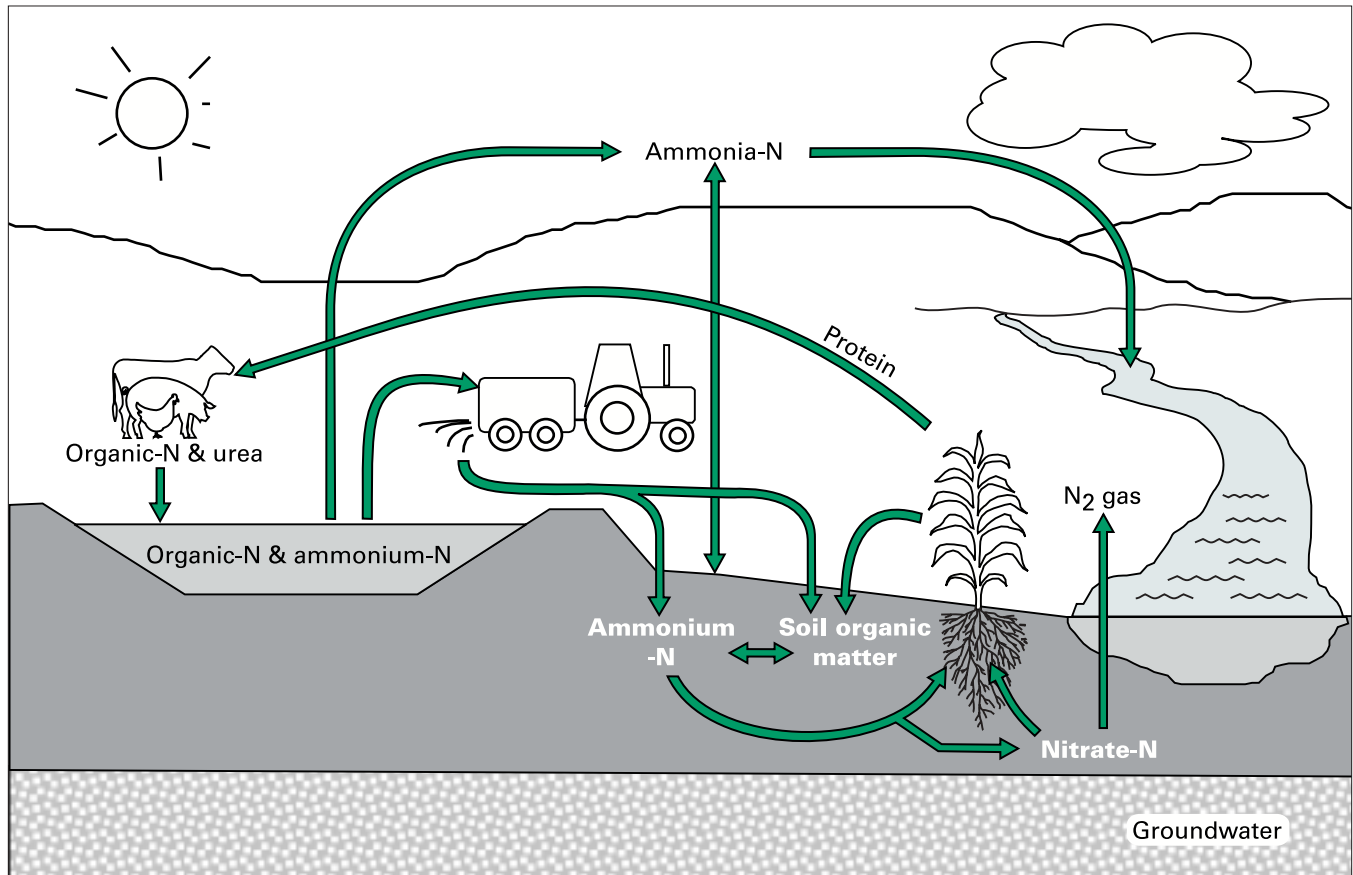


Figure 1-2. Common nitrogen pathways on a livestock and crop production system.

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Atlantic states as well as red tides and brown tides along the Florida and Texas coasts. Growing evidence exists that nutrient loading is a contributor to hypoxic conditions in coastal waters. While it has not been clearly established that nutrients from agriculture and other sources are responsible for outbreaks of *Pfiesteria* and other harmful alga blooms, there is some scientific consensus about this linkage.

