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**Increased Animal Waste Production From Concentrated Animal
Feeding Operations(CAFOs): Potential Implications for Public
and Environmental Health**

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Introduction

The purpose of this document is to present background information about Concentrated Animal Feeding Operations (CAFOs)^a from a public health perspective. Since 1987, the size of cattle, swine, and poultry operations has been increasing in Nebraska and across the U.S. Conversely, the actual number of operations has been decreasing.¹

At the center of public and environmental health discussions concerning the implications of larger and fewer livestock production operations is the increased production of manure per operation. While the increase in manure production in and of itself may not be a problem, there may be increasing difficulty in managing these larger quantities because the handling methods used in the past may become less effective as operations increase in size.

Public health advocates are becoming concerned that as the amount of manure produced in a concentrated area increases, traditional handling techniques may become less effective, and the manure (and by-products) may eventually pose a threat to the health of the public and the environment. After defining the CAFO, this document will consider three perspectives that characterize the public health concerns related to increased and concentrated manure production:

- Occupational health;
- Community health; and
- Public and environmental health.

Caveats

No new information or scientific research is presented in this document. This is a background paper, the focus of which is the **potential public health effects** of increased and concentrated manure production and storage associated with CAFOs. Some of the concerns discussed may not be unique to CAFOs, but may be exacerbated by virtue of the fact that a large amount of manure is stored or spread in a concentrated and/or confined space. This is a rapidly expanding field of study and we have included a selection of information gathered from previously published studies. Additionally, it is important to note that much of the research cited in this document pertains to the swine industry. Potential environmental and public health concerns will vary according to industry and method(s) of livestock production employed^b.

Given these caveats, the Nebraska Center for Rural Health Research (NCRHR) does not recommend that this document be used as a comprehensive review of all available scientific literature on this topic. **Rather, we offer this document as a point from which public discussions and future research about the long term health effects of CAFOs can begin.**

^aSee the EPA Code of Federal Regulations. Criteria for Determining a Concentrated Animal Feeding Operation. Title 40, Volume 13, Parts 87 to 135. Appendix B (Sec. 122.23).

^bFor example, housed, confined feeding operations (swine and poultry) verses open lot feeding operations (cattle).

I. Defining the Concentrated Animal Feeding Operation (CAFO)

A CAFO is defined by the U.S. Environmental Protection Agency (EPA) as an animal feeding operation (AFO) which contains “*more than 1,000 animal units*, or houses at least 301 units which discharge pollutants into U.S. waters” (See box on page 3 for this definition). The EPA defines the *animal unit* as a unit of measurement used to determine when animal feeding operations with different types and sizes of animals meet the CAFO definition. Based on its size, each animal is assigned a different weighting factor in the regulations. For example, an animal feeding operation with feeder cattle and swine would be defined as a CAFO when the number of feeder cattle multiplied by 1.0 plus the number of swine (over 55 pounds) multiplied by 0.4 totals more than 1,000.²

In order for an AFO to be considered a CAFO, a facility must first meet the National Pollutant Discharge Elimination System (NPDES) definition of an AFO. An AFO is a:

- lot or facility where animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period; *and*
- where crops, vegetation, forage growth, or post-harvest residues are not sustained over any portion of the lot facility in the normal growing season.

Under the NPDES program, an AFO is considered a CAFO if:

- more than 1,000 animal units are confined at the facility, *or*
- from 301 - 1,000 animal units are confined at the facility and it also meets one of the specific criteria addressing the method of animal waste discharge.

Additionally an AFO can be designated a CAFO on a case-by-case basis by the authority empowered to do so by the NPDES. In Nebraska, this is the Department of Environmental Quality.

The Environmental Protection Agency: Criteria for Determining a Concentrated Animal Feeding Operation

An animal feeding operation is a concentrated animal feeding operation for purposes of Sec. 122.23 if either of the following criteria are met.

