PCIFAP Staff Summary of Occupational and Community Public Health Impacts

The Pew Commission on Industrial Farm Animal Production was established by a grant from the Pew Charitable Trusts to the Johns Hopkins University Bloomberg School of Public Health. The two year charge to the Commission was to study the public health, environmental, animal welfare and rural community problems created by concentrated animal feeding operations and to recommend solutions.

Bearing in mind that the World Health Organization defines health as “a state of complete physical, mental and social well being” (WHO 1992), the Commission set out to access the public health impacts of IFAP. This report advises the Commission on the direct health impacts of IFAP on workers in the facilities, neighbors of and communities surrounding IFAP facilities, and the public at large. It is not, however a comprehensive assessment. The important public health issue of antimicrobial resistance is addressed in the report entitled “Industrial Farm Animal Production, Antimicrobial Resistance and Human Health.” Similarly, this report is not intended to be a detailed assessment of the environmental impacts of livestock waste which is the topic of the report on “Environmental Issues Related to Industrial Food Animal Production.” Finally, while this report cites a number of community impacts, their associated economic and social factors are covered in two other reports, “An Economic Analysis of the Social Costs of the Industrialized Production of Pork in the United States” and “Community and Social Impacts of Concentrated Animal Feeding Operations.” All of these technical reports can be found at www.ncifap.org/reports/.

It is also important to understand that this Pew Commission technical report is limited to public health impacts that were judged to arise directly from industrial farm animal production. As a result, the public health impacts of downstream meat processing as they may affect production workers, distributors or the public are not the subject of either the Pew Commission Final Report or this technical report. Also, any association between industrial farm animal production as it relates to an important source of dietary protein and cancer and cardiovascular disease is beyond the scope of these reports.

By releasing this technical report, the Commission acknowledges that the authors fulfilled the request of the Commission on the topics reviewed. The consensus position of the Pew Commission on Industrial Farm Animal Production, “Putting Meat on The Table: Industrial Farm Animal Production in America,” may also be found at www.ncifap.org/reports/.

OCCUPATIONAL AND COMMUNITY PUBLIC HEALTH IMPACTS

A. INTRODUCTION

The impact of industrial farm animal production on human health implies more than an assessment of any disease, injury or impairment that may arise from exposure to livestock, livestock products or livestock production waste streams. Rather, health is defined by the World Health Organization as "a state of complete physical, mental and social well being" (WHO (World Health Organisation), 1992). This definition is widely recognized in the developed world and is increasingly being adopted by American employers as they describe and seek to enhance the health, productivity and well-being of their employees. The WHO standard can also apply to those who live in communities proximate to the industrial production of livestock, recognized by the federal government as a CAFO (concentrated animal feeding operation) based on federally defined animal units (http://cfpub.epa.gov/npdes/afo/cafofinalrule.cfm). While such a definition is useful in partitioning "industrial" production of livestock from "agricultural" production of livestock, that distinction does not necessarily imply greater or lesser health risk since adverse exposures can arise from traditional agricultural as well as intensive industrial operations.

B. POPULATIONS AT RISK

The populations at risk in industrial farm animal production are impossible to define with precision. They include farmers, farm workers and farm worker family members including many women and children who commonly work in agricultural livestock production, but typically not in intensive industrial farm animal production. Also engaged in the breeding and rearing of livestock are animal breeders; veterinarians; feed suppliers and distributors; those engaged in the sale and distribution of feed additives, growth promotion agents and antimicrobials (including antibiotics); construction and maintenance workers; agricultural and environmental extension agents and inspectors; and numerous others. Adding to the imprecision in defining the occupations directly or indirectly exposed to livestock operations is the engagement of migrant or visiting workers, some of whom are not documented workers. Further imprecision arises from the relatively rapid turnover of workers who typically earn low wages and have no health insurance coverage and who often move on to better paying jobs with benefits as soon as possible. Therefore, any census of workers in this industry is a snapshot rather than a characterization of a stable workforce more typically found in the manufacturing sector.

Another difficulty in defining the population at risk is the wide variability in occupational exposures. Those engaged directly with livestock production have more frequent and more concentrated exposures to chemical or infectious agents than those tangentially exposed, or bystander exposures. Thus, there is wide variation in the level of occupational exposure risks among the types of livestock-exposed workers. Finally, defining risk by systematic exposure or health monitoring is usually not possible because neither employers nor state or federal agencies systematically monitor industrial farm animal production; much of that production is defined by state and OSHA federal law as "agricultural" which exempts smaller producers from industrial exposure monitoring, inspection and injury-disease reporting and surveillance (OSHA, 1998).

Similar difficulties are encountered when one seeks to define populations at risk in communities proximate to CAFO operations and identify which residents may be exposed to air emissions arising from livestock production. Such exposures are dependent on emissions at the source (the CAFO operation itself), and also on distribution of manure arising from CAFO production.