If sufficient oxygen is available, ammonium-N can be transformed into nitrate-N (nitrification), which is soluble in water, and can leach through soils to groundwater. Nitrate-N from manure is likely to exist only in soil following land application of manure and in mechanically aerated lagoons.

Nitrate contamination of drinking water supply restricts the oxygen in the bloodstream in infants under the age of 6 months, causing methemoglobinemia (blue baby syndrome). Infants and pregnant women are at greatest risk. In addition, there are other less well-documented health impacts. The U.S. EPA has set a maximum contaminant level of 10 parts per million (ppm) for nitrate-N in public water supplies.

Phosphorus (P). Because it is essential to plant growth and development, P is essential for modern crop production. It plays many critical functions; the primary one being the storage and transfer of energy through the plant. In confined livestock production, supplemental P is often essential to bone development and optimum animal performance. Commercially mined P has

limited reserves remaining in the United States. Thus, better use of manure P provides an increasingly important alternative to commercial fertilizers.

Phosphorus transported from agricultural lands to surface waters can promote eutrophication. Eutrophication, one of the leading water quality issues facing the nation's lakes and reservoirs, refers to an abnormally high growth of algae and aquatic weeds in surface waters. As this organic material dies, natural oxygen levels decline, which can cause changes in fish population or fish kills. Other common problems associated with eutrophied water bodies include less desirable or restricted recreational use, unpalatable drinking water, and increased difficulty and cost of drinking water treatment. Eutrophic surface waters may also experience massive blooms of cyanobacteria, which can kill livestock and pose health hazards to humans.

Eutrophication is caused by an overabundance of nutrients in runoff water feeding a lake or reservoir. Excess P is the limiting nutrient for most freshwater lakes and reservoirs. In brackish and saline estuaries, N can be the limiting nutrient triggering alga blooms. The U.S. EPA is discussing national criteria for P compounds in water. Their current recommendations suggest that total P should not exceed

- 0.05 mg/L in a stream at a point where it enters a lake or reservoir.
- 0.1 mg/L in streams that do not discharge directly into lakes or reservoirs.

Phosphorus typically moves with runoff and erosion. It is stored in soils primarily fixed to soil minerals (iron, aluminum, and calcium) or in organic matter (living soil bacteria, crop residue, and partially decayed organic matter). Thus, soil erosion is a primary transport mechanism of P to surface water.

Soil water also contains a small amount of dissolved P, essential for plant uptake. Because the balance among the various P pools is heavily in favor of the organic and soil mineral forms, P leaching is rarely an issue. However, as soil, mineral, and organic pools of P increase, dissolved P in runoff water is becoming a greater concern. Dissolved P is readily available to algae and the key contributor to eutrophication of surface waters.

Agriculture and, in particular, livestock production will receive significant scrutiny relative to solving N- and P-related water quality concerns. A Government Accounting Office (GAO) report (USGAO 1995) to the U.S. Senate suggested that livestock and poultry manure is a major contributor of total N and P inputs into U.S. watersheds (Figure 1-3). Manure nutrients inputs were substantially greater than those associated with more traditional sources of pollution (e.g., municipalities, industry). The comparison in Figure 1-3 is not a good comparison of “apples” with “apples.” The point source category (municipalities and industry) represents a direct discharge to rivers and lakes. Animal manures and fertilizers are land applied with only a fraction reaching surface water. The livestock industry's management of manure in land application will determine the magnitude of risk associated with manure.

Pathogens. A pathogen is typically considered any virus, bacterium, or protozoa capable of causing infection or disease in other animals or humans. For the purpose of this discussion, the focus will be on pathogens in livestock and poultry manure representing a risk to human health.

