Concentrating on Clean Water:
The Challenge of Concentrated Animal Feeding Operations

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The Iowa Policy Project

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By Carol J. Hodne, Ph.D.

Introduction

Public concern about the quality of water in Iowa includes unease about the potential effects of concentrated animal feeding operations (CAFOs) on water quality (e.g., Beeman, 1999; Glover, 1999). CAFOs involve the production of large numbers of animals confined in buildings or feedlots, which produces large amounts of manure. This report summarizes contemporary scientific literature while offering sources of information on CAFO-related water quality issues regarding:

1. Agents (e.g., nitrogen) and sources (e.g., manure spills) of water quality impairment
2. Effects of impaired water quality on the environment and human health
3. Socioeconomic impacts
4. Regulation and policymaking.

The central body of this report pertains to agents of potential water quality impairment from CAFOs, including nutrients, ammonia, pathogens and antibiotics, and to a lesser extent, hormones, salts and trace elements. The nature and sources of these agents of water quality impairment are first described, in this sequence. The next section of the report describes the processes by which these agents (in similar sequence) may affect water quality in Iowa and elsewhere. Then, possible human health effects are described, followed by related socioeconomic impacts. Sustainable livestock production is briefly summarized before the concluding discussion of regulation and policy making.

Structural Changes in Livestock Production: From Diversified Farms to CAFOs

Livestock production in the United States continues to undergo major restructuring in ownership, management and labor relationships, as part of the intensified industrialization of agriculture over the last 50 years (McBride & Key, 2003). Two main structural features of the industrialization of livestock, poultry and dairy production are: (1) the increased market share of large-scale operations that are vertically integrated; and (2) the decreased number of independent, family farm operations engaged in livestock, poultry and dairy production (Kellogg, Lander, Moffitt, & Gollehon, 2000). Vertical integration is the production/distribution of goods and services in a manner that is coordinated through common ownership and management in at least two stages of production and distribution; it is increasingly common in agriculture. This sector is also characterized by intense market concentration in which fewer and fewer firms dominate domestic and global markets (Heffernan, Hendrickson, Gronski, 1999).

An example of the restructuring processes of industrialized livestock production is that the 750,000 U.S. swine producers in 1974 dropped by two-thirds to 250,000 in 1994, while the number of swine produced remained stable (U.S. Department of Agriculture, National Agricultural Statistics Service, multiple years). The portion of Iowa farms with cattle dropped from 80 percent to less than 40 percent (Melvin, et al., 2002). The significant decrease in the number of diversified, conservation-oriented family farms that produce cattle and the increased production of cattle in large-scale feedlots has affected the natural environment in Iowa and elsewhere.

The industrialization of agriculture is integrally related to the production of livestock in large-scale concentrated animal feeding operations (CAFOs) in which animals are confined in buildings or feedlots, thereby, generating large volumes of manure, the central cause of CAFO-related pollution, whether in liquid forms from swine, beef, or dairy, or drier forms from poultry (Kellogg, et al., 2000). The main characteristics of CAFOs – large numbers of animals, confinement, minimal land base and external sources of grain – have fundamental implications for environmental quality, including water quality. The large amounts of CAFO-generated manure are not readily usable as a source of nutrients for grain production within CAFOs, given their minimal land base, and can exceed needed nutrient levels when applied in a surrounding area (Kellogg, et al., 2000; Mulla, et al., 1999). CAFO manure, which is not cost-effective to transport long distances, can, therefore, become a source of pollution, particularly when inadequately managed.

CAFOs' inherent disconnection from crop production and an integrated land base is a fundamental cause of the greater amounts of pollution generated from CAFOs than from the combined livestock-crop production that has characterized traditional diversified family farms. While water pollution (e.g., excess nitrogen from fertilizers) from the latter is significant (U.S. EPA, 2000) and of public and professional concern (e.g., Becker, 2002; Robson & Schneider, 2001), areas with high levels of CAFO production experience additional water pollution risks (e.g., Kellogg, et al., 2000; Kalkhoff, 2000). As large-scale, vertically integrated CAFOs have taken over livestock production, fewer conditions exist for manure management that is closely integrated within holistic conservation programs managed by farm family members with a tradition of historic, intimate knowledge of the quality, topography and nutrient needs of soil (Ikerd, 1998a,b; Jackson, 1998).

Family farmers, including in Iowa, began to raise livestock in confinement in the 1970s and still do so, in decreasing numbers (Braun, 1998; Frerichs, 1998; Kellogg, et al., 2000). Confinement production, including on a contract basis, is sometimes seen as a way to begin or continue farming. Over time, however, family farmers' entrepreneurial, management and marketing autonomy has eroded (Braun, 1998; Honeyman, 1996). Some farmers now feed confined livestock and poultry through contractual relationships with vertically integrated corporations (i.e., integrators) that have concentrated market power and severely limit the marketing opportunities of the remaining independent producers (Braun, 1998; Harl, 2000). Integrators also limit the abilities of independent producers to discover livestock prices. The Organization for Competitive Markets (www.competitivemarkets.com) and other organizations are seeking to restore these traditional capacities of independent producers (Stumo & O'Brien, 2003).

Contract producers tend to provide the production facilities, labor and land, while the integrators provide young animals, feed, veterinary services and management services. Contract producers follow the production and management directives of the integrators, sometimes to the disadvantage of the producers who are trying to develop greater protections (Hamilton, 1995; Morrison, 1998). For example, Roth (1995) summarizes some of the common complaints of poultry growers about their treatment by integrators – under-weighing of their finished birds, unfair improvement requirements, poor quality inputs and misrepresentations about profitability – and offers related legal remedies.

Contract producers, compared to independent producers, have narrower options for manure management and other practices that affect water quality (e.g., Morrison, 1998). For example, independent producers raise the majority of the feed for their livestock (Honeyman, 1996), while integrators generally supply feed to growers (McBride & Key, 2003; Roth, 1995). Therefore, the components of feed additives, which affect water quality, are largely determined at corporate, not producer, levels, as are veterinary services and medicines (Welsh & Hubbell, 1999).

Another issue surrounding the feed used in CAFOs that has environmental implications is their reliance upon monoculture cash grain (especially corn) production (Jackson, 1998). The price of grain for CAFO production is kept low through decades-old federal policies that enforce poor supply management and low farm commodity prices that tend to be below the cost of producing the grain on family farms (Harl, 2003; Hodne, 2004). These low grain prices necessitate federal subsidies to grain producers in order to keep them in business. These grain subsidies become, in effect, a major subsidy for businesses that purchase large amounts of grain, such as large scale CAFOs, the international grain trade and food corporations. These policies provide major advantages to large-scale CAFO corporations over family farm livestock producers, because the former pay less for their grain than the cost of production for the grain raised by family farmers and fed to their own livestock (Hodne, 2004).

Fewer and fewer corporations, at national and transnational levels, control the vertical and horizontal integration of the production, processing and marketing of meat, poultry, dairy and other agricultural products (Heffernan, et al., 1999). Production of livestock in large-scale, vertically integrated CAFOs shares common features of industrialized agriculture (Altieri, 2000; Ikerd, 1998a; Kimbrell, 2002):

- Reliance upon monoculture (i.e., cultivation of a single crop) cash grain production (Jackson, 1998) and prices for grain that are set below the cost of production (Hodne, 2004)
- Use of external inputs, including grain produced outside the community
- Emphasis on external capital, management and labor
- Market concentration, monopolization and vertical integration in production, processing and marketing, including on a global scale (Heffernan, Hendrickson, & Gronski, 1999)
- Externalization of costs to the broader society and to the environment (Buttel, 2003).

CAFOs in Iowa

The portion of Iowa farms with hogs dropped from 70 percent in the early 1960s to about 12 percent in 2000 (Melvin et al., 2002). Still, as large firms dominate production, Iowa, a state of less than 3 million people, ranks number one in the number of hogs and pigs (15,900,000) and in the value of hogs on farms ($1,106,000,000), as of December 1, 2003. Iowa also leads egg production, with 10,446,000,000 eggs produced in 2003 (U.S. Department of Agriculture, National Agricultural Statistics Service, 2004).

Over the last three decades, a large share of fed cattle production moved from Midwestern family farms to the large, vertically integrated feedlots of the lower Great Plains and Southwest. Iowa now ranks eighth in the number of all cattle and calves, with 3,450,000 head as of January 1, 2004 (U.S. Department of Agriculture, National Agricultural Statistics Service, 2004).

Kellogg et al. (2000) provide comprehensive, detailed information on spatial and temporal trends in CAFO production in the United States, including the differing capacities of states to assimilate nutrients from manure. In this context, they describe concentration in livestock production. Of the counties in the U.S. that were in the category of experiencing the greatest decrease in the number of livestock operations and livestock operations with confined livestock, Iowa exhibited the highest proportion of such counties (Kellogg, et al., 2000; p. 20-22).

A number of online resources provide Iowans with updated information regarding CAFOs in Iowa, including the location of different types of operations (e.g., with constuction permits, without permits, feedlots) and information regarding their effects on water quality (e.g., manure spills). The Iowa Department of Natural Resources (DNR), which regulates Iowa's animal feeding operations, provides valuable online resources at www.iowadnr.com/afo/index.html regarding: regulations regarding confinements, open feedlots and manure management; proposed rules; publications; and maps.

In 2002, the Iowa General Assembly passed Senate File 2293 regarding the siting/expansion of CAFOs and land application of manure. More stringent manure management was designed in order to better protect the quality of particular "high quality water resources."

A number of important maps regarding animal feeding operations in Iowa are provided on the Iowa DNR map website at www.iowadnr.com/afo/afomaps.html. The general maps and maps regarding vulnerable waters include:

- *Animal Feeding Operations in Iowa:* This map shows animal feeding operations above 200,000 lbs. live weight and distinguished as permitted (with a construction permit), non-permitted and registered open feedlots. This map consolidates information from the following maps.
- *Non-Permitted Animal Feeding Operations in Iowa:* This map shows known animal feeding operations that must submit manure management plans to the DNR (not including permitted operations).
- *Permitted Animal Feeding Operations in Iowa:* This map shows animal feeding operations that must have a permit (i.e., those that use certain waste control structures and those over a designated live weight).
- *Registered Feedlots in Iowa:* This map shows feedlots that have voluntarily registered with the DNR.
- *Animal Feeding Operations in Iowa and Groundwater Vulnerability – Aquifers and Wells:* This map shows animal feeding operations as they are laid over regions of varying degrees of groundwater vulnerability.
- *Animal Feeding Operations in Iowa and Groundwater Vulnerability – Special Areas:* This map shows animal feeding operations as they are laid over areas of sinkholes and agricultural drainage wells, which are more direct and rapid ways for surface pollutants to reach groundwater.

Sources of Water Quality Impairment from CAFOs

Manure is an important fertilizer and soil conditioner. Manure provides major plant nutrients, such as nitrogen, phosphorus and potassium, and releases them more slowly than does commercial fertilizer, thus, increasing utilization by plants and decreasing water contamination. Manure can significantly improve the chemical, physical and biological qualities of soil (Risse, et al., 2001). A variety of institutional supports (e.g., Heartland Regional Water Quality Coordination Initiative) are available to encourage best management practices to increase the benefits of CAFO manure application and reduce the potential impairment of water quality.

While well-applied manure has numerous positive attributes, the excessive amounts of manure from large-scale CAFOs have generated considerable concern over water quality impairment (e.g., Kellogg, et al., 2000; Mulla, et al., 1999). As Cooperband and Good (2002, p. 5075) observed, "Intensively managed livestock production systems have exacerbated conditions where manure use in crop production is more akin to waste disposal than beneficial fertilization." CAFOs annually produce approximately 575 billion pounds of manure, according to the USDA's Agricultural Research Service

(2002). Manure from CAFOs has been the main focus of research and policies regarding water quality impacts of CAFOs (e.g., Kellogg, et al., 2000; U.S. EPA, 1998; 2002), and is, therefore, the focus of this report. As the structure of animal production has shifted since the early 1980s toward fewer, but larger, operations, a significant increase has occurred in the number of counties in the United States in which the nutrients from manure exceed the assimilative capacity of cropland and pastureland (Kellogg, et al., 2000).

In addition to the manure-related impacts of CAFOs on water quality at local levels, potential broader effects on water quality exist. They include heavy water usage (Donham, 2000) and impacts beyond the region, such as the Dead Zone of low oxygen waters in the Gulf of Mexico and elsewhere (Diaz, 1999). Large amounts of water are needed for animal consumption and lagoon management (i.e., cleaning, flushing, filling, recharging; Donham, 2000). In addition, the processes used in siting CAFOS inadequately consider water quality issues at regional and watershed levels (Jackson, Keeney, & Gilbert, 2000). Welsh and Hubble (1999, p. 887) observe that while technologies to reduce environmental impacts exist, it is "possible to concentrate so much manure in an area that waste management technologies would be overwhelmed, resulting in agricultural pollution."

Agricultural production (crops, grazing, CAFOs, aquaculture) causes much of the impairment of the rivers (59 percent), lakes (31 percent) and estuaries (29 percent; U.S. EPA, 2000) in the United States. While there is more evidence of water pollution from fertilizers and pesticides than from CAFO manure (Poggi-Varaldo, 1999), several aspects of CAFO manure pollution are important. The main components of CAFO manure that may cause water pollution are nutrients (i.e., nitrogen, phosphorus and potassium), ammonia, pathogens (e.g., bacteria), feed additives (e.g., antibiotics, hormones), salts and trace elements, organic matter, and solids (U.S. EPA, 1998). The types and amounts of pollutants in animal manure vary with the characteristics of animals (e.g., species, size, maturity and health), the content of animal feed (e.g., protein content, antibiotics), veterinary care, climate, time of year and waste handling system (Ham & DeSutter, 2000). Only a small portion (e.g., 25 percent in swine and 17 percent in cattle) of feed inputs leave CAFOs in finished animals, while 60 to 80 percent of the inputs are excreted and remain in the CAFO, creating the major issue of manure management (Ham & DeSutter, 2000).