Ambient exposures to CAFO emissions are also dependent on interactions among the many chemical agents in CAFO emissions, meteorologic conditions, the concentration of CAFOs in a given area and movement of the human population through a gradient of exposure over time, all of which will determine dose.

It is also recognized that community-based populations include a substantial number of individuals who are impaired and may therefore be at greater risk to any CAFO exposure, whether it is airborne or waterborne and whether chemical or infectious in nature. Communities include both children and the elderly who are known to have a higher incidence of asthma and who are less mobile and therefore less able to select themselves away from, for instance, prevailing winds carrying air emissions from a CAFO or CAFOs. Communities also include those with pre-existing conditions such as chronic obstructive pulmonary disease, asthma and heart disease—all known to have heightened morbidity and, with very high exposures, heightened mortality associated with air pollutants (National Research Council, 1985; Peters *et al*, 1999). Populations at risk from contaminated water may extend a significant distance from the source of contamination depending upon whether drinking water is taken from a shallow well or a contaminated aquifer. Populations exposed to infectious agents arising in CAFOs are even more difficult to define as some agents, such as a novel avian influenza virus, may be highly transmissible in or well beyond a community setting, or an infectious agent that originated at a CAFO may pass through meat processing and into a consumer meat product resulting in a serious infectious disease far from the CAFO. With current limited animal identification and meat product labeling practices, such infections are often difficult or impossible to trace to the source.

More precise definitions of populations at risk are therefore dependent on a multitude of factors but would be greatly advanced by systematic animal and worker identification and surveillance systems, and enhanced occupational and environmental monitoring. Linkage of these two forms of surveillance would allow human health effects arising from CAFOs to be more clearly linked to specific exposures.

C. OCCUPATIONAL IMPACTS OF FARM ANIMAL PRODUCTION

C.1. Farm and Industrial Sectors

It is important to understand the evolving structure of US agricultural enterprises and the terminology that describes the demographics of the agricultural work force. The work force that sustains the agricultural operations of approximately 2 million US farms (Bureau, 2005) includes principal operators, also called owner-operators; non-wage-earning family members; and wage-earning employees or farm workers (indigenous and foreign-born nationals). In addition, large industrial farms employ farm managers, and like larger family farms, may hire workers either full time or as seasonal labor. The majority of the agricultural work force across industrialized countries is involved in family-style operations, which include a principal operator who is also the owner-operator, and non-wage-earning family members. The key feature of these family operations is that residence, ownership, management, and any hired labor are all unified. Another type of agricultural enterprise—niche farming—is a newer variant of the traditional family farm operation. These operations produce and market products (e.g. organic foods, exotic food crops and livestock) to small, often localized markets not met by the traditional family or industrial operations.

Approximately 80% of the principal operators of family farms in developed countries are men although women principal operators have been increasing in both North America and Europe. Nearly 25% of farms in the U.S. are operated by women. The average age (in 1997) of the male principal operators in the US was 54 years, with a trend toward increasing age (Bureau, 2005). Over 95% of the family farm work force in the US is Caucasian, primarily of Northern European descent. About 1.5% of the principal farm operators are of Hispanic origin, 1% are black, and an additional 1% include Native American Indians, and Asian or Pacific Islanders. Over 70% of the principal operators live on their farm (Bureau, 2005; USDA Agricultural Statistics, 2004). Both men (30-50%) and women (45-60%) on US family farms have additional employment off the farm (US Department of Labor, 2002-2003), a trend that has increased over the past three decades in all industrialized countries as profit margins have decreased.

Global economic forces have created stresses on the traditional family farm operation, causing a decline in their numbers that began in the 1940s. Meanwhile, the component of large industrial-style operations has grown (and has grown more rapidly in the US than in other industrialized countries). Whether industrial operations or large family corporations, these farming operations are typically less diversified than family farms. They take on the general structure and work organization of an industry, emphasizing high productivity based on routine and tightly managed work processes. Hired labor is essential, and labor and management are separated (as are often the farm and residence). They may rely on funds from stock holders or venture capitalists to start up or expand operations. Some operations are connected to large, multinational, vertically integrated food conglomerates. Although these large industrial operations make up less than 5%

of the total farms, they contribute about 50% of total US commodity production (US Department of Labor, 2002-2003).

The industrial farm employs the majority of hired farm workers. These workers may come from the local area or foreign countries. Generally speaking, in the US indigenous farm workers, such as the farm youth who work seasonally or part-time on another farm, make up about 25% of the farm worker population (U.S. Department of Labor). US farm operators hire (at some time during a year) about 2.5 million documented foreign-born migrant and seasonal workers, the highest among industrialized countries (ILO, 2004). In North America, these workers make up nearly a quarter of the agricultural work force. They are largely Hispanics from Mexico, although Central and South America contribute workers as well as Bosnia, Asia, Africa, and the Caribbean Islands. Undocumented worker numbers, while not known, may be as many as an additional 2.5 million. US Department of Labor statistics (2002-2003) indicate that 30% of US farmers hire one or more employees, but just over 8% of the farms hire more than 10 employees. The latter figure is significant because Federal worker protection laws apply only to those farms with more than 10 employees (OSHA, 1998).