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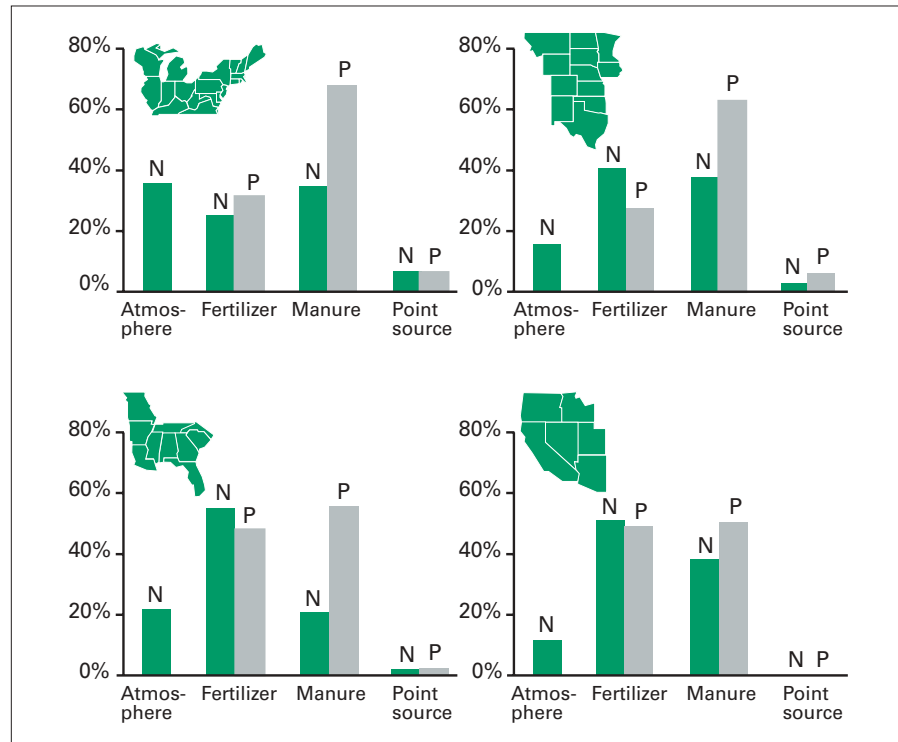


Figure 1-3. Sources of N and P inputs to watersheds in the four regions of the United States.

Source: USGAO 1995.

water. The concern about these organisms is a result of three factors:

- (1) A healthy adult human can become infected with relatively few oocytes.
- (2) These protozoa originate from a variety of domestic animals, wildlife, and humans.
- (3) Commonly used water disinfectants such as chlorine are not effective in controlling these protozoa.

C. parvum and giardia are parasites that cause severe diarrhea, nausea, fever, vomiting, and fatigue in humans. In healthy humans, the infections from either organism are usually self-limiting and do not pose serious health risks. However, the risk can be much greater for the very young, elderly, and those with immune depressed systems (e.g., those receiving chemotherapy, those with AIDS, or those who have received organ transplants).

Livestock and poultry shed a number of viruses in feces, but as a general rule, these viruses are not transmitted to humans. However, influenza viruses from swine may be an exception although the route of transmission does not typically involve swine excrement. Several potential bacterial pathogens shed by livestock are also capable of infecting humans. However, unless bacteria in feces has direct access to a drinking water supply, it is relatively unlikely that bacteria originating from livestock will infect humans. In addition, bacteria can be controlled with common water disinfectants such as chlorine. Location of drinking water wells (no chlorine treatment) in close proximity to animal housing or manure storage has caused human illnesses and deaths due to bacteria such as *E. coli* from livestock feces.

Because of the human health risks associated with *C. parvum* and giardia

and the challenges of removing these pathogens from public water supplies, much of the remaining discussion will focus on these two organisms.

Three potential reservoirs for *C. parvum* and giardia exist: wildlife, domestic animals, and humans. A recent national study of *C. parvum* in beef and dairy cattle found that 59% of dairy farms and 22.4% of heifers tested positive. *C. parvum* was greatest for calves between 1 and 3 weeks of age and was rare for animals older than 3 months. Generally, cattle testing positive for giardia were less than 6 months but older than those with *C. parvum*. Another study has suggested that *C. parvum* is common to cow calf herds supplying young stock for beef production but at lower rates than observed in dairies.

Additional studies have found unweaned foals and suckling lambs have the greatest risk of infection within these species. Among pigs, infection is not limited to young animals and is strongly affected by management practices such as sanitation. Dogs, cats, and rodents can all be affected and are partially responsible for pathogen transmission on many farms. Poultry is not a carrier of *Cryptosporidium* organisms that infect humans.

Most pathogens, including *C. parvum* and giardia, do not multiply outside a host organism and have a limited lifetime outside a host. The viability of these organisms can range from a few days to many months, depending upon a number of environmental factors. Those environmental factors include

- Temperature: Environmental temperatures above 100°F and especially those commonly achieved by composting will dramatically reduce pathogen survival.
- pH: High and low pH are effective for reducing pathogen survival. A pH of 9.0 or greater will limit most pathogen survival. For pathogen control, municipalities often treat human sludge to achieve a pH above 12.
- Freezing or freeze/thaw: Freezing temperatures and freeze/thaw cycles can reduce the survival of bacteria and viruses. Moderate temperatures can extend the life span of pathogens.
- Anaerobic/aerobic decomposition: Normal microbial decomposition of manure under anaerobic and aerobic conditions produces antibacterial and antiviral compounds.