Comparisons of the amounts, biological treatment and regulation of CAFO manure, compared to human manure, indicate the significance of CAFO manure. Daily averages of wet-weight manure (feces and urine) for livestock (on a basis of pounds per 1,000 pounds live unit weight) are: dairy – 86 lb., broiler – 85 lb.; swine – 84 lb.; layer – 64 lb.; beef – 58 lb.; and turkey – 47 lb. (American Society of Agricultural Engineers, 1999). These averages contrast with 30 pounds per human (again, 1,000 pounds live unit weight). The waste for humans, while of the least weight, is highly regulated and is usually treated at wastewater treatment plants, in contrast to animal waste.

Nutrients and Ammonia

Nitrogen, phosphorus and potassium are the main nutrients in manure. Nitrogen (N) occurs in three general forms: gaseous, organic and water soluble (i.e., ammonium-N). Much of the nitrogen in fresh manure is in the organic form, which is not usable as fertilizer for plants. However, organic nitrogen can be metabolized by microorganisms, generating ammonium-N (i.e., water soluble nitrogen) and nitrate, which are usable as fertilizer. Nitrogen is present as ammonium-N or organic-N in the anaerobic (i.e., without free or dissolved oxygen) liquids of waste lagoons (Krapac, Dey, Smyth, & Roy, 1998). The ammonia content of manure varies with age, animal species and volatilization (i.e., the process by which ammonia converts to ammonia gas and is released to the atmosphere). The ammonia content of manure may increase as organic matter decomposes and decrease with volatilization.

When CAFO manure enters groundwater systems (e.g., through seepage from earthen manure storage structures) and meets aerobic (i.e., with free or dissolved oxygen) conditions, ammonium-N and organic-N are oxidized to nitrate, which can become highly concentrated in groundwater that is downstream from earthen manure storage structures (Quade, Libra, & Seigley, 1996). Nitrate has been found in relatively deep areas of aquifers that underlie agricultural areas, particularly those with well-drained and permeable soils (Hamilton & Helsel, 1995). Most of the phosphorus (P) in most fresh manure is in the organic form. With age, it becomes inorganic phosphate compounds, which are usable as fertilizer (U.S. EPA, 2001).

Pathogens

Pathogens are microorganisms (e.g., bacteria, viruses, parasites) that can cause disease. Animal waste may carry infectious organisms including those that cause food-borne illness in humans, such as *Campylobacter*, *Escherichia coli (E. coli) and Salmonella*. Animal manure can carry protozoa, including *Cryptosporidium parvum* and *Giardia* species. Comprehensive listings and descriptions of CAFO-related pathogens are available online (Addis, et al., 1999; Mulla, et al., 1999; U.S. EPA, 2001). The Centers for Disease Control and Prevention provides a useful general description of infections from *Campylobacter* and *E. coli* O157:H7 (Division of Bacterial and Mycotic Diseases, 2003, 2004).

Fecal coliform, bacteria that inhabit the intestines of warm blooded animals, are used to indicate the possible presence of pathogens and include *E. coli* (U.S. EPA, 2001). The concentrations of fecal bacteria in manure can vary with animal age and health, ration, use of antibiotics, type and cleanliness of housing, environmental stressors and manure management systems (Crane, Moore, Grismer, & Miner, 1983). In their review of 27 studies regarding the indicators of the quality of recreational waters, Wade and colleagues (2003) found that in fresh water, *E. coli* is a more consistent predictor of gastrointestinal (GI) illness than are other bacterial indicators. In marine water, enterococci are better indicators of GI illness.

Antibiotics

Antibiotics are used in CAFO animals to treat disease, prevent the spread of disease, promote growth and enhance feed efficiency (Cole, Hill, Humenik, & Sobsey, 1999; McEwan & Fedorka-Cray, 2002). Common estimates of the amounts of antibiotics used in the U.S. annually for animal production include: 17.8 million pounds (Animal Health Institute, 2000); 20 million pounds (Institute of Medicine, 1998); and 29.5 million pounds (Mellon, Benbrook, & Benbrook, 2000). Depending on the source, 40 percent (Nawaz, et al., 2002) to 70 percent (Mellon, et al., 2000) of antibiotics used in the United States are fed to livestock to promote growth, treat disease and minimize the risks of confinement (e.g., stress from crowding).

Hormones

Hormones, strong chemical messengers, help regulate growth and reproductive functions. Synthetic estrogen and testosterone, which are used in livestock feed to stimulate growth, increase feed efficiency and increase productivity, end up in animal manure (Mulla, et al., 1999). Testosterone is naturally present in poultry and is a feed additive in aquaculture (Casey, Hakk, Simunek, & Larsen, 2003).

Salts and Trace Elements

Undigested feed that passes through animals contains salts with sodium and potassium. Trace elements in manure include those that are often added to feed as growth stimulants and biocides – arsenic, copper, selenium and zinc. Organic arsenic is often added to poultry and swine feed in the United States in order to control parasites and improve growth rates. Additional trace elements in manure include cadmium, moybdenum, nickel, lead, iron, manganese, aluminum and boron (Sims, 1995). The pesticides used to control flies with cattle and other livestock may also generate trace elements in manure.

Organic Matter and Solids

Various biodegradable, carbon-based compounds are found in livestock manure. As these compounds are decomposed in surface water by bacteria and other microorganisms, oxygen is used, thereby, reducing the oxygen available for aquatic life. Depletion of oxygen can cause fish kills and reduction in species diversity and numbers (Environmental Integrity Project, 2004).

The oxygen required to decompose the waste of different types of animals is much greater than that for human waste. For example, the biochemical oxygen demands (BODs) for swine manure are: 27,000-33,000 (untreated); 13,000 (anaerobic lagoon influent); and 300 – 3,600 (anaerobic lagoon effluent), while the BODs for human waste are 100 – 300 (untreated) and 20 (after secondary treatment; U.S. EPA, 2001).

The solid materials within CAFO wastes can include litter, bedding, spilled feed, hair, feathers and corpses. Such materials can increase water turbidity (i.e., presence of suspended matter). Suspended particles can disrupt the environment needed for healthy plant and fish growth (U.S. EPA, 2001). Proper disposal of carcasses is especially important for environmental and human health. Pathogens in diseased carcasses can become very concentrated (Cole, et al., 1999).

Summary

In summary, primary sources of potential water quality impairment from CAFOs include: nutrients (i.e., nitrogen, phosphorus and potassium); ammonia; pathogens; feed additives (e.g., antibiotics, hormones, salts and trace elements); organic matter; and solids. When nutrients from CAFO manure exceed the amounts needed for crop production, water pollution may occur, particularly in areas of heavy concentration of CAFOs and downstream of such areas. Nutrients and other components of CAFO manure can enter various water bodies and groundwater systems, including aquifers. Potential consequences for aquatic life (e.g., from oxygen depletion) and human life (e.g., from nitrate and bacterial contamination) will be discussed later. CAFO waste, while being more voluminous and dependent on oxygen to decompose than human waste, is less regulated and treated than human waste, which is highly regulated and is usually treated at wastewater treatment plants.

Processes of Water Quality Impairment from CAFOs

Water pollution from CAFOs can occur through discharges into surface waters from lagoon spills, runoff, erosion and deliberate discharges (Mallin, et al., 1997; Mallin, 2000). Contaminants can leach into groundwater from leaks from lagoons and from manure applied to land (Ham, 2002; Parker, Schulte, & Eisenhauer, 1999). Pollutants can discharge to the air and then be deposited in soil and water (Ham & DeSutter, 2000). Major storm events (e.g., heavy rains, hurricanes) can also cause CAFO-related water pollution (e.g., Mallin, 2000; Wing, Freedman, & Band, 2002). The following discussion will describe these general pollution pathways and will then focus upon particular agents of water pollution (e.g., nutrients and pathogens) from CAFOs.

General Processes of Water Quality Impairment

Lagoon Spills and Discharges

CAFO manure may contaminate surface water through incidents involving manure storage and treatment facilities, including lagoons, which are earthen facilities for the biological treatment and storage of wastewater. Manure is diluted with water to promote the growth of anaerobic microorganisms that decompose solids into ammonia, methane, carbon dioxide and hydrogen sulfide. This decomposition process causes 70-80 percent of nitrogen to be lost as ammonia is released to the atmosphere (Glanville, Baker, Melvin, & Agua, 1999). Lagoons are designed to control odors while reducing the volume of manure and stabilizing it. Most lagoons are soil-lined basins that are between 0.5 to 2.5 hectacre in area, are between 3 to 6 meters deep and have compacted soil liners, between 0.3 and 0.6 meters thick that are intended to keep seepage rates within regulated levels (Ham & DeSutter, 2000). Storage ponds or slurry pits, which temporarily store undiluted runoff and animal waste until it is applied to land, are shallower than lagoons and receive less concentrated wastewater (Parker, et al., 1999). Large spills from manure facilities can be caused by: (1) major rainfalls or storms, including in floodplains; (2) mechanical failures in pumps, irrigation systems, pipes and walls; (3) accidental discharges by operators; and (4) intentional releases from overly full lagoons.

Mallin et al. (1997) compared the effects of a major poultry waste lagoon spill (following high rainfall and high river conditions), which sent 32.6 million liter (L) of waste into a creek, and a swine waste lagoon spill (under dry conditions), which sent 7.6 million L of waste into a system of creeks. These spills occurred in North Carolina, where more than 30 CAFO manure lagoon breaches, overtoppings and inundations were reported from 1995 to 1996. Nitrogen loads were greater for the poultry spill than the swine spill; phosphorus loads were greater for the swine spill. Each spill generated high fecal coliform concentrations. Each spill caused high turbidity and low dissolved oxygen in receiving waters, and, therefore, conditions that made it difficult for fish and aquatic life to receive enough oxygen to survive.

Mallin (2000) described the 1995 rupture of a swine manure lagoon in Onslow County, North Carolina, which dumped approximately 25 million gallons of waste into the New River and New River Estuary. High concentrations of nitrogen and phosphorus contaminated the river, causing dramatically decreased dissolved-oxygen levels, toxic and persistent algal blooms, and a massive fish kill extending more than 20 miles. Fecal coliform counts reached 3.4-million-units, compared to the state standard for human safety of 200 colony-forming units per 100 milliliters. The settling of fecal coliform to sediments represents a latent human health threat. This is because natural or human disturbances may cause the contaminated sediments to become resuspended (i.e., released into the water again), thereby, becoming a source of contaminated water for humans (Burkholder, et al. 1997). North Carolina also suffered similar major and extensive water pollution from CAFOs from the lagoon spills and extensive flooding following Hurricane Floyd in 1999, which drowned massive numbers of swine and poultry, drawing national attention (Wing, et al., 2002).

Manure Spills in Iowa

There were 329 documented manure spills from livestock facilities in Iowa from 1992 through 2002 (Environmental Integrity Project, 2004, p. 14). The Iowa Department of Natural Resources (DNR) documented the spills for 259 of the 329 spills, most of which came from swine facilities (74 percent), followed by beef (2 percent), dairy (11 percent) and poultry (3 percent) facilities; confinements caused 69 percent of the spills, while open feedlots caused 27 percent of them (Environmental Integrity Project, 2004, p. 19). Causes of 307 of the 329 spills were documented by the DNR. They included: manure storage structure failures or overflows (74 spills), equipment failure (73 spills), uncon-trolled runoff from open feedlots (56 spills), improper manure application or overapplication of manure on cropland (43 spills), transportation accidents (43 spills) and deliberate spills (18 spills; Environmental Integrity Project, 2004, p. 20). Spills from improper manure application have decreased over time.

Richard and colleagues (1999), in a study for the Iowa Legislature, found that 76 percent of the 33 earthen manure structures (lagoons and pits) that they studied in Iowa posed potential risk to water quality from management and maintenance issues. Most of these risk factors had not caused major water quality problems; three (9 percent) of the facilities had experienced major spills. The most common risks were minor spills during manure unloading (55 percent), erosion of compacted clay liners or berms caused by agitation or manure flow at inlets (27 percent), animal burrows around pipes or in the berm (24 percent), plugging or freezing of gravity flow inlet pipes (12 percent), tree growth in the berms (6 percent) and inadequate freeboard (i.e., additional height of the structure above the high water level to prevent overflow) caused by overfilling with manure (6 percent).

A map, Animal Feeding Operations in Iowa and Distribution of Reported Manure Spills, is provided on the DNR map website at www.iowadnr.com/afo/afomaps.html. The animal feeding operations are indicated along with human-caused manure spills, as indicated by type and the number of spills that have occurred at a location. Another map on this website, Animal Feeding Operations in Iowa and Impaired Waters (TMDL Program) indicates animal feeding operations along with human-caused manure spills among impaired watersheds.

Seepage from Lagoons

Earthen manure storage lagoons (that are soil lined or clay lined) allow seepage of wastewater, creating a source of potential groundwater contamination (Ham & DeSutter, 2000). Several researchers have reviewed the various factors that affect seepage from lagoons and risks of groundwater contamination (e.g., Ham, 2002; Ham & DeSutter, 1999; Maulé, Fonstad, Vanapalli, & Majumdar, 2000), along with related state regulations (Parker, et al., 1999). Factors that can affect groundwater contamination from lagoon seepage include: depth to groundwater; the natural flow of groundwater; location of nearby surface water; soil structure and texture; type of animal; types of lining such as clay; penetration by roots, earthworms, or rodents; and weathering of side embankments (Ham, 2002; Ham & DeSutter, 1999, 2000; Parker, et al., 1999). The liner along the shorelines of lagoons may be weakened by freezing-thawing, erosion and wetting-drying. These processes can cause greater seepage into the side embankments of lagoons (Ham, 2002).