C.2. Occupational Environmental Exposures

Confined Animal Feeding Operations (CAFOs) are animal production systems that include facilities for ventilation, heating, feed preparation and delivery, and disposal of animal wastes (Donham, 1991). CAFOs began with poultry production in the late 1950s, and swine CAFOs began to appear in the late 1960s. This system of production began to rapidly proliferate in the last half of the 1980s (Donham, 1993). CAFOs may be open feedlots or totally enclosed buildings, the latter being more of a concern from an occupational health standpoint. CAFOs in North America are concentrated in North Carolina in the East, most states of the Midwest, and in the West including in Oklahoma, Texas, Colorado, and Utah. Poultry CAFOs (including turkey, broiler and egg production) are concentrated in the East-Central, Southeast, Midwest, and Western US. Other types of CAFOs (beef, dairy, veal), not as common as swine and poultry, are located in regions where principal feedstuffs such as corn and wheat are grown.

Toxic dusts and gases in confinement houses. CAFO dust is a complex mixture of potentially hazardous agents that is generated primarily from the animals (hair and dander), dried feces, and feed (Donham and Gustafson, 1982; Donham *et al*, 1985 (a); Nilsson, 1984). In addition to the dust, gases are generated inside the building from decomposition of animal urine and feces (ammonia, hydrogen sulfide and methane among others) (Donham and Gustafson, 1982; Donham and Popendorf, 1985; Donham *et al*, 1995). Furthermore, fossil fuel–burning heaters that may be used inside the buildings can emit carbon dioxide and carbon monoxide that may add additional risks for workers. Toxic gases in these facilities can rise to concentrations that may be acutely hazardous to human and animal health (Donham and Gustafson, 1982). The mixture and concentrations of dusts and gases inside CAFOs vary depending on numerous factors including management practices; ventilation and other engineering controls; the age, number, and type of animals in the building; and the design and management of the feeding and waste handling systems. Dust and gas concentrations and composition also vary over time relative to the season of the year.

Concentrations of dust, endotoxin, as well as H_2S, CO_2, and CO, may all exceed safe levels. The more toxic nature of this dust is related to the high degree of its biological activity, inflammatory in nature, resulting in additive and synergistic health impacts of the mixed dust and gas exposures. Safety levels of dust and gas concentrations in CAFOs, however, are considerably lower than levels set for industrial standards. Table 4.1 compares recommended maximum exposure concentrations from current research to levels set by OSHA and ACGIH (ACGIH, 1985; OSHA, 2006).

Table 4.1 Comparison of OSHA and ACGIH TLVs to Recommended Exposure Limits to Toxic Dusts and Gases Based on Current Research.

Toxic Substance	Current Research Recommendations for CAFOs	Typical Findings In CAFOs	ACGIH[1]	OSHA[2]
Total Dust	2.5 mg/m^3	3-6 mg/m^3	4 mg/m^3	15 mg/m^3
Respirable Dust	0.23 mg/m^3	0.5-1.5 mg/m^3	——	——
Ammonia	7 ppm	5-15 ppm	25 ppm	50 ppm
Hydrogen Sulfide	——	0.5-5 ppm	10 ppm	10 ppm
Carbon Dioxide	1,500 ppm	1,000-4,000 ppm	5,000 ppm	5,000 ppm
Endotoxin	100 EU	50-1,000 EU	——	——

Source: ACGIH 1985; OSHA 2006.

Dust particles in CAFOs contain approximately 25% protein, and range in size from less than 2µ to 50µ in diameter (Donham *et al*, 1985 (a); Donham *et al*, 1985 (b)). One-third of the particles are within the respirable size range (less than 10µ in diameter) (Donham *et al*, 1985 (a); Nilsson, 1984). Fecal material particles are quite small (≤ 10µ) relative to other dust components, and consist of high concentrations of gut-flora bacteria and exfoliated gut epithelium. This component of the dust deposits in small airways, and possibly in alveoli. Larger particles are mainly of feed grain origin, and primarily impact the upper airways. Also present are animal dander, broken bits of hair, bacteria, endotoxins, pollen grains, insect parts, and fungal spores (Donham, 1986; Donham *et al*, 1985 (a)). In recent years, researchers have focused on the microbial by-products contained in this dust as the primary hazardous substances. Endotoxin, and (1→3) β-D-glucan, well-known inflammatory mediators, originate respectively from the cell wall of gram-negative bacteria and from certain yeasts, molds, and bacteria. The dust adsorbs NH_3 and possibly other toxic or irritating gases, adding to the potential hazards of the inhaled particles (Do Pico, 1986; Donham and Gustafson, 1982; Donham *et al*, 1982 (b); Sigurdarson *et al*, 2004 (b)). Dust combined with ammonia results in 2-4 times the extent of cross-shift decline in pulmonary function compared to a single exposure of dust or ammonia (Donham *et al*, 2002).