(a) More than the numbers of animals specified in any of the following categories are confined:

- (1) 1,000 slaughter and feeder cattle,
- (2) 700 mature dairy cattle (whether milked or dry cows),
- (3) 2,500 swine each weighing over 25 kilograms (approximately 55 pounds),
- (4) 500 horses,
- (5) 10,000 sheep or lambs,
- (6) 55,000 turkeys,
- (7) 100,000 laying hens or broilers (if the facility has continuous overflow watering),
- (8) 30,000 laying hens or broilers (if the facility has a liquid manure system),
- (9) 5,000 ducks, or
- (10) 1,000 animal units; or

(b) More than the following number and types of animals are confined:

- (1) 300 slaughter or feeder cattle,
- (2) 200 mature dairy cattle (whether milked or dry cows),
- (3) 750 swine each weighing over 25 kilograms (approximately 55 pounds),
- (4) 150 horses,
- (5) 3,000 sheep or lambs,
- (6) 16,500 turkeys,
- (7) 30,000 laying hens or broilers (if the facility has continuous overflow watering),
- (8) 9,000 laying hens or broilers (if the facility has a liquid manure handling system),
- (9) 1,500 ducks, or
- (10) 300 animal units; and

either one of the following conditions are met: pollutants are discharged into navigable waters through a man-made ditch, flushing system or other similar man-made device; or pollutants are discharged directly into waters of the United States which originate outside of and pass over, across, or through the facility or otherwise come into direct contact with the animals confined in the operation. Provided, however, that no animal feeding operation is a concentrated animal feeding operation as defined above if such animal feeding operation discharges only in the event of a 25 year, 24-hour storm event.

The term animal unit means a unit of measurement for any animal feeding operation calculated by adding the following numbers: the number of slaughter and feeder cattle multiplied by 1.0, plus the number of mature dairy cattle multiplied by 1.4, plus the number of swine weighing over 25 kilograms (approximately 55 pounds) multiplied by 0.4, plus the number of sheep multiplied by 0.1, plus the number of horses multiplied by 2.0.

The term man-made means constructed by man and used for the purpose of transporting wastes.

Source: EPA Code of Federal Regulations. Criteria for Determining a Concentrated Animal Feeding Operation. Title 40, Volume 13, Parts 87 to 135. Appendix B (Sec. 122.23).

II. Considerations for Occupational Health^a

There are several occupational hazards associated with working in livestock operations of all types and sizes. Among these are chronic and acute respiratory illnesses, musculoskeletal injuries (upper back injuries, strains, and sprains), electrical shock due to damaged/faulty wiring, hearing loss, accidental needle sticks, and exposure to zoonotic infections.³ **Table 1** lists some of the respiratory disorders which have been observed among farm workers exposed to dust and gases in confined animal feeding environments.

Disorder	Comments/Symptoms
Acute Respiratory Tract and Eye Inflammation	May include one or more of the following: cough, dyspnea, nasal stuffiness, headache, fever, chills, malaise, airway irritation, chest heaviness, and eye irritation.
Asthma-Like Syndrome	Characterized by cough, chest tightness, dyspnea, and wheezing without airway obstruction.
Asthma/Irritant Asthma	Characterized by recurrent episodes of wheezing, dyspnea, chest tightness, and cough. It is unknown whether asthma can be caused by work in CAFOs.
Chronic Bronchitis	Includes intermittent cough and sputum production.
Organic Dust Toxic Syndrome	Symptoms may include malaise, myalgia, chest tightness, headache, and nausea.
Mucus Membrane Inflammation Syndrome	Includes chronic nasal, eye and throat irritation.
Hydrogen Sulfide Poisoning	Hydrogen sulfide exposure can result in respiratory failure and unconsciousness. May be fatal within minutes of exposure.
Asphyxiation	Associated with oxygen displacing gases, specifically methane and carbon dioxide, which are generated in deep pit waste-handling systems. Also associated with ventilation failures in animal confinement buildings.
Infectious Diseases	Infectious diseases which have been linked to working with hogs include: swine influenza, pneumonia, meningitis, hepatitis E, and other disorders caused by <i>Brucella suis</i> , <i>Erysipelothrix rhusiopathiae</i> , and <i>Salmonella</i> species. Poultry workers are at risk of contracting psittacosis and Newcastle disease. Psittacosis symptoms can present as an atypical pneumonia or as a severe systematic illness which may include headache and fever. Newcastle disease in humans presents as an influenza-like illness with conjunctivitis.
Hypersensitivity Pneumonitis (also known as allergic alveolitis or farmers lung)	Symptoms include fever, cough, dyspnea, and malaise. Rare in animal confinement workers, occurring primarily among chicken and turkey farm workers.
Source: Data abstracted from Susanna Von Essen and Kelly Donham (1999). Illness and Injury in Animal Confinement Workers. <i>Occupational Medicine</i> 14(2): 337-50.	