Sampling of groundwater near two moderately-sized CAFOs in Iowa with newly constructed earthen manure-storage structures on predominantly fine-grained, clayey materials revealed seepage to groundwater as indicated by an increase in concentrations of chloride and total organic carbon and a decline or disappearance of nitrate-N and sulfate (Libra & Quade, 1998; Quade, Libra, & Seigley, 1996). (If ammonium-N seeps from a waste structure, it may be transported by groundwater to an aerobic setting and convert to nitrate.) Seepage of fecal coliform was generally not significant. Some slowing of seepage may have occurred at one site, as indicated by declining chloride concentrations, while sealing had not occurred within three years of operation. Phosphate and ammonia-N were largely being retained on the clayey materials below the basin, until the latter part of the monitoring period. A third site did not indicate seepage; possible seepage could have been masked by the large amount of shallow groundwater discharged by the tile-drain that ringed the site (Libra & Quade, 1998; Quade, et al., 1996).

Seepage rates are generally lower in fine-grained soils and over time (Huffman & Westerman, 1995; Miller, Robinson, & Gallagher, 1976; Parker, et al., 1999). Less information is available on the seepage from structures that have been used for five years or longer (Parker, Schulte, & Eisenhauer, 1999). Glanville et al. (1999) did not find differences in seepage rates due to the length of time (ranging from 3 to 11 years) that earthen manure structures were in use in Iowa. Glanville et al. (1999) found lower seepage rates from lagoons and slurry pit sites with glacial till than with sand and gravel, loess and colluvium geologic materials.

Of the 27 lagoons and ponds analyzed by Glanville et al. (1999), in a study for the Iowa Legislature, four sites (15 percent) had seepage rates less than the 1999 Iowa seepage limit (1/16th inch/day when filled to design depth, as assessed prior to start-up). Ten (36 percent) sites had seepage rates greater than the limit. Fourteen (49 percent) sites had seepage rates that were at the limit. Seepage rates at one site were about three times greater than at another site, so this outlier was not used in data analyses. When using the previous allowable seepage rate that was effective when the structures were built, 43 percent of the structures had seepage rates below the limit and only one structure was above the limit. Fifteen sites were at the limit. No differences in seepage rates between lagoons and slurry pits were found.

Thirty-one basins (including the above sites) were also examined by Baker and colleagues (1999) for possible contamination, in a study for the Iowa Legislature. Elevated ammonium-N, nitrate-nitrogen, and/or chloride concentrations occurred somewhere around the perimeter of nearly all the basins, but generally at only one or two of the eight sampling sites, indicating localized contamination. The presence of a previous feedlot and/or spillage during manure handling was also a possible cause of the elevated concentrations for all but five of the sites. The elevated chloride concentrations from half of the basins were not a health concern, per se. Nine of the 17 basins with elevated ammonium-N did not have elevated chloride, so current seepage was not the cause of the elevated ammonium-N.

Huffman and Westerman (1995) report that estimated seepage losses were small on five of the eleven swine lagoon systems they studied in North Carolina. Four of the sites showed moderate seepage losses and two showed severe seepage, as estimated by total nitrogen export. The main factor affecting seepage was soil materials used in construction, with coarser soils allowing more seepage, rather than soil systems or construction style. The authors concluded that about half of the older, unlined swine lagoons in the lower coastal plain of North Carolina were contributing to local contamination of the surficial aquifer.

Hydraulic conductivity, the rate at which fluid flows through soil, is greatly reduced by the organic sludge that covers the bottom of lagoons (Ham, 2002; Maulé, et al., 2000). This sludge tends to reduce the variance in seepage rates among sites (Ham, 2002). If a lagoon basin is thickly lined with heavy clay, which greatly decreases seepage, the sludge layer will probably have little effect on seepage. Sludge may have a large effect in the early weeks of operation of a pit that is excavated (Ham, 2002). Lagoon sealing at least partially occurs as organic particles from manure physically plug soil pores and organic and bacterial mats on the lagoon soil surfaces decrease the infiltration rates of lagoon soil (Krapac, et al., 1998). However, the results of studies to assess the magnitude and mechanisms of sealing are variable (Parker, et al., 1999). With or without liners, lagoons are at risk for seepage due to freezing and thawing, burrowing animals, roots, and cracking from drying walls following pumpout (Jackson, 1998).

Groundwater contamination caused by CAFO lagoons decreases as depth to groundwater increases. A thicker layer of soil between the bottom of a lagoon and the water table (i.e., the vadose zone) slows movement, adsorbs compounds and transforms some compounds into less toxic forms (Ham &

DeSutter, 2000). Less information is available on the effects of seepage on deeper groundwater (Parker, Schulte, & Eisenhauer, 1999).

While small amounts of seepage can be diluted to harmless concentrations, excessive amounts of seepage can contaminate groundwater in the area of a lagoon. In order to minimize the risks of groundwater contamination from CAFOs, many states regulate the maximum allowable seepage rates or maximum allowable hydraulic conductivity (Ham & DeSutter, 2000; Parker, et al., 1999). Iowa limits the maximum seepage rate in new earthen structures to 0.16 cm/day when filled to design depth (maximum allowable depth). Proof of compliance is submitted prior to start-up of new structures, so Iowa's regulations are mostly used to evaluate new construction, not monitor existing structures (Glanville, et al., 1999). Iowa does not specify a maximum hydraulic conductivity rate. Iowa does not require earthen liners to be constructed to a minimum compacted thickness (Parker, et al., 1999), which may increase the risk of seepage from some lagoons.

Manure Application and Runoff

The potential for water pollution from the land application of manure is diminished when manure application rates are based on the nutrient requirements of vegetation. However, excess nutrients and other pollutants can be transferred to surface and ground waters by runoff, overapplication of manure on land, volatilization/redeposition, heavy rainfall and other conditions (U.S. EPA, 2001). Manure may runoff to surface waters from open feedlots and the application of manure on land. Uncontrolled runoff from open feedlots has caused 56 manure spills in Iowa since 1992 (Environmental Integrity Project, 2004, p. 20). Runoff increases with steep slopes, overapplication and misapplication of manure, certain rainfall and soil conditions and nearness to surface waters. Rainfall risk factors include high rainfall and rainfall soon after manure application (Crane, et al., 1983). Manure runoff to surface waters is increased by manure application to: flood plains; steep land slopes; and soil that is frozen, snow covered, saturated, or of low porosity (Mulla, et al., 1999). Manure application near waterways, natural drainage paths and surface waters increases runoff (Crane, et al., 1983; U.S. E.P.A., 1998). Crane et al. (1983) indicate the need to avoid application of manure under these conditions in order to minimize pathogen contamination.

CAFO manure also becomes a source of water pollution when it is intentionally applied to land in excess of crop nutrient requirements. This may be due to inadequate availability of land for manure application, failure to follow manure management plans, or nutrient ratios that differ from crop needs (Jackson, et al., 2000). Phosphorus (P) and nitrogen (N) are present in manure in nearly equal concentrations, yet crops need about six times more N than P (Cooperband & Good, 2002). About 400,000 Mg of manure P were produced in the U.S. at the farm-level beyond the amount needed for crop production; this excess is about 65 percent of recoverable manure P (that is potentially useable for cropland application) in the U.S. (Kellogg, et al., 2000). The application of manure at a nitrogen-based agronomic rate leads to significant over-application of P, relative to crop needs (Cooperband & Good, 2002; Sims, 1995). Iowa's Environmental Protection Commission voted on June 21, 2004, to require CAFOs to include phosphorus in their manure management plans (in addition to the nitrogen that was already included), in an effort to reduce water quality impairment.

Volatilization/Deposition

Pollution of surface waters from CAFOs can derive from the discharge of pollutants to air and subsequent deposition to soil and water bodies. The volatility of ammonia causes large losses of ammonia from CAFOs through lagoons, manure piles and land application, particularly when manure is not injected into soil but is left on the surface. Up to 80 percent of the nitrogen in lagoon waste is released into the atmosphere from the lagoon surface by ammonia volatilization (Ham & DeSutter, 2000).

Siting of Waste Storage Structures

Water contamination may increase with poorly planned CAFO siting that ignores issues such as regional and watershed water quality, sandy soils, shallow groundwater and flood plains (Jackson, et al., 2000). Simpkins et al. (1999) identified several siting problems of earthen waste storage structures in Iowa that increase the risk of water contamination. Of 34 sites, 18 percent were located directly over an alluvial aquifer, which is generally recognized as the most vulnerable type of aquifer in the Midwest. All of the structures that were on alluvial aquifers were also located on flood plains, a high risk condition for direct contamination of nearby streams. More than 75 percent of the site areas included a majority of well-drained to moderately- to well-drained soils within two miles of each site. This increases the risks of leaching and runoff and increases the amount of land needed for safe manure application.

Nearly 65 percent of the site areas included a majority of soils with seasonally high water table depths of less than five feet from the ground surface. Location of waste storage structures in these areas increases the risks of contaminants reaching the water table, particularly because 90 percent of the structures were deeper than 10 feet (i.e., below the water table). The site areas were dominated by soils with permeability exceeding 1 inch/hour. Seepage will probably saturate any liner material and maintain a hydraulic connection to the water table.

Water Quality Impairment from Particular Agents

Nutrients and Ammonia

Microbial breakdown of nitrogen in manure and fertilizer forms nitrate, which can leach into groundwater or run off into surface water. Nitrate from manure can reach surface waters through direct discharge of manure, seepage from lagoons, land application of manure, artificial drainage systems, and, to a lesser extent, overland runoff. In the central states, 37 percent of nitrogen and 65 percent of phosphorus inputs into watersheds are from manure (USFWS, 2000).

Streams in several eastern Iowa waterbeds ranked in the upper 25th percentile nationally for median nitrate concentrations (Kalkhoff, et al., 2000). The median nitrate level in Iowa's agricultural areas was 5.1 ppm, compared to the 1.8 ppm median in Iowa's urban areas. While 39 percent of samples taken from shallow alluvial aquifers in Iowa's agricultural areas exceeded the maximum contaminant level (MCL) for nitrate of 10 ppm, none of the urban samples did so (Kalkhoff, et al., 2000).

High nutrient concentrations have been found in Iowa surface water in river basins with denser concentrations of CAFOs. Kalkhoff et al. (2000) found that nitrate levels in the South Fork of the Iowa River were 1.8 times higher than the nitrate levels in the Iowa River upstream from Rowan, with the former area having more than twice the number of swine than the latter area. Both areas have similar amounts of row crop production, so that is not a likely cause of the different nitrate levels. Similarly, phosphorus levels were 2.5 times higher in the South Fork of the Iowa River, the area with denser concentration of CAFOs.

Nitrate contamination has also been associated with dairy CAFOs in California areas that supply drinking water for heavily populated Orange County (U.S. EPA, 1993). In addition, dairy CAFOs in southern New Mexico with lagoons lined with clay had greater nitrate concentration than did lagoons lined with cement or synthetic membranes, which were also more effective at reducing groundwater contamination from ammonia (Arnold & Meister, 1999). Average concentrations for nitrate (17.8 mg/L; milligrams per liter) and ammonia (.44 mg/L), as well as for chloride and total dissolved solids, exceeded groundwater quality standards at all dairies and monitoring wells. Only nitrate concentrations increased over time.

Nitrate contamination and other water quality impairments (e.g., bacterial contamination) have increased in the Bosque and Leon River watersheds of North Central Texas as dairy CAFOs took over dairy production from family farms beginning in the 1970s. Over 180 dairy CAFOs in this area now contain over 130,000 head of cattle, which produce about 1.8 million tons of manure per year, within a very weak regulatory climate (Texas Water Sentinels Project, 2003).

Ham's (2002) study of seepage from 20 anaerobic lagoons in Kansas showed that concentrations of nitrogen and phosphorus were three to five times higher in swine lagoons than cattle feedlot lagoons. Concentrations decreased significantly with depth of seepage and generally returned to normal levels around 3 meters beneath the lagoons. Seepage losses, as indicated by high ammonium-N concentration, from five of the North Carolina swine waste lagoons studied by Huffman and Westerman (1995) were low, while seepage losses were moderate in four lagoons and severe in two lagoons.

Ham (2002) describes how ammonium-N and organic-N will accumulate under lagoons over time, generally remaining close to the lagoon, especially if it has some clay lining. Over the 25-year lifetime of a lagoon, nitrogen accumulations under a 2.5-hectacre swine waste lagoon may exceed 2.3×10^5 kg (Ham, 2002). The greater risk of groundwater contamination may be after a CAFO stops operating and is associated with nitrate-N. It is highly mobile in soil and develops when a lagoon is dewatered and cleaned and oxygen is diffused into the contaminated subsoil. When lagoons are closed, excavation and movement of some of the nitrogen-laden soil may be necessary. Remediation costs should be considered when the lagoon is designed (Ham, 2002).

To protect against nutrient and pathogen contamination, the preparation for closure of earthen manure structures without linings involves: (1) protection during the closure of the soil/organic matter interface layer that naturally lines the structure contents, (2) removal of all liquids and pumpable slurry, and (3) land application of removed liquids and sludge at agronomic rates (Jones, et al., 2001). Iowa, Oklahoma, Missouri and Kansas have legal mechanisms to ensure that CAFO owners have the funding needed to close lagoons (Jones, et al., 2001; Volland, Zupancic, & Chappelle, 2003).