Worker exposure to dusts and gases. Workers' risk of chronic respiratory health effects in CAFO buildings is related to several factors, including other respiratory exposures such as smoking; the extent of the concentrations of dusts, endotoxin and ammonia; and the length of time the person has worked in the buildings. Those who have worked more than two hours daily and for six or more years are at greatest risk of respiratory impairment (Donham *et al*, 2000; Donham and Gustafson, 1982; Donham *et al*, 1977). Owners and managers, hired hands, and family members of traditional family-owned CAFOs may work in the houses anywhere from a few hours a week to eight or more hours daily. However, as livestock production has become more specialized, workers may spend 40 or more hours per week in the building. The very large facilities are using hired workers, and increasingly, new immigrant workers. There is rapid turnover among these workers, and it is rare to find one who has worked more than two or three years in the buildings.

Hydrogen sulfide has been found to be an acute hazard arising from first-generation CAFOs with liquid manure pits (Donham *et al*, 1982 (b); Osbern and Crapo, 1981). During agitation, H_2S can be released rapidly, soaring from usual ambient levels of less than 5 ppm to lethal levels of over 500 ppm within seconds (Donham *et al*, 1982 (b); Donham *et al*, 1988).

C.3. Occupational Zoonotic Exposures

While modern animal husbandry's economies of scale have increased meat production and decreased costs, the resultant high animal stock densities have also amplified opportunities for zoonotic pathogen transmission to humans. This increased risk is due to at least three factors: prolonged worker contact with animals, increased pathogen transmission within a herd or flock, and increased opportunities for the generation of novel viruses.

Prolonged contact with animals. Fifty years ago a US farmer who raised pigs or chickens might be exposed to several dozen animals for less than an hour a day. Today, while there are many fewer animal agricultural workers, these workers have much more intense and prolonged animal exposures. A modern confinement facility worker is often exposed to thousands of pigs or hundreds of thousands of chickens for 8 or more hours each day. While sick or dying pigs might have been a relatively rare exposure event 50 years ago, today's agricultural workers care for sick or dying animals daily in their routine care of much larger herds and flocks. This prolonged contact with livestock, both healthy and ill, increases agricultural workers' risks of infection with zoonotic pathogens.

Increased or endemic pathogen transmission. Fifty years ago a farmer might occasionally see his flock or herd suffer from a disease with the potential to infect humans, but such outbreaks were generally short-lived. The outbreak quickly burned out as the susceptible animals were relatively few. Today, many large industrial CAFOs segregate animals by age and have a near constant influx of young, immunologically naïve animals. This continuous supply of susceptible animals, combined with the inadvertent movement of pathogens from barn to barn on equipment, shoes, and clothing, sustains transmission of some animal pathogens and allows them to become endemic in large facilities. For instance, years ago swine influenza was a seasonal disease among pigs. Today, due to partial immunity through swine influenza vaccinations, adaptation of the virus to pigs, and continual transmission among pigs in large facilities, swine influenza infections are often detected year-round. Similarly, porcine reproductive and respiratory syndrome virus and porcine circovirus have also become endemic in large facilities. This nearly constant transmission of animal pathogens increases the agricultural workers' risk of infection.

Generation of novel viruses. While transmission of avian or swine influenza viruses to humans seems a rather infrequent event today ((Gray *et al*, 2007; Myers *et al*, 2007a), the continual cycling of swine influenza viruses and other animal pathogens in large herds or flocks provides increased opportunity for the generation of novel viruses through mutation or recombinant events that could result in more efficient human-to-human transmission of these viruses. In addition, agricultural workers serve as a bridging population between their communities and the animals in large confinement facilities. This bridging increases the risk of novel virus generation in that human viruses may enter the herds or flocks and adapt to the animals. Reassortant influenza viruses with human components have ravaged the modern swine industry (Karasin *et al*, 2006; Olsen *et al*, 2000). Such novel viruses not only put the workers and animals at risk of infections, but also potentially increase zoonotic disease transmission risk to the communities where the workers live. For instance, 64% of 63 persons exposed to humans infected with H7N7 avian influenza virus had serological evidence of H7N7 infection following the 2003 Netherlands avian influenza outbreak in poultry (Meijer *et al*, 2006). Similarly, the spouses of swine workers who had no direct contact with pigs had increased odds of antibodies against swine influenza virus compared to non-exposed university workers and students, suggesting swine influenza virus transmission in the home (Gray *et al*, 2007b). Recent modeling work has shown that among communities where a large number of CAFO workers live, there is great potential for these workers to accelerate pandemic influenza virus transmission (Saenz *et al*, 2006).