^aMany of the hazards discussed here are not exclusive to concentrated/confined livestock production. Occupational health hazards will vary in level and intensity with livestock type and method of confinement (indoor production facilities verses outdoor feedlots).

The risk for chronic disease development, such as asthma-like syndrome, asthma, bronchitis, and mucus membrane inflammation syndrome, does appear to be linked to occupational exposure to endotoxins, gases, and dust.⁴ These are adverse health conditions which can be controlled with environmental monitoring systems.⁵ **Table 2** shows some of the common contaminants found in the swine confinement environment and the maximum levels recommended by Donham⁶ for maintaining human and animal health in these buildings. In most cases, the levels of gases and dust in these environments do not exceed the standards listed in this table set for these contaminants.⁷ *“However, multiple toxic exposures in animal confinement facilities reduces the threshold limit for health effects from any one toxic exposure.”⁶*

Table 2 Maximum Indoor Air Contaminant Levels Recommended for Human Health in Swine Buildings: Selected Contaminants		
Air Contaminant	Exposure Thresholds Recommended for	
	Human Health	Swine Health
Total dust (micrograms/cubic meter)	2.4	3.7
Respirable dust (micrograms/cubic meter)	0.23	.23
Endotoxin (grams/cubic meter)	0.08	.15
Carbon dioxide (parts per million) ^a	1,540	1,540
Ammonia (parts per million) ^b	7.0	11.0
Total microbes (colony forming units/cubic meter)	4.3×10^5	4.3×10^5

Sources: Donham, Kelly J. (1995) Health Hazards of Pork Producers in Livestock Confinement Buildings: From Recognition to Control. [Agricultural Health and Safety: Workplace, Environment, Sustainability](#), Edited by Helen H. McDuffie, et al. CRC Press, Boca Raton Florida.

^a The National Institute for Occupational Health and Safety (NIOSH) for ammonia is 25 parts per million. The Occupational Safety and Health Administration guideline is 50 parts per million. See the [Online NIOSH Pocket Guide to Chemical Hazards](http://www.cdc.gov/niosh/npg/pgdstart.html). See <http://www.cdc.gov/niosh/npg/pgdstart.html>.

^b The National Institute for Occupational Health and Safety (NIOSH) for carbon dioxide is 5000 ppm. The Occupational Safety and Health Administration guideline is also 5000 ppm. See the [Online NIOSH Pocket Guide to Chemical Hazards](http://www.cdc.gov/niosh/npg/pgdstart.html). See <http://www.cdc.gov/niosh/npg/pgdstart.html>.

III. Considerations for Community Health

Odors are associated with land application and storage of manure. Odors from wastes are carried away from livestock facilities on dust and other particles in the air.⁹ Of the several manure-based compounds which produce odor, the most commonly reported are ammonia, hydrogen sulfide and other sulfur compounds, volatile organic acid, and phenols.¹⁰

As this is a relatively new field of study, there is little research which has been conducted on the effects of concentrated animal operations on the health and quality of life of residents in nearby communities. **Table 3** summarizes selected, recently published research about how residents living near intensive livestock farming operations *may be* affected by odors and other airborne emissions from CAFOs.^a

After odor, flies are one of the most frequently mentioned nuisances for residents of communities living near livestock and poultry producers.¹¹ The common house fly breeds in warm organic materials, and animal and poultry waste is an excellent breeding environment.¹² Further, house flies are strong fliers and can become widely distributed by wind, vehicles, and animals. These characteristics, along with the house fly's propensity to invade homes and feed on human food, enable the fly to carry many microbes that can cause dysentery and diarrhea.¹³ Consequently, there is some concern among public health advocates that the increased and concentrated production of large amounts of manure will lead to the transmission of manure based pathogens to residents who live in close proximity to waste storage/handling areas.