In the U.S. and the world, the amount of nitrogen produced (e.g., fertilizers, fossil fuels) far exceeds what is usable by soil, and is polluting water systems on a large scale (Kellogg, et al., 2000; Moffat, 1998). Excessive nitrogen and phosphorus may lead to eutrophication (i.e., nutrient over-enrichment) and related algae blooms (i.e., rapid growth of populations of microorganisms), causing significant decreases in the oxygen levels in water bodies, including rivers, lakes, estuaries and coastal oceans (Carpenter, et al., 1998). In their review of studies of nutrient pollution of surface waters, Carpenter et al. (1998) conclude that nutrient flows to water bodies are related to the density of animal production and under high densities, manure is applied to land in excess of crop needs. In surface water, fish kills, decline of native plants, reduced biodiversity (i.e., reduction in desirable species), and problems with water transparency, taste and odor can be caused by the waste's oxygen demands, as well as by ammonia content (Carpenter, et al. 1998).

Ammonia can reach surface waters through direct discharges and erosion from land application, as well as from the deposition that follows atmospheric volatilization from manure piles, lagoons, land application and CAFO buildings. These sources are increasing the level of ammonia in rain and surface waters (U.S. EPA, 2001). Hoff and colleagues (2002) carefully reviewed the factors that influence the ammonia emissions from various types of CAFOs. For example, ammonia emissions from land application of CAFO manure are greatly reduced by injecting manure, rather than by broadcasting it or applying it to the surface without covering it. Failing to consider the release of ammonia into the atmosphere and its subsequent deposition in decisions regarding siting of CAFOs can contribute to algae blooms in areas of intense CAFO concentration (Burkholder, 2004).

Eutrophication can cause blooms of toxic algae and other toxic microorganisms. An example is *Pfiesteria piscicida,* an "ambush predator" dinoflagellate found in estuarine ecosystems in the mid- to south Atlantic coast; it attacks finfish and shellfish with toxins (Burkholder & Glasgow, 1997). Because nutrients from poultry and swine CAFOs are considered among the sources of the *Pfiesteria* outbreaks, policy responses to reduce nutrient loading have included consideration of improved CAFO manure management (Silbergeld, Grattan, Oldach, & Morris, 1999).

Hypoxia (i.e., low levels of dissolved oxygen in water bodies) is caused by organic enrichment of sediments and eutrophication and increasingly occurs around the world in over 60 large "dead zones" (Diaz, 1999). The resulting large-scale algae blooms eventually die and are consumed by bacteria, causing depletion of the oxygen in the lower half of the waters. While some finfish, shellfish and crustaceans can leave the area as the oxygen is depleted, from spring or earlier until fall, many cannot leave and, therefore, die. The reduction in fishing is exacerbated as some less desirable species (e.g., jellyfish) may thrive in low oxygen waters.

Hypoxia in the deep waters off the coast of the northern Gulf of Mexico is caused from nutrient discharge into the Mississippi River. This nutrient discharge is mostly from the nitrogen in agricultural fertilizers. About 20 percent of the nitrate in the Mississippi River comes from Iowa sources (Libra, 1998). About 15 percent of the nitrogen discharge from the Mississippi River Basin to the Gulf of Mexico is from animal manure (USGS, 2000).

As ammonia in water oxidizes, dissolved oxygen is used. Related oxygen demands can reduce the diversity of species in affected waters and cause fish kills, especially when animal wastes are discharged directly into surface waters, as with lagoon spills. For example, Mallin (2000) described the 20-mile long fish kill along the New River following a swine lagoon spill in North Carolina in 1995.

Over 2.6 million fish were killed in Iowa, due to 108 manure spills from 1992 through 2002, based on the analysis of DNR data by the Iowa Environmental Council (Environmental Integrity Project, 2004, p. 14). Some CAFO spills did not lead to fish kills because chronic water pollution had already killed the fish in the area. The DNR is allowed to assess damages for these fish kills, but has a history of only minor, if any, assessments (Environmental Integrity Project, 2004, p. 30-31). The DNR, therefore, does relatively little to recapture the externalized costs associated with these fish kills.

An Iowa DNR map, *Animal Feeding Operations in Iowa and Reported Fish Kills Attributed to Human Causes,* can be accessed at www.iowadnr.com/afo/afomaps.html. The animal feeding operations are indicated along with human-caused fish kills within a decade. The percentages of fish kills due to particular causes are noted in the map inset.

Manure nutrient levels can vary from month to month. Levels of phosphorus and nitrogen in feedlot cattle manure were found to vary at different times of year (Canada Alberta Beef Industry Development Fund, 2004). Dr. Jim Miller noted, “This shows the importance of nutrient testing to help match manure application rates to soil and crop requirements.”

The organic P in manure is usually water-soluble. The repeated application of manure P in excess of crop needs creates elevated concentrations of P in soils and increased amounts of P that runoff into surface waters, erode from land applications and leach through soil into groundwater (Kellogg, et al., 2000). Inorganic phosphate readily attaches to soil particles, so erosion makes up the majority of P that reaches surface waters from soil. Mulla et al. (1999) report that livestock manure can contribute up to 65 percent of the P in surface waters.

The concentrations of total phosphorus and dissolved reactive phosphorus from runoff are increased as rates of manure application to soils increase (Kleinman & Sharpley, 2003). Phosphorus runoff is greater from the application of manure from poultry and swine than from dairy manure. These differences in phosphorus runoff from application rates and types of manure have been found to decrease with repeated (experimental) rainfall events (Kleinman & Sharpley, 2003). The authors suggest that differential erosion of broadcast manure may contribute to the variation in runoff of total phosphorus concentrations among soils.

Pathogens

Surface waters can become contaminated by pathogens from CAFOs through surface discharges, lagoon leaks and runoff from land application and feedlots, particularly runoff involving fresh manure (Mulla, et al., 1999). Subsurface water may also transport pathogens, particularly in conjunction with sandy soils, limestone, or sinkholes. Pathogens may live longer and in greater numbers on land bearing repeated and heavy manure applications (U.S. EPA, 2001). A number of studies (e.g., Burkholder, et al., 1997; Mallin, et al., 1997) have shown that fecal coliforms can live in surficial sediments and become resuspended into water following rainfall or dredging.

E. coli bacteria can pollute surface and ground waters through leaching, runoff and flow from and through contaminated soils. A recent Iowa experiment showed that *E. coli* from swine manure can be leached through the upper portion of soil after manure has been on the soil surface for extended periods before the first rainfall and that leaching can occur after subsequent rainfalls, in decreasing amounts (Saini, Halverson, & Lorimor, 2003). The leachability of *E. coli* was not affected by manure application procedures (i.e., no-till broadcast, broadcast on tilled soil, and incorporation following broadcast).

Samples of groundwater and manure associated with two Illinois swine CAFOs manure lagoons contained indicator organisms that are used to determine the safety of potable water – *E. coli, Streptococcus faecium, Streptococcus faecalis* – as well as fecal coliform and fecal strepto-coccus. Fecal streptococcus was more common than fecal coliform. Results suggest that the filtration of bacteria by soils may not adequately protect groundwater used for drinking (Krapac, et al., 1998, 2002).

The fecal excretion of *E. coli* O157 and *Campylobacter* mostly occurs from cattle and tends to peak in the spring and late summer, coinciding with the beginning of the peaks in reported human infections (Jones, 1999). While pathogens, including *E. coli*, often decrease in number as manure is exposed to heat, sunlight, and air, limitations to this decrease exist (Jones, 1999). While *E. coli* tend to thrive with cooling, some strains tolerate extended periods of heating. *E. coli* are facultative pathogens (i.e., they grow in aerobic and anaerobic conditions). Under anaerobic conditions, *E. coli* O157 will grow, even under heat stress (Jones, 1999).

E. coli bacteria have been carried downstream by surface runoff and can survive semi-arid conditions (Abu-Ashour & Lee, 2000). *E. coli* and other bacteria have been found to survive in cattle feedlot manure and catch basin effluent for up to several months (Canada Alberta Beef Industry Development Fund, 2004). *E. coli* bacteria were present in the soil at the bottom of catch basins, even as they emptied or dried out, leading the researchers to recommend lining catch basins with clay to minimize the leaching of *E. coli* into groundwater. However, leakage from lagoons, even those with clay liners or into clayey soils (e.g., Arnold & Meister, 1999; Jackson, 1998; Krapac, et al., 2002) may make this less than totally effective at preventing the leaching of *E. coli* into groundwater.

Canadian researchers (Canada Alberta Beef Industry Development Fund, 2004) found that *E. coli* and other types of bacteria could survive from several days to several months in manure and effluent, and they encouraged proper manure management in order to minimize the transfer of these bacteria to the environment. Applying cattle manure in cooler weather was suggested because it controlled the levels of *E. coli* and total coliform, reducing the risk of bacteria reach-ing groundwater. When catch basin effluent was used for irrigation, *E. coli* bacteria survived in barley crops and soil from several days to several weeks. This led to the recommendation to avoid *E. coli* contamination in feed by leaving adequate time from irrigation to harvest. It was also recommended that manure not be applied to sloped fields, due to risk of runoff, and sandy soils, due to the potential for *E. coli* to leach into groundwater.

The Centers for Disease Control and Prevention (CDCP, 1998) studied lagoon, surface water and ground water samples from farm sites in Iowa counties with high densities of swine CAFOs. Pollutants and pathogens, with the exceptions of nitrate and sulfate, were generally highest in the earthen manure lagoons. They were also found in drainage ditches, agricultural drainage wells, tile line inlets and outlets, and a river**.** Bacterial pathogens were highest in the earthen lagoon samples, and they were found in other water samples (e.g., drainage ditches, drainage wells, tile line outlets). Indicators of fecal contamination, *Enterococcus* and *E. coli,* were found in 87 and 78 percent of the samples, respectively. *Salmonella* were found in 9 percent of samples and no *Campylobacter* were found. Many of the *E. coli* species and all three *Salmonella* species showed resistance to the antibiotics that are used in swine feed. *Cryptosporidium parvum* oocysts were found in over half of the water samples, with the highest amounts found in the earthen manure lagoon samples. The results generally suggested the possibility that pollutants and pathogens can move through soil and away from the point of higher pollution (i.e., lagoons) and by overland flow away from the area of manure application.

Ninety-one percent of the 11 dairy farms studied in the northeastern United States had *Cryptosporidium parvum* on site. Younger calves were the primary reservoir, with 15 percent of them (0-3 weeks of age) testing positive. Nine percent of farm-associated stream samples were *Cryptosporidium*-positive (Sischo, Atwill, Lanyon, & George, 2000). The single risk factor for surface water was the increasing frequency of spreading manure on fields, suggesting runoff of *Cryptosporidium p*. These dairy farms had an average of 87 cows in the milking herd.

Antibiotics

Of antibiotics given to CAFO livestock, 25-75 percent pass unchanged into manure waste and may contaminate soil and water through transmission through surface water and ground water (Chee-Sanford, Aminov, Krapac, Garrigues, & Mackie, 2001). The review by Hallig-Sorensen and colleagues (1998) of research on the occurrence and effects of pharmaceuticals in the environment included several agricultural antibiotics that were detected in samples of manure, soils, sediment and water bodies. Meyer and colleagues (1999) found that tetracycline antibiotics were found in all six liquid waste samples from swine lagoons. The sample concentrations ranged from approximately one to several hundred parts per billion in the liquid swine waste. Tetracycline was also found in one of the three groundwater samples, but not in the 14 surface water samples.

Various types of antibiotics were found in all samples of swine manure lagoons in Iowa and in 31 percent of nearby water samples. Antibiotics were found in 67 percent of the water samples near poultry CAFOs in Ohio (Campagnolo, et al., 2002). These results suggest that manure stored in lagoons or applied to land can act as a non-point source of antibiotic residues in water.

The Iowa CDCP (1998) study of water impacts of large-scale swine CAFOs found that four types of antibiotics were found in eight of the 23 samples (i.e., all seven earthen lagoon samples and one earthen lagoon monitoring well). Tetracyclines were, by far, the most common. Sulfonamides, ß-lactams and macrolides were also detected, but not fluoroquinolones.

Antibiotic compounds were among the organic waste contaminants found in over 80 percent of the 139 streams across 30 states, including Iowa (with 10 sample sites), sampled by the U.S. Geological Survey (Kolpin, et al., 2002). The frequency of detection of antibiotics was 50 percent and they made up about 3 percent of the total concentration of organic waste contaminants. Agricultural and residential sources are involved. The authors indicated that even low-level concentrations in the environment increase the rate at which bacteria develop antibiotic resistance (Kolpin, et al., 2002).

Bacterial pathogens are increasingly able to resist antibiotics. The development and spread of resistance is caused by: mutation in genes that increase their spectrum of antibiotic resistance, transfer of resistance genes among various micro-organisms, and selective pressures that favor the development of resistant organisms (Barza & Gorbach, 2002; Halling-Sorensen, et al., 1998). Resistance to numerous antibiotics is documented in various bacteria in different animals (McEwan & Fedorka-Cray, 2002). The use of antibiotics, including subtherapeutic use as growth promoters, in CAFOs has been associated with the selection and spread of antibiotic resistance among populations of bacteria in animals. Resistant organisms may spread through infected carrier animals, feed, wildlife, or clothing (Addis, et al., 1999; Cole, et al., 1999; McEwan & Fedorka-Cray, 2002). Methods of transmission of antibiotic resistance to humans include direct contact, animal manure and contaminated food (Gorbach, 2001; McEwan & Fedorka-Cray, 2002).

Surface water and groundwater may also spread bacteria carrying antibiotic resistant traits. For example, tetracycline-resistant genes have been found in lagoons and groundwater underlying swine CAFOs in Illinois, as far as 250 meters away (Chee-Sanford, et al., 2001). In addition, *E. coli* that are resistant to multiple antibiotics can be transferred through surface waters. Antibiotic resistant *E. coli* have been found in a study of monthly samples from 30 eastern Iowa rivers. The organisms were most commonly resistant to sulfamethoxazole, streptomycin, tetracycline and chloramphenicol, which are used in human medicine. Some sample sites indicated repeated contamination (Winokur, et al., 2002).