Pathogens are most likely to be transported to water with surface runoff and erosion or by direct animal access to surface water. Streams and lakes used for drinking water supply and recreational purposes provide the greatest opportunity for transporting these pathogens to humans. Livestock operations located upstream of surface water used for drinking water supply or recreation should recognize the potential risks associated with pathogens.

Pathogens are unlikely to move through soils to groundwater. Soils provide a filtering mechanism, especially for larger organisms such as protozoa and bacteria. Filtering of smaller organisms such as viruses may be more dependent on organic matter and the soil's clay content. Macropore flow can lead to pathogens bypassing the soil's filter and reaching tile drainage or shallow water tables. Researchers have commonly observed contaminated drainage from tile shortly after the land application of manure.

A wide range of livestock, domestic animals, wildlife, and humans carries pathogens. It is important to recognize that any of these animals can play important roles in transporting pathogens between livestock and to local surface waters. Control measures must consider the potential for transport by domestic animals, wildlife, and humans.

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Fish kills are often caused in part by ...depletion of oxygen.

Nitrates are the primary contaminant that leaches to groundwater.

Organic matter. Organic matter in manure, like nutrients, can be a valuable environmental resource if managed properly or an environmental pollutant if managed poorly.

If manure is allowed to discharge to a water body or run off from a land application site, the organic matter can become a harmful pollutant. Organic matter in the form of manure, silage leachate, and milking center wastewater degrades rapidly and consumes considerable oxygen (often measured as biological oxygen demand, BOD, or chemical oxygen demand, COD). If this occurs in an aquatic environment, oxygen can be quickly depleted. Fish kills are often caused in part by this depletion of oxygen. Manure, silage leachate, and waste milk are extremely high in degradable organic matter. These products can be 50 to 250 times more concentrated than raw municipal sewage (primarily because livestock production does not add the large volume of fresh water that is used in dilution and transport of municipal waste).

Organic matter, like pathogens, P, and ammonia, is transported to water primarily by surface water runoff. Rarely does it leach through soils. Organic matter is unlikely to be transported in sufficient quantities to nearby surface waters unless one of the following situations occurs:

- (1) A direct discharge from a livestock housing, manure storage, open lot, or other facilities is allowed to enter surface water drainage.
- (2) A catastrophic failure such as an earthen storage break or continuous application by an irrigation system on the same location.
- (3) Significant rainfall occurs immediately after the surface application of manure.
- (4) Significant application is made on frozen, snow-covered, or saturated soils in close proximity to surface water.

Contaminant pathways

The potential pollutants discussed previously typically follow one or more of five possible pathways for reaching water, including runoff, leaching, macropore flow, wells, and ammonia volatilization and deposition (see Figure 1-4).

Runoff. Runoff from open lots, land application sites, and manure and feed storage units is a common pathway for contaminant transport. All contaminants in manure will travel with surface water runoff and soil erosion. Pollution associated with P, pathogens, ammonia, and organic matter are most commonly associated with runoff or erosion.

Leaching. Nitrates are the primary contaminant that leaches to groundwater. Dissolved contaminants such as nitrate -N will leach beyond a crop's root zone when the soil moisture exceeds its water-holding capacity and eventually contaminate groundwater. Most contaminants in manure and other byproducts (e.g., organic matter, pathogens, and typically P) are filtered by soil and will NOT leach to groundwater. Soil structure, chemical bonding with soil minerals, and negatively charged soil particles typically restrict the movement of most contaminants. However, it is possible to exceed the soil's ability to restrict contaminant movement. For example, soils with low cation exchange capacity (sandy soils) can allow ammonia movement of up to a few feet per year below manure storages.

Macropore flow. Most contaminants in manure can travel through soil to shallow groundwater tables or tile drains by macropore flow. Macropore flow (root holes, wormholes, and cracks due to soil drying) can provide pathways for contaminants to bypass the soil's filtering capability. Sinkholes and karst

topography also provide opportunities for contaminants to directly reach groundwater.

Wells. Wells can provide a direct pathway for contaminants to reach groundwater. Abandoned wells, wells with poor well-casing designs, or wells located in close proximity to open lots or manure storage can provide a pathway for all manure contaminants to move to groundwater.