There is very little research that has been published regarding the potential human health effects of flies which breed in CAFO-generated manure. Research conducted by the Ohio Department of Health indicates that selected residences which were located in close proximity (within half a mile) to a poultry CAFO (a large egg production facility) had 83 times the average number of house flies compared to residences at study control sites. The number of flies experienced by surveyed residences decreased as the distance between the egg facility and the home increased. Because of this, these data suggest that there is an increased nuisance factor related to flies experienced by the residents who live near large egg production operations. However, these data did not suggest a significant relationship between the proximity of the residences to the egg production facility and increased manure based pathogen transmission to humans.^{14,15}

^aNote that nearly all of these articles pertain to swine production. Also note that community effects, and the intensity of these effects are dependent upon several factors including: type of livestock facility (swine, cattle, or poultry), method of animal confinement (e.g. indoor confinement, verses outdoor feedlots) and climatic conditions.

Table 3

A Summary of Selected Research on the Impact of Intensive Livestock Operations on Nearby Residents

Wing, S. & Wolf, S. (1999). *Intensive livestock operations: health and quality of life among Eastern North Carolina residents. A report prepared for the North Carolina Department of Health and Human Services, Division of Public Health. Available on-line at <http://www.dhhs.state.nc.us/pressrel/5-7-99.htm>*

Wing and Wolf conducted a survey of residents of three rural communities - one near a large hog operation, one within the vicinity of large cattle operations, and the third where residents lived at least two miles from livestock operations which use liquid waste management systems.

Health Effects: Wing and Wolf found that hog community residents reported increased occurrence of headaches, runny nose, sore throat, coughing, diarrhea, and burning eyes compared to the community without an intensive livestock operation nearby. Respiratory and mucus membrane effects in hog community residents are consistent with results of studies of occupational exposures among swine confinement workers.

Quality of Life Effects: In this study, quality of life was measured by the number of times residents could not open windows or go outside even in nice weather. The authors found that, on these measures, quality of life was similar in control communities and cattle communities but was greatly reduced among the residents who lived near the hog operation.

Reynolds, S. J., Donham, K.J., Stookesberry, J., Thorne, P.S., Subramanian, P., Thu, K. & Whitten, P. (1997). *Air quality assessments in the vicinity of swine production facilities. In K. J. Donham, R. Rautiainen, S. H. Schuman, & J. A. Lay (eds.), Agricultural Health and Safety: Recent Advances. New York: Hayworth Medical Press.*

The first study to show contamination from swine facilities in outdoor air using air sampling techniques. However, outside air contamination levels were generally lower than the occupational health guideline level recommended for inside swine facilities (7 ppm). Researchers sampled the air quality inside and outside of eight self selected farming operations of various sizes in Iowa. Seven of the operations included swine production facilities of various sizes. One farm, without livestock production, served as a control. Higher concentrations of air contamination were associated with larger confinement type swine facilities. Concentration of outdoor airborne ammonia was significantly higher at swine production facilities than at the control farm.