Hormones

Hormones, like other substances, are excreted in animal waste and have been found in surface water and groundwater in association with land-applied manure (Casey, et al., 2003). Estrogen and testosterone are typically transferred to surface waters by runoff and leaching, respectively (Shore, Correll, & Chakraborty, 1995). Estrogen and testosterone have been found in poultry manure, most of which is applied to soil for fertilizer. Estrogen has been found in runoff from fields that were applied with poultry manure. An irrigation pond and streams in a watershed near the Chesapeake Bay contained estrogen and testosterone, with the latter being more concentrated in the streams (Shore, et al., 1995). Testosterone, compared to estrogen, has a greater potential to migrate through soil, therefore, creating a risk to subsurface water quality, particularly if it migrates to lower soil depths, which have limited biodegradation activity. Heavy rainfall and irrigation may increase these risks (Casey, et al., 2003). In a thirty state study, Kolpin et al. (2002) detected biogenic and synthetic hormones in approximately 40 percent of the sampled streams, while the total concentration of organic wastewater contaminants due to hormones was less than 2 percent.

Salts and Trace Elements

Salts and trace elements from discharges from feedlots and land-applied manure, especially when applied excessively and repeatedly, can accumulate, as they persist in the environment, and can ultimately harm soil quality and plant growth. Salinization can reduce soil permeability and cause poor tilth (i.e., soil health and balance). The salts and trace elements can also leach into groundwater and reach surface waters. Increased salts and trace elements may cause environmental imbalances in fresh waters and on agricultural lands, harming birds and reducing yields. Excessive amounts of copper and zinc have been found in creek sediment and wetlands, in association with cattle CAFO and swine CAFOs, respectively (U.S. EPA, 2001).

Krapac et al. (1998, 2002) found that concentrations of chloride, potassium and sodium were greater in groundwater samples that were associated with seepage from two swine lagoons in Illinois (particularly the lagoon with a shallow, continuous sand layer that likely intersected the bottom of the lagoon). They did not find evidence of groundwater contamination from trace elements. Ham’s (2002) study of 20 anaerobic lagoons in Kansas revealed greater concentrations of chloride, on average, in cattle feedlot lagoons (652 mg/L) than in swine lagoons (497 mg/L) and greater concentrations of sodium in the swine lagoons (329 mg/L) than in the cattle lagoons (268 mg/L).

The Iowa CDCP (1998) study found trace metals and common ions in water affected by large-scale swine CAFOs, especially in earthen manure lagoons, but also in drainage ditches and wells, tile line inlets and outlets, and an adjacent river. Just detectable levels of arsenic (i.e., 0.01-0.03 mg/L) were found in three of the seven lagoons and in one monitoring well (0.07 mg/L), but not in the other 19 samples. Chloride was highest in most of the lagoons and next highest in two of the four monitoring wells.

Hancock et al. (2001) found arsenic in the Pocomoke River Basin in Maryland and Delaware, an area in the Chesapeake Bay Watershed with many large-scale poultry CAFOs. Concentrations of total arsenic in fresh poultry manure were as high as 27 mg/kg and in older, composted manure were less than 2 mg/kg. The authors indicated that arsenic may volatize from composting manure and leach into water during rainfall. Runoff probably contributed to the increase in dissolved arsenic in agricultural ditches and the Pocomoke River during high flow. Shallow groundwater and part of the surficial aquifer system, a drinking water source, had relatively high concentrations of arsenic.

Summary of Processes of Water Quality Impairment from CAFOs

Research regarding agents of water pollution from CAFOs has focused on nitrogen, phosphorus and pathogens (e.g., *E. coli*, *Campylobacter, Salmonella and Cryptosporidium p.*) and has increasingly included antibiotics, hormones, salts and trace elements. CAFOs can cause pollution of surface waters and groundwater through: lagoon spills, discharges and seepage; improper manure application; runoff; volatilization and deposition; and poor siting decisions (e.g., involving aquifers, flood plains, high water tables and sandy soils). Contaminants can leach into groundwater from lagoon seepage and the manure applied to land. Major storms and heavy rains, including on flood plains, can cause dramatic lagoon spills and runoff and may cause pollutants in sediments to again become released into water bodies. Iowa experienced 329 manure spills from livestock (mostly swine) facilities, mostly confinements, from 1992-2002 (Environmental Integrity Project, 2004, p. 14).

Seepage of CAFO wastewater from earthen manure storage lagoons may contaminate groundwater. Contamination from seepage decreases as: the depth to groundwater increases, soils are more fine-grained, and linings contain more clay. Lagoons are at risk for seepage due to natural processes such as weathering (e.g., freezing/thawing, drying) of side embankments, burrowing animals and root growth.

Excess nutrients, pathogens and other pollutants can be transferred to surface and ground waters by the runoff of manure from open feedlots and the misapplication of manure on land. Risks of runoff increase with: nearness to surface waters; high rainfall; and over-application and misapplication of manure (e.g., to flood plains, steep slopes and soil that is frozen, snow covered, saturated, or of low porosity). CAFO manure is sometimes applied to land in excess of crop nutrient requirements because of inadequate availability of land for manure application or failure to follow manure management plans. Phosphorus is often over-applied because phosphorus and nitrogen are nearly equally present in manure, yet crops need much more nitrogen than phosphorus. The vote by the Iowa Environmental Protection Commission to include phosphorus in manure management plans needs to generate effective implementation and monitoring in order to ensure reduction of pollution from phosphorus.

Nitrogen and phosphorus from CAFO manure are of particular concern. They contribute to the excesses that are causing eutrophication (i.e., nutrient over-enrichment) and related algae blooms (i.e., rapid growth of populations of microorganisms) on a large scale in the U.S. and elsewhere. The resulting serious decreases in the oxygen levels in water bodies cause fish kills, decline of native plants, reduced biodiversity, growth of toxic algae and water quality problems. For example, over 2.6 million fish were killed in Iowa from 1992 through 2002 due to 108 manure spills (Environmental Integrity Project, 2004, p. 14). Nitrate, which is formed by the microbial breakdown of nitrogen in manure and is highly mobile in soil, reaches surface waters and groundwater. High nitrate levels have been linked to CAFOs in Iowa, California, Texas and elsewhere.

The antibiotics used in CAFO production, for therapeutic use and subtherapeutic use as growth promoters, and related antibiotic-resistant bacteria are receiving increased attention by researchers, clinicians and producers. Antibiotics, such as tetracyclines, have been found in lagoons and streams, including in Iowa. As bacterial pathogens are increasingly able to resist antibiotics, surface water and groundwater are among the pathways of spreading antibiotic resistant bacteria, including those from CAFOs.

Hormones, salts and trace elements from CAFO manure can also be found in surface water and groundwater. Estrogen and testosterone typically travel to surface waters by runoff and leaching, respectively. Salts and trace elements can accumulate, particularly with heavy manure application, and can reach surface water and groundwater, causing environmental imbalances.

Human Health Effects of Water Quality Impairment from CAFOs

Environmental health encompasses environmental conditions that may harm human health or the ecological balances essential to human health and environmental quality whether in the natural or man-made environment, according to the National Environmental Health Association (1996). The main environmental health concerns of nearly 400 rural health care providers in the United States are groundwater and surface water pollution, pesticide misuse and soil erosion (Robson & Schneider, 2001).

Some Iowans in rural and urban areas, like these rural health care providers, are concerned about the possible health effects of CAFOs from impaired water quality. Of 440 southern Iowans surveyed about the potential location of a large sow CAFO near their residence, over 80 percent were "somewhat" to "seriously concerned" about the potential of nitrate contamination of their drinking water. Increased concerns were associated with increased education (Holtkamp, O'Gorman, & Otto, 1994).

Welsh and Hubbell (1999) found some variation in the environmental health attitudes of independent swine producers and contract producers in five southern states. The two groups tended to agree that: (1) manure management is an important issue for the hog industry, (2) their family's health was not threatened by groundwater contamination from hog operations, and (3) neighbors had not expressed concerns about potential water pollution from their operations. Contract producers more strongly agreed that: (1) ground and surface water pollution from hog manure was an important issue for their operation, and (2) hog producers should be required to use water pollution control practices.

The authors suggested that the greater number of animals on the smaller land holdings by contract producers might underlie the differences in the groups' attitudes, because contract producers have a more limited land base for proper manure utilization. Contract producers, instead, need to rely on monitoring and ameliorative approaches to manure management, rather than expanding their land base, particularly given their limited control over factors that affect their production costs and income (Welsh & Hubbell, 1999). Of the 11 manure management practices that were measured, the contract producers more often used four of them (i.e., nutrient management plan, sediment or settling basin, manure storage down slope from water supply, manure storage at least 45 meters from wells).

Recent reviews of the environmental and human health effects of CAFOs (e.g., Cole, et al., 1999; Cole, Todd, & Wing, 2000; Donham, 2000) include discussions of air- and water-borne hazards, including pathogens. A comprehensive review of the public health risks of CAFOs (Addis, et al., 1999) discussed ways in which pathogens from animals may be transmitted to humans by water (drinking water, groundwater and recreational water bodies). These reviews describe the need for proper manure management to protect public and occupational health, especially from microbial pathogens. Kirkhorn's (2002) review includes a discussion of clinical treatment issues of CAFO operators, workers and neighbors. The strong evidence of health problems among CAFO producers and workers emphasizes respiratory problems relating to air emissions (see Donham, 2000 for a review). Less focus has been placed on water-related occupational health hazards. Antibiotic-resistant bacteria, which may be transferred from animals to humans by water-based mechanisms (Barza & Gorbach, 2002) may become an emerging occupational health hazard, as later discussed.

CAFO pollutants transmitted through surface water and groundwater may impair drinking water. Private wells are the main source of drinking water for rural Iowans. The shallowness of many rural private wells makes them especially vulnerable to contamination. The related risks to human health health are exacerbated by the common lack of wellhead protection, regular testing and treatment of such wells (Weyer, 2001). Public health officials are encouraged to increase private well testing among rural residents in areas of CAFO concentration. Such testing could be especially beneficial following conditions of manure spills, high rainfall and flooding in areas of vulnerable water bodies (Simpkins, et al., 1999).

Nutrients and Ammonia

Manure nutrients and fertilizers can increase nitrate levels in drinking water, increasing human intake of nitrate. Nitrate can leach into groundwater, the source of approximately 90 percent of rural drinking water, or, less often, run off into surface water. Nitrate, the most common agricultural contaminant in drinking water wells, poses a threat to some private wells in rural areas (Hamilton & Helsel, 1995; U.S. EPA; 2002), the main source of drinking water for rural Iowans. The sampling of nearly 700 private rural wells in Iowa from 1988-89 in the Iowa Statewide Rural Well Water Survey revealed that 18.3 percent of these wells were contaminated with nitrates from various sources (e.g., fertilizers, manure, private septic systems) beyond 10 ppm (Kross, Hallberg, Bruner, Cherryholmes, & Johnson, 1993).

The maximum contaminant level (MCL) for community water supplies is 10 mg/L and 1 mg/L for nitrate-nitrogen and nitrite-nitrogen, respectively. The Environmental Protection Agency (EPA; 2002) estimates that, nationwide, approximately 1.3 million households in counties with CAFOs have domestic wells with nitrate concentrations above the 10 mg/L threshhold, based on the approximately 13.5 million households located in counties with CAFOs that have domestic wells. Should public water supplies become contaminated, traditional drinking water treatment processes cannot remove the nitrate, and additional, more expensive, treatment processes are required (Environmental Integrity Project, 2004; EPA, 2001), including in Iowa (Becker, 2002).

Public or community water supplies may also become contaminated by excess nutrients leading to algae overgrowth, taste and odor problems, and health hazards. Phosphorus in water, which is not considered to be directly toxic to humans and animals, is not regulated by drinking water standards, but it can have indirect effects on human health (Carpenter, et al., 1998).

The reduction of nitrate to nitrite, including through bacterial and other reactions, not nitrate *per se*, may affect human health (Weyer, 2001). A severe form of nitrite poisoning is “blue baby syndrome” or methemoglobinemia, in which the oxygen-carrying capacity of infants’ blood may be diminished enough to be fatal in rare cases. Infants produce more nitrite because they have more nitrate-reducing bacteria in their digestive tracts. They also have fewer enzymes to reduce methemoglobin – which carries inadequate amounts of oxygen – to hemoglobin, which adequately carries oxygen. Similarly, some adults may also be at risk for methemoglobinemia. The role of nitrate in drinking water in causing methemoglobinemia is widely discussed (Weyer, 2001).

Weyer (2001) recently summarized the human reproductive hazards that are at least tentatively linked to high amounts of nitrate in drinking water. For example, maternal ingestion of private well water with high levels of nitrate is associated with central nervous system defects in infants (Arbuckle, Sherman, Corey, Walters, & Lo, 1988).

While experimental studies suggest that nitrites reduce to N-nitroso compounds (NOCs), which are strong carcinogens, the epidemiological evidence that links nitrate in drinking water to risks of a variety of cancers is mixed or inconclusive (Weyer, 2001). A prospective study of elderly women in Iowa showed increased risks for ovarian cancer and bladder cancer from nitrate concentration in drinking water, but decreased risks for rectal cancer and uterine cancer. A nearly three-fold risk for bladder cancer was associated with long-term ingestion of drinking water with high nitrate concentrations (Weyer, et al., 2001). This study did not find the increased risk for non-Hodgkin’s lymphoma linked to long-term ingestion of drinking water with high nitrate concentrations that was earlier found in Nebraska (Ward, et al., 1996).