Bovine spongiform encephalopathy. The problem of bovine spongiform encephalopathy (BSE) is important because of the predictable impact of even a small cluster of cases on the beef industry. Animal feeds often contain “rendered” animal protein that is not suitable for human consumption. When such protein contain prions, animal-to-animal transmission is possible. Such transmission is not exclusive to concentrated animal feeding operations. Any cow that ingests contaminated feed has the possibility of acquiring BSE. In addition there is the possibility that animal feeds prepared for one species may contaminate the feed of other species, influencing transmission. For example animal feeds from rendered cattle may be fed to chickens, and poultry feed waste infused into cattle feed thus indirectly facilitating cow-to-cow transmission. In addition, the large numbers of animals that could be fed contaminated feed in a short time period, and the speed with which animals and animal products are brought from farm to fork, make surveillance and containment more difficult.

BSE is a 100% fatal neurodegenerative disease in cattle. Its symptoms include tremor, paranoia and other physical and psychological deterioration (DeArmond and Prusiner, 2003). BSE, and other transmissible spongiform encephalopathies (TSEs), are caused by accumulation of a misfolded form of the prion protein (PrP^C) in the central nervous system (CNS) (Prusiner, 1982), resulting in neurodegeneration (Chesebro, 1999; Prusiner, 1998).

D. OCCUPATIONAL HEALTH EFFECTS

D.1. Health Impacts

Human health effects of work in swine CAFOs were first described in veterinarians in 1977 (Donham *et al*, 1977); since that time, numerous studies have been published by many authors around the world regarding the health of CAFO workers. Even with improvements in the engineering of these buildings over the subsequent 30 years, CAFO-exposed workers still experience a complex of agricultural dust–related respiratory conditions (Andersen *et al*, 2004).

CAFO workers experience the same type of symptoms as grain handlers, including acute and chronic bronchitis, non-allergic asthma-like syndrome, mucous membrane irritation, and non-infectious sinusitis. An individual's specific response depends on characteristics of the inhaled bioaerosol (such as particulate size, endotoxin, ammonia, and total inhaled mass) and on the individual's susceptibility, which is moderated by coexisting factors (including atopic status, relative genetic sensitivity to endotoxin, length and concentration of exposure, and smoking history). The most common respiratory symptoms (cough, sputum production, chest tightness, shortness of breath, wheezing) are manifestations of airways disease, composed of bronchitis (dry cough or cough with phlegm) that is often associated with increased airway hyper-responsiveness. Chest tightness, coughing, nasal, and eye irritation symptoms have been experienced in some persons within 30 minutes of entering these houses for the first time (Dosman *et al*, 2006).

Evidence suggests that those chronically exposed develop heightened airway responsiveness to the confinement environment with increasing exposure (greater than two hours per day and six years work experience) (Donham and Gustafson, 1982; Donham *et al*, 1989). In general, the symptoms are more frequent and severe among smokers (Mustajabegovic *et al*, 2001; Palmberg *et al*, 2002; Rylander and Carvalheiro, 2006) and among those working in larger swine operations (related to longer hours working inside CAFO buildings) or working in buildings with high levels of dusts and gases (Donham *et al*, 2000; Donham *et al*, 1995; Reynolds *et al*, 1996).

Chronic airways effects manifest as chronic bronchitis with or without obstruction, and are experienced by about 25% of all swine CAFO workers. This is the most common clinical finding of this occupational group, and is typically observed two to three times more frequently compared to farmers who work in non-confinement swine housing units or in agricultural operations other than swine or poultry production (Donham, 1990). Symptoms include chronic cough, with excess production of phlegm and sometimes chronic wheezing and chest tightness. Smokers experience a greater prevalence and severity of chronic bronchitis than nonsmokers.

Although fixed airways obstruction has not been a consistentfinding among CAFO workers, there is objective evidence of obstructive lung disease (Chaudemanche *et al*, 2003; Jenkins *et al*, 2005; Monso *et al*, 2004). Lavage studies of bronchial fluids show a persistent leukocytosis, and sputum studies show persistent inflammatory cells, and epithelial cells (Djuricic *et al*, 2001; Schwartz *et al*, 1990). While pre-shift FVC and FEV1 may be preserved, flow rates at 25%-75% of lung volume (FEF_{25-75}) are typically significantly reduced (Donham, 1990; Palmberg *et al*, 2002). Work shifts decrements in lung function, as measured in volumes (FEV1), and flow rates (FEF 25 - 75) are also predictive of an accelerated annual decline in pulmonary function (Schwartz *et al*, 1995; Senthilselvan *et al*, 1997). A longitudinal study has shown a decline in lung function with increasing evidence of obstruction over the years in cohorts of CAFO workers (Eckert, 1997) which confirms that chronic obstructive pulmonary disease occurs among CAFO workers (Schwartz *et al*, 1995).