Thu, K., Donham, K., Ziegenhorn, R., Reynolds, S., Thorne, P. S., Subramanian, P., Whitten, P., & Stookesberry, J. (1997). *A control study of the physical and mental health of residents living near a large-scale swine operation. Journal of Agricultural Safety and Health 3(1), 13-26.*

A study of the physical and mental health of residents (n=18) living in the vicinity (within 2 miles) of a large-scale swine confinement operation compared to randomly selected and demographically comparable rural residents (n=18). Neighbors of the swine facility reported respiratory symptoms similar to those reported by swine confinement workers (symptoms associated with chronic bronchitis and hyper reactive airways; high rates of nausea, weakness, dizziness, and fainting; high rates of headaches and plugged ears, and other symptoms often associated with chronic sinusitis; and eye, nose and throat irritation). Increased distance from the operations appeared to mediate the effects of the odors, resulting in less severe, less frequent, but still persistent physical symptoms. These researchers did not find that there were higher psychological health problems associated with proximity to the operation. The authors recommend that a larger, population based study be conducted to test the relationship between proximity to large swine production operation and the occurrence of physical symptoms.

Schiffman, S. S., Miller, E. A. S., Suggs, M. S., & Graham, B. G. (1995). *The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. Brain Research Bulletin, 37, 369-375.*

A study of the moods of people living near commercial swine operations in North Carolina. Those who lived closest to the operations (n=44) appeared to experience more tension, anger, depression, fatigue, and confusion than those living away from commercial swine operations (n=44). Authors suggest several factors which may contribute to the altered moods including: the general unpleasantness of experiencing the odor; the unpredictability of the odor; learned aversions to and unpleasant memories associated with the odor; and physiological response to the odor that activates the immune system and neural centers in the brain.

Schiffman, S. S. (1998). Livestock odors: Implications for human health and well-being. Journal of Animal Science, 76, 1343-55.

A study of the potential effects of livestock odors on the health and well-being of neighbors. A review of recent studies found that the main complaints of health symptoms from odors are eye, nose, and throat irritation, headache, and drowsiness. According to Schiffman, odors may potentially affect mood and memory. The author also notes that irritation from odors can be produced by a broad range of odorous volatile organic compounds from trees, flowers, and foods, as well as emissions from livestock operations. She further states that more research is needed to fully assess the health impact of odors in order to establish recommendations for air quality guidelines based on scientific data.

IV. Considerations for Environmental and Public Health

Sources of manure-related pollution include direct discharges, open feedlots, pastures, treatment and storage lagoons, manure stockpiles, and land application fields.¹⁶ When manure is spread over crops and pasture lands there is the possibility that the application of nutrients may exceed crop nutrient requirements.¹⁷ The discharged nutrients, whether they originate from holding system leaks (catastrophic events) or from routine applications to pastures, have the potential to adversely affect plant, animal, and human health.

For the environment, there are both positive and negative impacts that may be associated with the increasing size of livestock and poultry operations. The aggregation of resources associated with large scale operations *could* lead to improved practices, because of:

- increased control over manure because of its concentration, and potential for managing manure in an environmentally sound manner;
- availability of technical expertise;
- investments in manure management facilities and systems;
- investments in environmental planning, manure storage and handling, and land application.¹⁸

However, the aggregation, and concentration, of animals in single locations can exacerbate environmental impacts from:

- nutrients, carbon, and pathogens now in a single location;
- failure of the system managing the environmentally risky byproducts, including natural disasters such as floods or structural failures of systems;
- concentration of volatile emissions in a single site.¹⁹

The Environmental Protection Agency identifies nitrate, ammonia, and phosphorous as manure based pollutants of concern that may originate from animal feeding operations.²⁰ These substances are valuable as fertilizers; however, *in excess*, they may produce negative impacts on the environment.²¹

Nitrate.^{a,b}

According to a national survey conducted by the EPA, nitrate is the most widespread agricultural contaminant^a in drinking water wells.²² Being extremely water soluble, nitrate is able to move easily from the soil to surrounding water sources. When ingested by humans, nitrate may reduce the ability of blood to carry oxygen.²³ **Table 4** lists some of potential human health effects of drinking water contaminated by nitrates.

^a While nitrate contamination of ground and well water arises partially from manure/nutrient application to farmlands, a significant amount can be attributed to commercial (inorganic) fertilizer use and excess application of irrigation water.