CAFO odors derive from buildings, manure storage and manure application practices (Schiffman, 1998). Injecting liquid manure in farm fields may generate fewer odors for CAFO neighbors than applying manure to land surfaces. CAFO odors are the partial cause of diminished quality of life for CAFO neighbors (Wing & Wolf, 2000) and resulting social conflict. Numerous CAFO wastes contribute to odor pollution, which can cause gastrointestinal, stress-related and respiratory symptoms. These physical symptoms may be caused by CAFO odors through interactions between brain and organ systems through mechanisms such as aversive conditioning and stress-induced illness (Schiffman, 1998; Schusterman, 1992). Wing and colleagues reported that neighbors of CAFOs in North Carolina had less immunoglobulin-A in their saliva, an immune system marker, when they reported moderate to strong CAFO odors (Beeman, 2004). These findings suggest that odor-related health problems could be lessened by improved siting of CAFOs, adherence to proper manure management practices, and notice to neighbors of expected periods of land application of manure.

Pathogens

Humans may be exposed to water-borne pathogens from animal manure through contaminated drinking water and direct contact (e.g., accidental ingestion; contact with skin, eyes and ears) with contaminated recreational waters. Eight of Iowa's thirty-seven state park beaches have been classified as "vulnerable" because of chronic bacterial contamination, some of which may be due to manure (Environmental Integrity Project, 2004, p. 12). These exposures pose greater hazards to people with compromised immune systems, infants and the elderly – nearly one-fifth of humans (Mulla, et al., 1999). Descriptions of the human health effects of CAFO-related pathogens are available online (Addis, et al., 1999; Mulla, et al., 1999; U.S. EPA, 2001).

The pathogen *Cryptosporidium parvum,* which is resistant to conventional water treatment, passed through the filtration system of one of Milwaukee's water-treatment plants in the spring of 1993, causing watery diarrhea among 403,000 people. Many residents also had abdominal cramps, fever and vomiting, with a median duration of illness of nine days. Possible sources of this outbreak, which killed 54 people, were cattle runoff from along two rivers that flow into the Milwaukee harbor, slaughterhouses and human sewage (Mac Kenzie, et al., 1994). This major outbreak of a pathogen that resists traditional water treatment underlines the importance of protecting the safety of drinking water by protecting its sources. Other, smaller scale examples of cryptosporidiosis linked to agriculture are described in Mulla et al. (1999).

Most human infections caused by *E. coli* are associated with contaminated food (e.g., beef, milk, produce), particularly beef, as cattle are the main reservoir (Elder, et al., 2000). *E. coli* infections through contaminated soil and recreational and untreated waters are also documented, especially contamination involving cattle production (Jones, 1999). *E. coli* infections from untreated or recreational waters can be serious, even life-threatening, particularly among more vulnerable populations (e.g., young children, pregnant women, elderly residents). *E. coli* O157 is particularly infectious in humans (Jones, 1999). The Centers for Disease Control and Prevention provides a useful general description of infections from *E. coli* O157:H7 (Division of Bacterial and Mycotic Diseases, 2004). A large outbreak at a New York county fair sickened over 700 people, sent 71 people to the hospital and killed two people. Likely causes were manure runoff or a dormitory septic system (U.S. EPA, 2001).

An outbreak of *E. coli* O157:H7 in Walkerton, Ontario in 2000 caused seven deaths and over 1,300 cases of gastroenteritis among people using water from the municipal water system (Bruce-Grey-Owen Sound Health Unit, 2000). Clark and colleagues (2003) provide a subsequent account of how two strains of *Campylobacter* within nearby cattle were also large contributors to this outbreak. This large-scale outbreak was caused by the combination of: the presence of *E. coli* O157:H7 and *Campylobacter* on neighboring lifestock farms, heavy rainfall and flooding; a well that was subject to surface water contamination; and an overburdened water treatment system. Following years of increasing public concern in Canada over the environmental and human health effects of cattle and swine CAFOs, the scale of the Walkerton outbreak raised awareness of possible links between GI illnesses and intensive CAFO production. Health official Dr. Paul Hasselback suggested that a "wake-up call" was sounded by the *E. coli* outbreak in Walkerton, which is located in the middle of a six-county Ontario area with intensive cattle production and generally high rates of *E. coli* infections, a combination also found in Alberta's Feedlot Alley. The CAFO-intensive Chinook region averaged 2.9 times the nation's rate for *E. coli* infections (Nikiforuk, 2000).

Three community health studies suggest that rural residents who live near CAFOs may experience greater incidence of diarrhea than those who do not live near CAFOs. North Carolina residents near a swine CAFO reported more diarrhea symptoms than did residents in an area without CAFOs or an area with cattle production (Wing & Wolf, 2000). In Utah, people living near or in Milford, a community with highly concentrated large-scale swine production, experienced more hospitalizations from diarrheal (and respiratory) problems than did residents in two similar communities without CAFOs and the state as a whole, according to hospital discharge data. Milford's diarrheal cases increased four-fold from 1992 to 1997 (Keller & Ball, 2000). Last of all, living close to a dairy in the dairy-intensive Mesilla Valley area of southern New Mexico was associated with greater reports of diarrhea among children (Arnold, 1999).

Toxins from the predator *Pfiesteria piscicida,* which is found in estuarine ecosystems in the Atlantic coast, as earlier described, may be associated with neurological, immunological and musculoskeletal symptoms in humans, including fishermen, who have had acute and chronic exposures (Burkholder & Glasgow, 1997; Silbergeld, et al., 2000). Details of these symptoms (e.g., cognitive impairment) in humans who have had direct contact with *Pfiesteria*-affected water bodies and surrounding controversies regarding the role of nutrients from CAFOs in *Pfiesteria* outbreaks are provided by Silbergeld and colleagues (2000).

Antibiotics

The increasing ability of bacterial pathogens to resist antibiotics, a growing threat to the effectiveness of traditional medical treatments, is generating concern among clinicians and public health officials (American Medical Association, 2001; American Public Health Association, 2003; Joint WHO/FAO/OIE Expert Workshop, 2003). The subtherapeutic use of antibiotics as growth promoters is of increasing concern to U.S. and international health experts because antibiotics are increasingly present in human and natural environments, and are increasing antibiotic resistance among humans (Barza & Gorbach, 2002). Inappropriate and excessive prescription of antibiotics for human disease is implicated in the growing problem of antibiotic resistance (Institute of Medicine, 1998).

The nontherapeutic use of antibiotics, especially as growth promoters, in animal production, is also increasingly implicated in the increase in antibiotic resistance (Cole et al., 1999; Joint WHO/FAO/OIE Expert Workshop, 2003; McEwan & Fedorka-Cray, 2002). The transmission of antibiotic-resistant bacteria from animals to people is documented. For example, van den Bogaard and colleagues (2001) found transfer of antibiotic-resistant *E. coli* from turkeys and broilers to turkey and broiler farmers in the Netherlands, but did not find these transfer patterns among laying-hens (which are produced with few antibiotics) and laying-hen farmers.

Many of the antibiotics in CAFOs are the same or nearly the same as those used for humans, so humans are more commonly becoming infected with bacteria that are less effectively treated with those antibiotics or similar drugs (Barza & Gorbach, 2002). Antibiotic resistance in food animals can affect the outcome of human infections by: (1) increasing the virulence of the strain, as shown in *Campylobacter* and *Salmonella*; (2) creating a reservoir of resistant traits in animal pathogens that could be transferred to human pathogens; and (3) complicating or narrowing the choice of medical treatments for humans (Barza, 2002; Travers & Barza, 2002). The effects of antibiotic resistance are of particular concern when the antibiotics (e.g., fluoroquinolones) are critically important to human medicine, that is, when they are the only treatment or one of the few available treatments for a certain disease (Joint WHO/FAO/OIE Expert Workshop, 2003).

Hormones

Excess estrogen and testosterone levels in the environment can disrupt the endocrine processes in humans and animals. Endocrine disruption has been associated with reproductive and developmental abnormalities in vertebrate and invertebrate animal species and reduced sperm counts in men (Colburn, vom Saal, & Soto, 1993).

Salts and Trace Elements

Excessive salts in drinking water require drinking water treatment to meet levels that do not pose risks for increased blood pressure among vulnerable individuals. The feed additives of zinc, arsenic, copper and selenium may pose human health hazards if they become overconcentrated in plants, animals and the environment (Sims, 1995). Silbergeld (2004) recently suggested potential public health risks from arsenic, a human carcinogen, in livestock feed and related dietary sources of arsenic exposure.

Summary of Human Health Effects of Water Quality Impairment from CAFOs

Research and public concern has focused on risks to human health from the CAFO-related environmental health hazards of nitrate contamination of groundwater and drinking water, bacterial contamination of drinking water and recreational waters, and antibiotic-resistant bacteria. Nitrates from the nitrogen in manure combine with nitrogen from other sources (e.g., fertilizers). Evidence exists of elevated nitrate concentrations in rural water bodies, rural private wells and urban water systems, including those affected by large-scale CAFOs. The shallow, private wells relied on in rural areas are particularly vulnerable to contamination. Water-borne pathogens such as *E. coli* can contaminate private and public drinking water systems and recreational waters, causing problems such as diarrheal illnesses and gastroenteritis. The risks and consequences of such problems are particularly serious for more vulnerable populations such as infants, the elderly, pregnant women and people with compromised immune systems.

Last of all, antibiotic-resistant bacteria are increasingly present in human and natural environments, including water bodies, due to overuse of antibiotics in human medicine and other human contexts and subtherapeutic use of antibiotics (e.g., as growth promoters) in CAFOs. Various forms of transmission of antibiotic resistance are seriously threatening the effectiveness of traditional antibiotic treatments, including those that are the sole treatment or one of the few treatments for a particular disease.

Socioeconomic Impacts

Some policy makers, development planners and rural residents still assume and assert that rural residents need to trade off their goals for a healthy environment for the benefits of local economic growth from CAFOS. However, many studies suggest this that is an illusory trade off. The local socioeconomic problems caused by large-scale, vertically integrated CAFOs, especially when they are highly concentrated in an area, may include local business revenue decline, property devaluation, social strife and other externalized costs (for reviews, see Flora, et al., 1999; 2002; Wright, et al., 2001). Weida's

(2001a) review of the negative regional economic effects of large feedlots includes water-related issues: manure-based pathogens, excessive water usage, lagoon seepage and costs to taxpayers of closing lagoons.

Such costs are part of the externalized costs of industrial agricultural production that involve passing the costs of environmental, health and social problems to the public (Buttel, 2003; Horrigan, Lawrence, & Walker, 2002) – in this case, particularly to the residents, businesses and governments of rural communities. Buttel (2003, p. 1656) describes externalities as "reductions in the welfare of others that are not accounted for in the price system or through compensation." He describes the growing concerns of the public and policy makers about some of the externalities of agricultural production regarding the environment, human health and animal welfare, while observing that CAFO externalities are of increasing concern.

An example of externalized costs of CAFO production is the estimated $60 million needed for remediation (i.e., the costs of removing or containing the nitrogen beneath wastewater management basins) of CAFO operations in Kansas. Estimates of remediation of some CAFOs with deep plumes of ammonium-N in sandy soils and limited access to farmland for deposition of sludge, which are not required to provide financial assurance for their closure, range from $500,000 to $650,000. These are costs for which county and/or state taxpayers are at risk if CAFOs are abandoned without adequate cleanup (Volland, et al., 2003). Sludge that may pose an environmental threat must be removed to the fullest extent practical and properly utilized, according to standards for closing waste impoundments (Natural Resources Conservation Service, 2001).

As large-scale CAFOs concentrate in an area, declines often occur in local business purchases, physical infrastructure and population (Flora, et al., 1999; Flora, et al., 2002; North Central Regional Center for Rural Development, 2000; Weida, 2002). For example, Chism and Levins (1994) found sharply decreased local farm-related expenditures as livestock operations in Minnesota communities increased in scale. Over a decade, purchases from small businesses, as measured by sales tax receipts, declined in rural communities in Illinois as the concentration of CAFOs intensified in communities (Gomez & Zhang, 2000). Large-scale CAFOs and contract feeders use animals, feed and supplies from non-local vertical integrators that purchase large volumes of feed and supplies from non-local sources. The revenue base, thereby, diminishes for local business owners, who have already experienced revenue losses as traditional family farm livestock producers have left farming or the local area (Kellogg, et al., 2000).

Several studies (e.g., Palmquist, Roka, & Vukina, 1997) have shown how the sales values of real estate and homes tend to decline with proximity to CAFOs, often dramatically with close proximity. Decreased air and water quality are part of the devaluation process. A recent study, which was conducted in north central Iowa, indicates that the negative effect of moderately sized CAFOs (i.e., with 250,000 pounds live weight) on property values are greater for properties close to CAFOs (compared to properties further from CAFOs) and downwind of CAFOs in winter (Herriges, Secchi, & Babcock, 2003). The authors suggest that the moderate size of the CAFOs that are associated with property devaluation is a proxy for their older age and greater reliance upon lagoon storage of manure.

The quality of life for neighbors of large-scale CAFOS has been shown to diminish due to odor pollution and decreases in neighborliness, social cohesion and trust (Flora, et al., 1999; North Central Regional Center for Rural Development, 2000; Wing & Wolf, 2000), along with increases in social conflict and alienation (DeLind, 1998; Frerichs, 1998). Quality of life also decreases with the loss of amenities related to the deterioration in the quality of rivers and lakes. These losses include diminished beauty and recreational use of waterways and loss of fish and wildlife (Environmental Integrity Project, 2004). These losses can become especially problematic in areas that are financially dependent upon water-based tourism.