Although dust exposure is the most common hazardous exposure in CAFOs, the most dramatic acute response results from exposure to hydrogen sulfide (H_2S). At moderately high concentrations (100-400 ppm), the irritating properties of H_2S produce rhinitis, cough, dyspnea, tracheobronchitis, bronchitis, and possibly pulmonary edema; at higher concentrations (400-1500 ppm), H_2S results in loss of smell, respiratory paralysis, pulmonary edema, and death. Often multiple deaths occur during exposure events, as would-be rescuers become victims (Fuller and Suruda, 2000).

D.2. Zoonotic Diseases Among Agricultural Workers

While CAFO facilities are the subject of this report, not only workers who have contact with CAFO animals are at risk of zoonotic pathogens that circulate in CAFO facilities. Veterinarians and abattoir workers, who may not enter a CAFO facility, are potentially at increased risk of a number of clinical and subclinical zoonotic pathogen infections as well. Apart from direct animal contact, there is potential for pathogens endemic to CAFOs to impact the health of persons in nearby communities through contaminated water sources, air pollution, contact with slurry, contact with hides or feces, and vector or fomite transmission.

Relatively few research studies have examined CAFO workers for evidence of zoonotic pathogen infection. This is not surprising as there are multiple barriers to gaining the cooperation of such workers before enrolling them in such a study. Barriers include the concerns of CAFO management that studies of workers might harm CAFO business practices, as well as language and cultural barriers among immigrant workers. Farm workers who care for swine have been studied for evidence of previous swine influenza virus infections and when compared to swine veterinarians, the farmers were more likely to have elevated antibodies (Myers *et al*, 2006). Hence, a review of evidence for zoonotic infections among veterinarians may shed light on the risk for CAFO workers. Such a review of the medical literature suggests that CAFO workers have an increased risk for hepatitis E, Q fever, brucellosis, zoonotic influenza A, toxoplasmosis, and norovirus infections (Table 4.2.).

Table 4.2. Serological Evidence Of Zoonotic Pathogen Infection Among Veterinarians.

Pathogen	Species	Veterinariary Professionals	Controls	References
Hepatitis E virus	human	26.4%	18.3%	Meng 2002
		33.3%	23.3%	Yan 2007
		11.0%	2.0%	Bouwknegt 2007
	swine	23.1%	16.5%	Meng 2002
Coxiella burnetii		12.9%	5.6%	Macellaro 1993
		10.5%	n/a	Valencia 2000
		9.5%	n/a	Nowotny 1997
		13.5%	3.6%	Abe 2001

Brucella spp.		4.5%	n/a	Omer 2002
		33.0%	5.0%	Ergonul 2006
		28.6%	n/a	Kumar 1997
		17.4%	2.6%	Thakur 2002
		8.2%	0.5%	Abo-Shehada 1996
	B. abortus	4.2%	0.0%	Lee 2007
	B. canis	41.2%	1.0%	Agasthya 2007
Influenza A virus	Swine H1N1	8.8%	n/a	Myers 2007
	Avian H5	12.2%	0.0%	
	Avian H6	23.8%	0.3%	
	Avian H7	14.6%	0.0%	
Toxoplasma gondi		54.7%	n/a	Nowotny 1997
		53.0%	n/a	Juncker-Voss 2004
Norovirus		28.0%	20.0%	Widdowson 2005
Chlamydia psittaci		8.8%	1.7%	Yan 2000

Source: (Abe *et al*, 2001; Abo-Shehada *et al*, 1996; Agasthya *et al*, 2007; Bouwknegt *et al*, 2007a; Ergonul *et al*, 2006; Juncker-Voss *et al*, 2004; Kumar *et al*, 1997; Lee *et al*, 2007; Macellaro *et al*, 1993; Meng *et al*, 2002; Myers *et al*, 2007b; Omer *et al*, 2002; Thakur and Thapliyal, 2002; Valencia *et al*, 2000; Widdowson *et al*, 2005; Yan *et al*, 2000; Yan *et al*, 2007).

Diseases associated with livestock occupations. While more than 200 animal pathogens have been shown to infect humans, it seems appropriate to review some of the most commonly recognized zoonoses and their association with animal production. While many of these diseases are relatively rare in their association with modern livestock operations, direct contact with livestock has historically been identified as a risk factor for all. Much of the following data are summarized from two recent excellent reviews (Cole *et al*, 1999; Weber and Rutala, 1999).

Brucellosis – A number of *brucella* species reside in livestock and cause disease in man. Abattoir workers, meat inspectors, animal handlers, veterinarians, and laboratorians are particularly at risk. Symptoms among the infected are often nonspecific and include influenza-like-illness, fever, sweats, malaise, anorexia, headache, myalgia, and back pain. Infections may become chronic and involve arthritis, depression, and neurologic symptoms. These bacteria may be transmitted through open wounds or aerosol. The vast majority of US herds are now free from this pathogen.