^bIn 1974, Congress passed the Safe Drinking Water Act requiring the EPA to determine safe levels of chemicals in drinking water which may cause health problems. These non-enforceable levels, based solely on possible health risks and exposure, are called Maximum Contaminant Level Goals. (MCLG). The MCLG for nitrates has been set at 10 parts per million (ppm), and for nitrites at 1 ppm. Based on this MCLG, the EPA has set an enforceable standard called a Maximum Contaminant Level (MCL). MCLs are set as close to the MCLGs as possible, considering the ability of public water systems to detect and remove contaminants using suitable treatment technologies. The MCL for nitrates has been set at 10 ppm, and for nitrites at 1 ppm, because the EPA believes this is the lowest level to which water systems can reasonably be required to remove this contaminant from drinking water, given current technologies. These drinking water standards and the regulations for ensuring these standards are met, are called National Primary Drinking Water Regulations. All public water supplies must abide by these regulations. Source: Environmental Protection Agency, National Primary Drinking Water Regulations, Consumer Factsheet on: NITRATES/NITRITES. Revised January 23, 1998.

Table 4
Potential Public Health Concerns Related to Ground Water Contamination by Nitrates

Methemoglobinemia.

Elevated nitrate levels in community water supplies have been associated with the consumption of drinking water containing high levels of nitrate.²⁴ This may cause health problems, particularly for infants under six months of age.²⁵ Nitrate poisoning (methemoglobinemia) is often referred to as “blue baby syndrome” because the reduction of oxygen in the blood of infants will cause the skin to look blue in color. Affected infants may present the following symptoms to the physician: a dark blueish or purplish coloring of the skin (cyanosis), shortness of breath, rapid breathing or difficulty/distress in breathing, and lethargy, drowsiness, and/or coma.²⁶ In acute cases, infants may present to the physician with vomiting episodes, incessant crying, and profuse diarrhea.²⁷

Spontaneous abortion.

The Centers for Disease Control reported three incidents of spontaneous abortion which may be linked to ingestion of nitrate contaminated well water. All three women in this report had obtained their drinking water from nitrate contaminated private wells while pregnant.²⁸

Other Health Effects.

There have been studies which have linked consumption of nitrate contaminated drinking water to increased risk of developing certain types of cancers^{29, 30, 31} and congenital malformations.^{32, 33} However, the methods used in these studies are inconsistent and they are generally unable to control for potential confounding variables. Therefore it is impossible to state conclusively that consuming nitrate contaminated drinking water puts humans at particular risk for cancer^{34, 35} or other adverse health effects.

Ammonia.

Ammonia in its toxic form depletes oxygen from surface waters.³⁶ This depletion of oxygen from water can kill aquatic life, resulting in reduced species diversity.³⁷ Additionally, ammonia itself can be easily transformed to nitrate, which at high concentrations, can lead to nutrient over-enrichment of surface waters. This over-enrichment is responsible for algal blooms and can produce significant ecological and human health impacts. Algae reduce light that penetrates surface water, thus decreasing growth of desirable aquatic plants. Algae can also affect drinking water processing, both by clogging treatment plants and by producing unusual tastes and odors resulting in increased water treatment costs.³⁸

Phosphorus.

According to the EPA, animal wastes contain inorganic and organic forms of phosphorous.³⁹ “Phosphorous can reach surface waters via direct discharge and runoff from land application of animal wastes.”⁴⁰ Runoff containing phosphorous has the potential to stimulate weed and algae growth (eutrophication) in streams and lakes.⁴¹ Excessive weed and algae growth may lead to negative effects on surface waters, including fish mortality, reduced bio-diversity, unpleasant taste and odor, and increased water treatment costs.⁴² Excessive algae growth may also interfere with recreational activities such as swimming, fishing and boating.⁴³