Ammonia volatilization and deposition. Ammonia-N volatilizes from manure storage, lagoons, and open lots. Once volatilized, most ammonia is redeposited with rainfall or through dry deposition. It can be transported over long distances. Many areas of the world profit from this nutrient deposition. However, some areas of the world are experiencing high enough deposition that it threatens vitality and growth in local ecosystems. In the United States, coastal areas are often adversely affected by ammonia deposition. Nitrogen availability rather than P typically limits eutrophication in coastal waters.

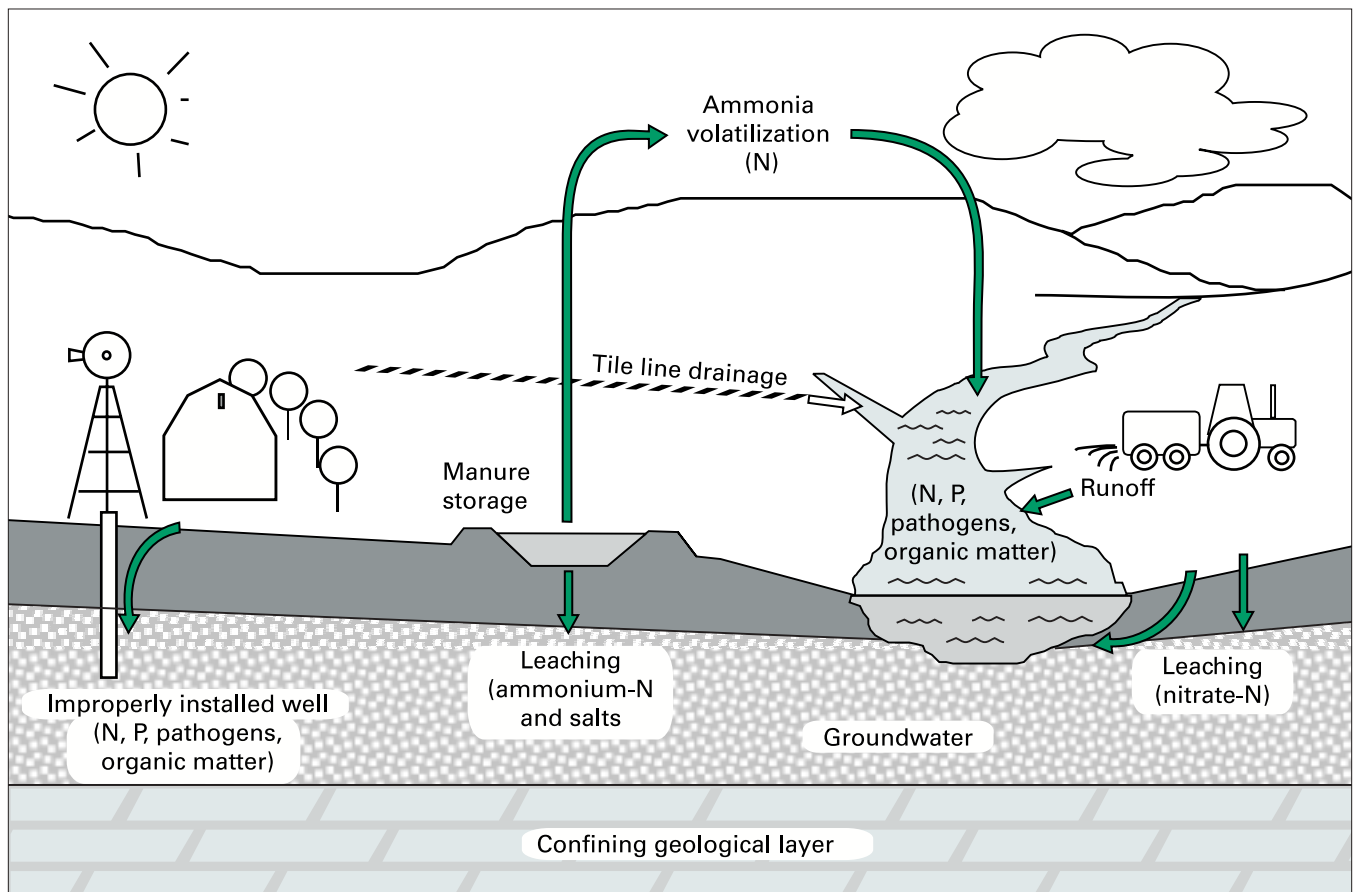


Figure 1-4. Common pathways for manure contaminants to reach surface and groundwater.