Psittacosis – *Chlamydia psittaci* only rarely causes zoonotic infection in the United States. Symptoms include fever, chills, headache, muscle aches, and a dry cough. Patients may also develop pneumonia. Infection occurs through the inhalation of dried bird secretions. Poultry workers and veterinarians are at risk.

Dermatomycosis (ringworm) – Ringworm is a fungal infection of the skin that can be acquired from direct or indirect contact with domestic animals. A number of fungal species are etiologic. Symptoms include itching, burning, cracking, and scaling of the skin.

Hepatitis E - Newly recognized to be widespread in pig populations, data suggest that infection with hepatitis E virus is an occupational hazard for pig workers, especially veterinarians (Bouwknegt *et al*, 2007b; Meng *et al*, 2002). Most infections are thought to be subclinical.

Leptospirosis – This disease is caused by a number of strains of bacteria that reside in animals. Livestock, especially cattle, may harbor specific types of these leptospira that are able to infect humans. Symptoms in humans often include fever, headache, chills, muscle aches, and vomiting, with occasional hepatitis, jaundice, and anemia.

Multi-drug resistant bacteria – Frequent use of antimicrobials in animal feeds has been implicated in the emergence of multi-drug-resistant bacteria. Both Salmonella typhimurium DT104 and Salmonella newport can cause disease in livestock and humans, and both are considered emerging pathogens of major concern. These bacteria are more likely than other salmonella species to cause human hospitalization and death. Exposure to ill farm animals and ingestion of unpasteurized dairy products are key risk factors.

Strains of staphylococcus aureus that are resistant the methicillin and related antibiotics have become widespread. A recent study from the Centers for Disease Control and Prevention (CDC), reported in the Journal of the American Medical Association, showed an increase in invasive methicillin-resistant staphylococcus aureus (MRSA) infections both within and outside of US health care settings in 2005 (Klevens *et al*, 2007).

MRSA can be carried on the bodies of pigs. This form of MRSA colonization was first studied in the Netherlands, where transmission of the bacteria between pigs, pig farmers, and their families has been documented (Huijsdens *et al*, 2006; Voss *et al*, 2005). A recent Canadian study also found a significant correlation between the presence of MRSA in pigs and humans on farms (Khanna *et al*, 2007; Khanna *et al*, 2008). Analysis of bacteria isolated from meat products suggests both animal (on-farm) and human origins (contamination during processing) (van Loo *et al*, 2007). The latter raises the possibility of MRSA transmission to processing plant workers and to consumers before the meat is cooked. This growing body of evidence makes this issue particularly relevant to the discussion of antimicrobial use in food animals.

*Orf*or *Milker's nodule* – Parapoxviruses cause these raised, sometimes painful skin infections among persons exposed to sheep (Orf) or cattle (Milker's nodule). The skin lesions may be accompanied by fever and lymphadenitis and most often affect the hands and arms. Both diseases normally resolve spontaneously after several weeks.

Pasteurellosis – Commonly caused by an animal bite or scratch, *Pasteurella multocida* infection often leads to soft tissue inflammation at the site of inoculation. Occasionally, infection can lead to septic arthritis and osteomyelitis. Pasteurellosis has also been associated with pig contact, especially pig bites.

Q fever – Q fever is an uncommon rickettsial disease caused by *Coxiella burnetti.* The pathogen is often transmitted to humans by aerosol. Many patients are asymptomatic but common symptoms include fever, chills, headache, myalgia, and influenza-like-illness. Some patients suffer atypical pneumonia, rash, or encephalitis. Occupational risk factors include working in meatpacking plants, dairies, and stockyards. Veterinarians, hide workers, butchers, and laboratory technicians have all been infected.

Salmonellosis – A number of salmonella species are highly prevalent among US livestock. Persons in contact with livestock and livestock waste are at increased risk of infection with these bacteria. The resultant illness commonly involves fever, abdominal cramping, and diarrhea but may also involve arthritis, severe disease and death. A common food-associated problem, salmonella is closely monitored in food production and national pathogen molecular fingerprinting systems for source trace back.

Taeniasis – Caused by human infection with the adult tapeworms, *Taenia saginata* (cattle) or *Taenia solium* (pigs) cause mild abdominal symptoms in man. Of major concern is the rarer condition of cysticercosis that is caused by the development of taenia cysts in human tissues. Cysticerci in brain tissue is particularly pathogenic and difficult to treat. Risk factors including livestock care, and the ingestion of undercooked beef or pork. Modern meat processing facilities intensely screen products to prevent transmission.

Toxoplasmosis – A parasite often found in pork or lamb, *Toxoplasma gondii,* causes this disease in humans. Generally, patients are asymptomatic unless immunocompromised or pregnant. Symptoms often include influenza-like-illness, fever, and lymphadenitis. Among the immunocompromised various ocular disorders may occur.