Potential Pathogens in Manure^a

A pathogen is defined as a **parasite**, **bacterium**, or **virus** capable of causing infection or disease in livestock or humans.⁴⁴ Manure consists not only of animal feces and urine, but also animal bedding materials and other animal secretions such as those that originate from the nose, throat, blood, vagina, mammary glands, skin, and placenta.⁴⁵ Manure and other animal wastes (such as animal carcasses) contain disease-causing organisms (pathogens) which are potentially threatening to human and animal life. Survival of manure-based pathogens, in the environment or in storage, can be affected by several factors. These factors may include: sunlight, moisture/dryness, temperature and temperature fluctuation, oxygen levels, and other microbial compounds.⁴⁶ Also, the number of pathogens needed to infect humans varies from pathogen to pathogen.⁴⁷

Healthy people exposed to these manure-based parasites, bacterium, and viruses typically recover quickly from illnesses caused by infection from these pathogens. However, people with weakened immune systems are at increased risk for illness or death when they come into contact with these bacteria and viruses. Those who are at increased risk include infants and young children, pregnant women, the elderly, chemotherapy patients, those with HIV infection, and those who take medications that suppress the immune system.⁴⁸

Parasites.

Cryptosporidium parvum and *Giardia spp.* are the parasites of primary concern to public health⁴⁹ and are responsible for the diseases *cryptosporidiosis* and *giardiasis* respectively.⁵⁰ These two parasites cause severe diarrhea in both animals and humans; *Cryptosporidium* may also cause respiratory problems.⁵¹ Human *cryptosporidiosis* infection occurs in immunocompetent persons (e.g., those who work with cattle in whom it causes a self-limited diarrhea syndrome) and in immunocompromised patients. Symptoms include prolonged debilitating diarrhea, weight loss, fever, and abdominal pain with occasional spread to the trachea and bronchial tree.⁵² Most who are infected with *Giardiasis* are asymptomatic, but a small percentage show a wide range of symptoms which include gastrointestinal discomfort, mild to profuse diarrhea, nausea, lassitude, anorexia, and weight loss.⁵³ The most common routes of infection are fecal-oral transmission and consumption of contaminated water. There are three sources (reservoirs) of infection of *Giardia* and *Cryptosporidium parvum* including wildlife, domestic livestock, and humans.⁵⁴ The reasons to be concerned about these contaminants with respect to public health include:

- Both parasites may be easily spread from manure to water supplies.⁵⁵
- Both parasites may remain viable in the environment for long periods of time as they are able to resist a wide variety of environmental pressures. *Cryptosporidium* has been observed to remain viable in the environment for 12 months.⁵⁶

^a This paper discusses only livestock based pathogens. Several of these contaminants are also released into the environment via human waste.

- Both parasites are unable to be controlled in water supplies simply by chlorination. "Removal of (*Cryptosporidium parvum* and *Girardia*) by filtration and controlling the entry of the pathogens into the water supply are the only methods available to protect the water supply from these two organisms."⁵⁷
- Both parasites are harbored by animals and humans alike.⁵⁸

Bacterium.

Table 6 shows some of the pathogenic bacteria found in manure, and some of the symptoms of infection in animals and humans. These bacteria are of public health concern because:

- *Salmonella* species appear to be the most common pathogen shed across livestock species.⁵⁹
- *E.coli* is also commonly associated with fecal contamination and is the only species of coliform bacteria which is not found in the environment and is found in the feces of animals.^{60, 61} When found in water, the presence of *E.coli* indicates recent contamination by feces.⁶²
- Prolonged survival of *Salmonella*, *Listeria monocytogenes*, *E.coli*, and *M. paratuberculosis* is possible in slurry that is stored under anaerobic conditions and low temperatures.⁶³
- *Campylobacter* and *Leptospira* are able to survive in water for several months.⁶⁴

Viruses.