Even in communities where water-based amenities are not on the scale that attracts tourism, smaller-scale, water-based amenities can enhance the quality of life, help maintain their working population and attract new workers. As CAFOs concentrate, these communities may find it increasingly difficult to enjoy their natural and social amenities and to use them in their population maintenance/recruitment attempts (Flora, et al., 2002). Protecting the physical, social and economic environment is essential to quality of life, economic development and population maintenance in isolated rural communities Weida (2001b; 2002).

CAFOs in North Carolina (Wing, Cole, & Grant, 2000) and Mississippi (Wilson, et al., 2002) are often sited in poor and African American rural communities, causing inequitable health and socioeconomic burdens. Health problems are intensified by reliance upon well water for drinking water and barriers to access to medical care. In North Carolina, 7.2 times as many swine CAFOS existed within the highest quintile of poverty as compared to the lowest quintile, adjusting for population density. Swine CAFOS were about five times as common in the highest three quintiles of the percentage nonwhite population as compared to the lowest quintile. The extensive flooding from Hurricane Floyd in North Carolina in 1999 caused major CAFO-related pollution that disproportionately affected African Americans who were more likely than whites to live in the flooded areas (Wing, et al., 2002). Loss of farms in North Carolina has been greater in: (1) counties with more long term and more concentrated sitings of CAFOs; (2) African American communities, regardless of income; and (3) low-income communities, regardless of race (Edwards & Ladd, 2000).

The environmental, health and socioeconomic burdens faced by rural counties that bear the externalized costs of large-scale CAFO production may be especially heavy in counties that experience diminished property tax revenues associated with large-scale CAFOs. For example, large-scale farrow to finish swine operations in Iowa generated the least net local and state government revenues per sow, compared to three smaller sizes of operations, while moderate-sized operations generated the most government revenues (Otto, Swenson, & Lawrence, cited in Kliebenstein, 1998).

Property tax policies can contribute to diminished revenues from CAFOs. The large amounts of property tax exemptions allowed CAFOS in Iowa (from the Pollution Control and Recycling property tax exemption) and implications for service reductions have been recently summarized for several Iowa counties (Jacobson & Bedford, 2003). In 2002, this exemption removed $154.2 million from county tax assessment rolls in Iowa, equivalent to approximately $5 million in unrealized tax revenue.

The results of these studies are generally consistent with the Goldschmidt (1978) tradition of research that shows how the socioeconomic health of rural communities that are dominated by large-scale, corporate agricultural production tends to be inferior to the socioeconomic health of communities in which farm family production predominates. A recent example is Peters' (2002) report of how socioeconomic indicators, especially relating to children's health, are more positive in rural Midwestern counties with greater farm proprietorship, household income and employment in education, health, information and communication services than in counties with greater employment in industrial agricultural production and meat processing.

The siting of large-scale CAFOs in rural Iowa counties may place inequitable economic, social and environmental health burdens upon such communities. Rural counties that are experiencing financial pressures face threats of additional pressures from decreased local business revenues and tax revenues, property devaluation, social strife, loss of amenities and the externalized environmental costs of large-scale CAFO production, including the ultimate costs of remediation of CAFOs (Flora, et al., 2002). The externalized costs of CAFO production relating to water quality problems are exacerbated because many of these rural residents rely upon private well water, which is particularly vulnerable to contamination (Kross, et al., 1993). In addition, many of these rural Iowa counties are medically under-served (The University of Iowa College of Public Health & Iowa Department of Public Health, 2001), which may exacerbate environmental health inequities.

Sustainable Livestock Production

Sustainable agriculture involves agricultural production, marketing and distribution systems that are environmentally sound, economically viable and socially just. *Sustainable Agriculture: Making Money, Making Sense* reviews twenty years of research on the profitability of sustainable agricultural production (Corselius, Wisniewski, & Ritchie, 2001). This research provides evidence of the economic viability of farm operations that utilize sustainable techniques such as rotational grazing, organic farming and a variety of soil/water conservation methods. Sustainable agriculture, especially when involving alternative marketing strategies (e.g., direct marketing to consumers), can provide livestock producers viable options to the economic risks and disadvantages currently faced by many contract livestock producers (e.g., Roth, 1995).

Not only can sustainable agriculture offer viable ways for independent producers and their families to successfully compete with large-scale CAFOs, it can also offer options for sustainable economic development for rural communities, as Ikerd (1998a,b) exemplifies with swine production. Ikerd (1998a, p. 289) notes in his review of research on sustainable swine production, “There is clear evidence that successful, modest-sized, family-operated hog farms contribute more to the economic and social well-being of rural communities than do their corporate counterparts.”

Alternatives to raising swine in confinement include raising them on pastures (Honeyman, 1996) during warmer months, including on rotational pastures, which help minimize nutrient pollution and soil erosion (Corselius, et al., 2001). Medium-scale producers are also raising swine in smaller hoop houses with bedding, which allows more sustainable management of manure through composting (Honeyman, Kliebenstein, & Harmon, 2001; Jackson, 1998). Sustainable livestock production, on an integrated land base, can be combined with other methods of sustainable, diversified crop production, such as crop rotation, no-till or low-till farming, and soil and water conservation (Corselius, et al., 2001; Horrigan, et al., 2002).

Sustainable livestock production offers viable ways to raise livestock, conserve and protect land and water resources, and keep farm families on the land and in their communities. Honeyman (1996) describes a model of sustainable swine production that addresses interrelated issues and the needs of producers:

- Viability for modest-sized, independent, diversified family farms
- Equitable access to information, technology, markets and genetics, including for young producers
- Emphasis on sustainability in research, producer education and demonstration priorities
- Sustainable manure management
- Enhancement of pork quality and leanness.

Sustainable livestock production may involve minimal use or no use of antibiotics and growth hormones (Horrigan, et al., 2002). For example, the Danish cattle and broiler industries voluntarily stopped the use of antibiotic growth promoters in Danish food animal production in 1998, in response to consumers' concerns over food safety (Evans & Wegener, 2003). A significant decrease in *Salmonella* was subsequently found in broilers, swine, pork and chicken meat, while no change in the prevalence of *Campylobacter* was found in broilers. The authors also note that productivity in broilers and swine has not been noticeably affected (Evans & Wegener, 2003).

Health-conscious food consumers in the United States and abroad are creating a demand for safer meat options. Food consumers in rural and urban areas are increasingly seeking ways to purchase meat that is viewed as safer in regards to antibiotics, hormones and pathogens. Fast-food places, such as McDonald's and Chipotle, and upscale restaurants are offering such meat. Direct marketing through farmers markets and internet-based marketing is increasing direct consumer access to meat raised without antiobiotics and hormones. The Iowa Department of Land Stewardship offers the *Iowa Family Farm Meats Directory* (www.agriculture.state.ia.us/meatdirectory1.htm), which is organized by counties. The *Eat Well Guide* of the Institute for Agriculture and Trade Policy and Global Resource Action Center for the Environment is an online (www.eatwellguide.org) guide to healthier, sustainably produced meat and dairy products in the U.S.

An example of institutional support for sustainable food and agriculture is the national Food and Society Program (www.foodandsociety.org) of the W.K. Kellogg Foundation. It supports programs that integrate food, agricultural, environmental and health issues and promotes sustainable local food systems. Another important state and national institution that supports sustainable agriculture, including research on sustainable livestock production (e.g., hoop houses), is the Leopold Center for Sustainable Agriculture at Iowa State University (www.leopold.iastate.edu).

Criteria for sustainable livestock production should address the socioeconomic (e.g., Flora, et al., 1999; 2002; Wright, et al., 2001) and environmental justice (e.g., Wing, et al., 2002) issues earlier discussed. Policy decisions regarding various types of livestock production and marketing should consider ways to promote the economic and social health of producers and rural communities along with promoting environmental sustainability and human health (Honeyman, 1996; Horrigan, et al., 2002).

The Executive Summary of the *Iowa Concentrated Animal Feeding Operations Air Quality Study* described benefits of more sustainable livestock production in Iowa (Iowa State University and The University of Iowa Study Group, 2002, p. 13).

> A more diverse livestock sector that was able to remain competitive and responded to increasingly differentiated consumer preferences would likely result in greater environmental (Donham, 2000), social (Wright, et al., 2001), and economic sustainability of rural areas than one dominated by large-scale CAFOs. Policies that encourage more diverse livestock/crop farms, particularly those using sustainable production systems, could also reduce the regulatory burden of the IDNR and other agencies.

Policymaking and Regulation

Political Context of the Externalities of CAFO Production

This report documents several water-related ways in which large-scale CAFOs externalize their costs, particularly in rural communities:

- Contamination of (surface, ground and drinking) water with excess nutrients, pathogens, antibiotics, etc.
- Health problems linked to impaired water quality
- Fish kills and threatened biodiversity
- Costs of remediation
- Government subsidies (e.g., property tax exemptions, federal subsidies for cheap grain)
- Declines in business and government revenues
- Property devaluation
- Diminished quality of life (social cohesion, equity, amenities).

In a discussion of the externalities of industrial agricultural production, Buttel (2003, p. 1658) identifies regulation and market incentives as the main strategies for internalizing the societal costs of agricultural production. Regulation involves "(a) use of the legislative process to develop liability and torts law, which establishes civil penalties for damages resulting from behavior that is harmful to other individuals or groups, and (b) legislative or administrative processes that result in government regulatory controls … that directly prescribe or proscribe producer behaviors and practices." Market incentives "modify the system of price signals in some significant way to encourage producers to engage in appropriate behavior."

Buttel (2003) describes how policy makers' consideration of policies to internalize the societal costs of agricultural production involves their weighing of the interests and recommendations of various groups: large-scale producers, trade groups, small- and medium-sized traditional family farmers, consumers and the general public, scientists, and activists in social movements (e.g., the environmental movement and the anti-environmental movement). Several reports document how CAFO-related policy development, including at the state level, is surrounded by the political influences of these various groups.

Furuseth (1997) describes how the rapid development of the large swine CAFO industry in North Carolina was supported by state initiatives including lax regulatory oversight, tax incentives, lack of restrictions on corporate ownership of farms, swine research programs, and minimal local government control over CAFO siting. Large-scale dairy CAFOs in Texas also developed quickly through the 1990s, supplanting traditional family dairy farms, through weak state regulations and enforcement (Water Sentinels Campaign, 2003). Kleiner and Constance (1998) describe the legislative and regulatory decisions regarding large-scale swine CAFOs in Missouri and the political resistance to CAFOs.

Similar accounts describe the political context of Iowa's policies favoring CAFO development. Frerichs (1998) details the socioeconomic changes brought to Franklin County, Iowa, by the influx of large-scale CAFOs. She describes the development of grassroots strategies to bring the concerns of CAFO neighbors to local and state policy makers. Nickles (1998) and Braun (1998) provide farmers' views of regional resistance to large-scale swine and poultry CAFOs in north-central Iowa in the 1990s and related statewide advocacy on proposals to protect Iowa's environment from risks from large-scale CAFOs. Each account describes challenges to social and economic viability and political democracy in rural Iowa as state and national policy leaders face pressures from representatives of industrial agriculture. Researchers, including those studying the environmental health effects of CAFOs, sometimes face similar political pressures from the industry, as Thu (2001) and Wing (2002) document in Iowa and North Carolina, respectively.

Enforcement of the Clean Water Act

At the national level, the main framework for regulating CAFOs in the U.S. is the federal Clean Water Act (CWA), passed in 1972, which sets the regulatory stage with its permitting, monitoring, reporting and penalty processes. The CWA (33 U.S.C. 1251(a)) was passed by Congress to "restore and maintain the chemical, physical and biological integrity of the nation's waters." The CWA includes provisions that prohibit the discharge of pollutants from a point source to U.S. waters except as authorized by a National Pollutant Discharge Elimination Permit (NPDES permit). According to the Environmental Protection Agency (EPA), CAFOs – operations that feed animals in a confined manner for at least 45 days, do not produce crops, and contain many animals (e.g., 2,500 hogs, 1,000 beef cattle) – are required to obtain a NPDES permit, in order to release pollutants into water. CAFOs are required to implement a nutrient management plan so that nutrients in manure are well utilized by cropland. Poultry CAFOs, even with dry manure handling, are now included in the new CAFO rules.

Iowa has until this spring to implement these CWA regulations, which were revised in early 2003 [(40 C.F.R. §122.23 (b) (4) (2003)]. The Iowa Department of Natural Resources (DNR) is the state agency that monitors and regulates CAFOs. The Environmental Integrity Project's (2004) recent evaluation of the Iowa CAFO regulatory framework, including past enforcement of the CWA, described several weaknesses, including with the DNR's record of implementing the CWA for CAFOs. First, the DNR is issuing NPDES permits for very few open feedlots. The DNR's penalties against violators are too low to provide deterrence or to compete with the economic benefit of violating CAFO regulatory standards. The report notes the need for more DNR resources to adequately regulate the approximately 3,500 CAFOs in the state.

In order to lessen the risks of pollution from Iowa CAFOs, the Environmental Integrity Project (2004) made several recommendations to improve the DNR's CWA permitting and enforcement activities. Among these recommendations is a proposed statewide moratorium on new construction and expansion of existing CAFOs until the DNR has the resources to regularly inspect CAFOs, issue NPDES permits as required by the CWA, and take proper enforcement actions against noncompliant CAFOs. Increased DNR funding was recommended, including through NPDES permit fees. The Environmental Integrity Project (2004) also recommended that the DNR issue NPDES permits that have strong technical standards and monitoring and reporting requirements and that the Iowa legislature should increase the DNR's penalty authority so penalties would better deter CAFOs from violating environmental standards.