There are several animal viruses that are present in feces.⁶⁵ However, because viruses cannot multiply outside of a host,⁶⁶ the long-term survival of a virus requires transmission from one host to a susceptible animal.⁶⁷ Stehman, et al., suggest that enteroviruses, rotaviruses, and parvoviruses appear to be the most environmentally stable viruses that are found in manure, and can survive weeks to months in the environment depending on temperature and other conditions.⁶⁸ Enteric viruses (includes adenoviruses, reoviruses, rotaviruses, enteroviruses, the hepatitis A virus, the hepatitis E virus, and others) multiply in the intestinal tract and are excreted in feces. Enteric viruses are able to enter the body through the oral route (for example, consuming contaminated drinking water). The implications of large numbers of animal viruses on human health is unknown.⁶⁹

Table 5. Selected Pathogenic Bacteria Shed in Manure

Bacterium	Source	Symptoms of Infection
<i>Salmonella spp.</i>	poultry, swine, cattle ^a - feces - most common	May be manifested as food poisoning with acute gastroenteritis, vomiting, diarrhea, and rarely septicemia or as typhoid or paratyphoid fever. Recurrent fevers and diarrhea with more serious gastrointestinal symptoms are seen in immunocompromised patients. ^b
<i>Campylobacter fetus</i> and <i>C. jejuni</i>	poultry, swine, cattle - feces	The organisms are found in the oral cavity, intestinal tract, and reproductive organs of humans and animals. Some species are pathogenic, causing enteritis and systemic disease in humans and abortion in sheep and cattle. ^b
<i>Listeria monocytogenes</i>	cattle and poultry, rare in swine	Listeria is found in the feces of animals and man, on vegetation, and in silage. <i>L. monocytogenes</i> is widely distributed in nature. Produces meningoenzephalitis, meningitis, perinatal septicemia, and other disorders in humans. Listeriosis is the infection caused by <i>L. monocytogenes</i> . In humans, in utero infections occur transplacentally and result in abortion, stillbirth, and premature birth; infections acquired during birth cause cardiorespiratory distress, diarrhea, vomiting and meningitis. Infection in adults produces meningitis, endocarditis, and disseminated granulomatus lesion. Infection in cattle and sheep causes encephalitis and abortion. ^b
<i>E. coli</i> verocytotoxigenic enteropathogenic or enterotoxigenic strains	swine, cattle, poultry (uncommon) - feces	<i>E. coli</i> is a species that occurs normally in the intestines of man and other vertebrates, is widely distributed in nature and is a frequent cause of infections of the urogenital tract and of diarrhea in infants. May produce sometimes serious gastrointestinal illnesses, especially severe in neonates and young children. The enterotoxigenic strain causes wasting diarrhea, and is chiefly water-borne via human feces. ^{b,c}
<i>Yersinia pseudotuberculosis</i> or <i>enterocolitica</i>	poultry, swine, cattle - feces	<i>Y. enterocolitica</i> : a widespread species isolated from mammals, birds, and frogs, and from material contaminated by feces. The organism causes acute gastroenteritis and mesenteric lymphadenitis, especially in young children, and arthritis, septicemia and erythema nodosum in adults. It is transmitted by infected food and water and by person-to-person contact. <i>Y. pseudotuberculosis</i> : a species found in the intestinal tract of birds, rodents, and other animals. It is pathogenic, causing mesenteric lymphadenitis in humans and pseudotuberculosis in guinea pigs, white rats, rabbits and other animals. Human infection occurs from contact with infected food or animals. ^b
<i>Leptospira species</i>	cattle, swine, wildlife - urine or aborted fetuses and fluids	Human infection is due to direct contact with the urine or tissue of infected animals or to contact with water, soil, or vegetation contaminated by the urine of infected animals. Severe forms of leptospirosis are usually characterized by jaundice ^b .

Sources: Table adapted from: Susan M. Stehman, Christine Rossiter, Patrick McDonough, and Susan Wade (1996). Potential Pathogens in Manure. Animal Agriculture and the Environment: Nutrients, Pathogens and Community Relations. Proceedings from the Animal Agriculture and the Environment North American Conference. Rochester, New York, December 11-13, 1996.

^aCattle refers to other domestic ruminants also.

Descriptions of symptoms added from the following references:

^bDorland's Illustrated Medical Dictionary, 28th Edition (1994); and, ^cStedman's Medical Dictionary, 26th Edition (1995).

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