An Iowa moratorium on new CAFO construction and expansion of existing CAFOs would be prudent in view of the weaknesses in Iowa's current regulation of CAFOs and in view of the possibility of Iowa becoming a more favored location for CAFOs seeking to locate in areas of weak environmental regulations in order to lower production costs (Weida, 2001b). Enactment of a moratorium on new CAFO construction in Iowa has precedent in North Carolina, the second largest swine producing state, which enacted a moratorium on new CAFO construction in 1997. This extended moratorium continues. Another precedent is the moratorium in 1984 on new pig and poultry CAFOs in the Netherlands, which included a prohibition on expansion of existing CAFOs in areas with large concentrations of CAFOs. Only limited expansion of existing pig and poultry CAFOs was allowed outside the areas of concentration. This two-year moratorium was designed to allow time for development of effective and comprehensive regulation of manure, with an emphasis on phosphate (Brussaard & Grossman, 1990).

A moratorium in Iowa would be consistent with the protection of public health, as it relates to water quality effects for rural neighbors of CAFOS and urban residents. Concern over public health effects of

CAFOs has led the American Public Health Association (2003) to call for such a moratorium: "Therefore, the American Public Health Association hereby resolves that APHA urge federal, state and local governments and public health agencies to impose a moratorium on new Concentrated Animal Feed Operations until additional scientific data on the attendant risks to public health have been collected and uncertainties resolved."

Areas of weakness in Iowa DNR regulatory practices may favor large-scale livestock production over diversified family farm operations, in a manner earlier described for states such as North Carolina (Furuseth, 1997) and Texas (Water Sentinels Project, 2003). Such policies that create disadvantages for diversified family farm operations are inconsistent with the DNR's general mission of protecting Iowa's natural resources. Diversified family farms are able to integrate small to medium scale livestock production into sustainable practices, such as crop rotations, pastures, production of hay and oats, and soil/water conservation practices such as terraces, contour strips and buffer strips (Corselius, et al., 2001). Such diversified production and conservation practices are fundamental to reducing water pollution, including CAFO-related pollution, in Iowa and elsewhere.

Regressivity in Regulations

Some researchers have discussed the benefits of targeting regulatory processes in a manner that emphasizes the risks from larger-scale CAFOs. Weida (2002) expressed the need to minimize regressivity (relative to the size of operations) in CAFO regulations, because smaller operators pay more per head in meeting standards and may have more financial difficulties in affording expensive technologies. He points out that regressivity violates the principle that a pollution tax should increase as the amount of pollution increases. He stresses the need for local control over pollution control regulatory processes. Parker and colleagues (1999) suggest that a probability-based, risk-based regulatory system would provide environmental protection from high risk operations, while benefiting those small producers who have low risk CAFOs or experience economic hardship from meeting environmental regulatory standards.

Ham and DeSutter (2000) similarly observe that a single set of state regulations may be unfair to producers with small-sized CAFOs who may not be able to absorb additional economic costs to meet "blanket" standards. They provide a framework for their recommended site-specific design standards for lagoons that consider variables such as soil properties, geology, depth to groundwater, seepage rate, and toxicity and concentration of waste. They argue that site-specific design standards would prevent overregulation of CAFOs in areas of low risk and inadequate regulation of CAFOs in areas of high risk.

Ham and DeSutter (2000) also recommend performance testing of lagoons (no sooner than six months after construction) as an integral part of a site-specific design. Such testing would reduce risks of contamination by enhancing: quality control over design and construction, performance of maintenance operations, voluntary inspections, and repair of problems. They note several reasons why monitoring wells provide limited or delayed assessments of contamination from lagoons (e.g., it can take years for contaminants to reach a monitoring well).

Antibiotics

Several professional and policy entities have adopted guidelines for the responsible use of antibiotics in animal medicine in order to reduce the threats to public health. For example, the American Medical Association (2001) adopted Resolution 508, Antimicrobial Use and Resistance, which addressed clinical use of antibiotics and stated in part, "RESOLVED, That our AMA oppose the use of antimicrobials at non-therapeutic levels in agriculture, or as pesticides or growth promoters, and urge that non-therapeutic use in animals of antimicrobials (that are also used in humans) should be terminated or phased out based on scientifically sound risk assessments; and be it further RESOLVED, That our AMA urge that increased surveillance of antimicrobial use and resistance be funded and instituted as recommended by the Institute of Medicine and American Society of Microbiology."

In December, 2002, the European Union Council of Ministers voted to phase out the use of antibiotic growth promoters in food animals, beginning in 2006. Clinical and public health organizations in the United States are working toward national legislation that would limit the use of nontherapeutic agricultural use of classes of antibiotics in order to protect the efficacy of antibiotics in treating human illness (Wallinga, 2002).

Summary of Policymaking and Regulation

Strong enforcement of the Clean Water Act in Iowa by the Iowa Department of Natural Resources is crucial to lessening the risks of water pollution from CAFOs. The DNR needs to: increase its issuance of NPDES permits as required by the Clean Water Act; incorporate strong technical standards, monitoring and reporting requirements within its permitting processes; and increase penalties for noncompliance. Local control over pollution control regulatory processes and siting decisions would increase consideration of local water quality and other issues, such as minimizing regressivity based on size of operation. A state moratorium on new CAFO construction and expansion of existing CAFOs, until the regulatory framework is strengthened, would enhance protection of Iowa's water systems "until additional scientific data on the attendant risks to public health have been collected and uncertainties resolved," as recommended by the American Public Health Association.

Limitations to the use of subtherapeutic use of antibiotics in livestock production are an essential part of protecting the efficacy of antibiotics in human and livestock medicine. Clinicians, public health officials, livestock producers and veterinarians need to continue and strengthen their collaborative efforts to protect the health of livestock, livestock producers and the general public. The phasing out of antibiotic growth promoters is occurring in Europe while protecting animal health and productivity. A similar phasing out of particular classes of antibiotic growth promoters in the U.S., especially of those that are crucial for human medicine, would represent a responsible contribution to multinational efforts to limit unnecessary use of antibiotics.

Large-scale CAFOs are being provided advantages over diversified, family farm livestock operations through public policies such as government-enforced cheap grain and related subsidies, tax exemptions, weak environmental regulatory enforcement, and weakened local control over CAFO siting. Iowa policy makers and Iowans have options to reverse policies that favor unsustainable livestock production and, instead, promote sustainable livestock production.

The historic richness of Iowa's natural heritage and leadership in agricultural production behooves Iowa to more responsibly shape a sustainable future for producers, rural communities, the environment and the general public. We have the resources, civic will and allies needed to shape livestock production in ways that emphasize sustainability through economic development, research, producer education, equitable producer-consumer relationships, and effective environmental regulation. Policies that promote sustainable livestock production in Iowa can:

- Enhance the economic viability and health of livestock producers, particularly those with moderate-sized, diversified operations
- Strengthen the economic and social well-being of rural communities and the state
- Respond to increasing demands from domestic and global consumers for safer, healthier meat options
- Restore and protect water quality, soil health and the general environment.

Glossary and Acronyms

AFO – animal feeding operation

Ammonium – a water soluble form of nitrogen (NH_4) that is produced when microorganisms decompose organic nitrogen products in aerobic or anaerobic environments

Aerobic – with free or dissolved oxygen

Anaerobic – without free or dissolved oxygen

Bacteria[1] – a group of universally distributed, rigid, essentially unicellular procaryotic microorganisms. Bacteria usually appear as spheroid, rod-like or curved entities, but occasionally appear as sheets, chains, or branched filaments.

CAFO – concentrated or confined animal feeding operation in which large numbers of agricultural animals are raised in buildings or large feedlots

CFR – Code of Federal Regulations

Coliform-group bacteria[1] – a group of long-living bacteria predominantly inhabiting the intestines of warm blooded animals, but also found in soil. It includes all aerobic and facultative anaerobic, gram-negative, nonspore-forming bacilli that ferment lactose with production of gas. This group of "total" coliforms include *escherichia coli* which is considered the typical form of fecal origin. The fecal coliforms are often used as an indicator of the potential presence of pathogenic organisms.

Concentration – the trend of increased monopolization and vertical and horizontal integration of production, processing and marketing of goods and services by fewer and fewer corporations, including at national and transnational levels

Contract feeding[2] – a method of livestock production in which companies provide farmers with young animals, feed, medications, etc., and the farmers provide the building, equipment, and labor, while receiving a set amount per pound or head and absorbing many of the risks of production

CWA – Clean Water Act, passed by Congress to restore and maintain the quality and integrity of the nation's water, including by prohibiting the discharge of pollutants from a point source except as authorized by a National Pollutant Discharge Elimination System permit

Diversified operations[2] – farms that produce a variety of grains and livestock in ways (e.g., crop rotation) that promote environmental sustainability

EPA – Environmental Protection Agency

Escherichia coli, E. coli [3] – one of the species of coliform bacteria in the intestinal tract of warm-blooded animals. Its presence may indicate fresh fecal contamination.

Eutrophication[1] – process by which excessive concentrations of phosphate and nitrogen enter the environment and upset the balance of water and soil ecosystems and diminish the quality of drinking water

Externalization of costs[2] – political and economic processes by which publicly unacceptable (e.g., polluting) aspects of manufacturing or production are directly or indirectly paid by the public, rather than by the manufacturer, such as through hiding or ignoring costs, passing costs along to consumers, or receiving public subsidies

Facultative bacteria[4] – bacteria that can grow in the presence or absence of oxygen

Groundwater[5] – that portion of the water below the surface of the ground at a pressure equal to or greater than atmospheric pressure

Health[6] – a state of complete physical, social and mental and social well-being and not merely the absence of disease or infirmity

Industrialized agriculture – large-scale, highly capitalized agricultural production with emphasis on monoculture production and market concentration, external management and labor; tends to favor corporate production over family farm production

Lagoon[3] – an earthen facility for the biological treatment of wastewater. It can be aerobic, artificially aerated, anaerobic or facultative depending on the loading rate, design and type of organisms present.

Land application[3] – application of manure, sewage sludge, municipal wastewater and industrial wastes to land either for disposal or for utilization of the fertilizer nutrients, organic matter, and improvement of soil tilth

Manure[3] – the fecal and urinary excretion of livestock and poultry. Often referred to as livestock waste. This material may also contain bedding, spilled feed, water or soil. It may also include wastes not associated with livestock excreta, such as milking center wastewater, contaminated milk, hair, feathers, or other debris. Manure may be described in different categories as related to solids and moisture content. These categories are related to handling equipment and storage types.

Methemoglobinemia[4] – illness caused by high levels of nitrate in drinking water, above about 45 ppm, to which infants are particularly susceptible

NH_3 – ammonia

Nonpoint source pollution[7] – Nonpoint source pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. Nonpoint source pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rives, wetlands, coastal waters and even our underground sources of drinking water. In rural areas these pollutants include bacteria and nutrients from livestock, soil sediments, fertilizers, herbicides and insecticides.

NRCS – Natural Resources Conservation Service of the USDA

Nutrient pollution[4] – contamination by excessive inputs of nutrient: a primary cause of eutrophication of surface waters, in which excess nutrients, usually nitrogen or phosphorus, stimulate algal growth

Point source pollution – pollution from a particular source

Pollutant[4] – a contaminant that adversely alters the physical, chemical, or biological properties of the environment.

Regulation[4] – a requirement or rule passed by an agency or department of federal, state, or local government that is authorized to create and enforce a requirement or rule through an authorizing statute or constitutional authority

Restructuring (agricultural restructuring)[9] – changes in the relationships among ownership, management and labor in the agriculture-food system, with particular emphasis on the production component. Restructuring generally involves technological changes (including shifts in levels of specialization/diversification) as cause or effect, and may include changes in vertical and horizontal integration or coordination, in ownership of resources (including tenancy and leasing), in farm/firm size, in geographic location of specific agri-food activities, in composition of the work force, and in levels of concentration at various levels in the supply chain.

Runoff[8] – occurs when input of water exceeds infiltration. Pesticide runoff includes losses from the dissolved and sediment-absorbed pesticide. Though runoff generally results directly in the contamination of surface water, it can also contribute to ground water contamination through recharging ground water by the surface water.

Trace elements[1] – chemical elements (such as copper, zinc) present in minute quantities in plant or animal tissues and considered essential to these organisms' physiological processes. An overdose, however, is harmful for the organism. Non-essential trace elements such as cadmium are harmful even in very low concentrations.

Turbidity – presence of suspended matter

USDA – United States Department of Agriculture; federal agency that oversees programs regarding agricultural production, conservation, food and rural development

Vertical integration - the production/distribution of goods and services in a manner that is coordinated through common ownership and management in at least two stages of production/distribution

Volatilization – the process by which ammonia converts to ammonia gas and is released into the atmosphere

[1] Glossary, Ministry of Agriculture, Nature Management and Fisheries, PO Box 20,401, 2500 EK, the Hague, The Netherlands.

[2] Hodne, C. J. (2001). *Glossary for Farm Advocates and Health and Mental Health Professionals.* Iowa City, IA.

[3] *Uniform Terminology for Rural Water Management.* (2000). ASAE S292.5, December 1999. American Society of Agricultural Engineers, ASAE Standards.

[4] Wefering, F., & Zering, K. *Glossary,* unpublished Internet document, Department of Agricultural and Resource Economics, North Carolina State University, Raleigh.

[5] Soil Science Society of America. (1997). Internet Glossary of Soil Science Terms, http://www.soils.org/sssagloss/.

[6] World Health Organization, Constitution. (1948). Health Promotion Glossary, Section I.: List of Basic Terms; WHO, 1998, Division of Health Promotion, Education and Communications; Health Education and Health Promotion Unit; WHO/HPR/HEP/98.1. http://www.who.int/hpr/archive/docs/glossary.pdf.

[7] http://www.epa.gov/owow/nps/qa.html; from EPA's Polluted brochure EPA-841-F-94-005. (1994).

[8] Honeycutt, R. C., & Schabacker, D. J. (Eds.) (1994). *Mechanisms of Pesticide Movement into Groundwater* (p. 5). Boca Raton, FL: CRC Press.

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