Yersiniosis – Most human disease with this group of pathogens occurs among children and is caused by one species, *Y. enterocolitica*. Infection is often associated with fever, abdominal pain, and diarrhea, which can be bloody. Pigs are the major reservoir for this pathogen. Risk factors include eating contaminated food, especially raw or undercooked pork products, preparation of such foods, drinking contaminated unpasteurized milk, and contact with infected animals. Generally, this cause of diarrhea is much less frequent in the United States as compared to human cases of campylobacter and salmonella species infections.

Influenza – Zoonotic influenza strains are occasionally detected among humans who are exposed to livestock (Myers *et al*, 2007a). Recently, serological evidence of infections with swine influenza virus have been detected among US farmers, veterinarians, and meat processing workers occupationally exposed to pigs (Gray *et al*, 2007b; Myers *et al*, 2006; Olsen *et al*, 2002). These data and swine influenza outbreaks among persons exposed to swine at agricultural fairs suggest that these infections are likely much more common than detected (Robinson *et al*, 2007). Similarly, US poultry veterinarians (Myers *et al*, 2007b) and poultry farmers (Gray and Baker, 2007) have been shown to have serological evidence of previous infection with avian influenza viruses. Infections may be without symptoms. Signs and symptoms of zoonotic influenza virus among humans are similar to those for human influenza viruses: fever, headache, myalgia, conjunctivitis, and malaise. Exposure to poultry has been the leading risk factor for many humans recently infected with the highly pathogenic H5N1 avian influenza viruses currently circulating in Asia, Europe, and Africa.

Diseases associated with foods of animal origin. The pathogens causing these diseases are closely monitored by the food processing industry. Even so, zoonotic transmission through US meat product consumption occurs.

Campylobacteriosis – Campylobacter is the most common bacterial cause of US diarrheal illness. Campylobacter species are commonly found among livestock and closely monitored in food production. The overwhelming majority of infections in humans are caused by *C. jejuni*. Symptoms often include fever, abdominal cramps, and diarrhea which is often bloody. This pathogen is closely monitored in food production, especially in poultry processing. National programs for laboratory surveillance closely monitor diarrheal disease for these pathogens. Many meat products are contaminated with campylobacter but appropriate handling and cooking greatly reduces transmission risk to those consuming the meat products.

Listeriosis – Once a frequent cause of food-related illness especially among the immunocompromised, *Listeria monocytogenes* is now more effectively controlled in meat production, and as a result US human illnesses have decreased in recent years. Infection is associated with fever, muscle aches, and sometimes gastrointestinal symptoms such as nausea or diarrhea and occasionally meningitis. This pathogen is closely monitored in food production and by US public health laboratory networks.

Enterohemorrhagic Escherichia coli (O157: H7) - This bacteria often causes acute bloody diarrhea and abdominal cramps, without fever. In some, infection results in hemolytic uremic syndrome, seizures, stroke, and death. A frequent source of infection is undercooked ground beef. However, infections have also occurred after contact with cattle and after ingestion of unpasteurized milk and juice, sprouts, and lettuce. Waterborne transmission occurs through swimming in contaminated lakes and pools, or drinking inadequately chlorinated water. In recent years, a significant portion of US cattle are thought to be infected. Clinical and laboratory surveillance among humans in recent years has helped to better understand the epidemiology of this pathogen. Intense surveillance for *E. coli* is conducted in food processing facilities as clinical disease has led to numerous massive meat product recalls in recent years.

Diseases associated with indirect contact with livestock. These pathogens are rather ubiquitous in the environment. While risk factors include exposure to livestock, the pathogens can also be carried by a number of species of wild animals (and excreted with feces).

Cryptosporidiosis – This diarrheal disease is caused by protozoans in the genus *Cryptosporidium. Cryptosporidium parvum* is often found in the gastrointestinal tract of calves. Cryptosporidium species are recognized as one of the most common causes of waterborne disease among humans in the United States. They are found in soil, food, water, or on surfaces that have been contaminated with infected human or animal feces. Cryptosporidium species can also be transmitted by ingesting undercooked food. Symptoms include watery diarrhea, abdominal cramps, fever, nausea, and vomiting.

Giardiasis – The protozoan, *Giardia intestinalis*, causes this intestinal disease. Symptoms include diarrhea, flatulence, abdominal cramping, and nausea. It is one of the most common causes of waterborne disease in the United States. Like cryptosporidium species the pathogen is found in soil, food, water, or on surfaces that have been contaminated with animal fecal material. Like cryptosporidium, *Giardia intestinalis* may reside in the intestinal tract of cattle.

Bovine spongiform encephalopathy. BSE is not the first prion disease, or the most common. Prion diseases have been known and observed since the 1700's, when "scrapie" was described in sheep and goats (Eggenberger 2007). The fact that scrapie was caused by prions, however, was not elucidated until 1982, shortly before the first description of BSE (Prusiner 1982). Other zoonotic prion diseases include chronic wasting disease (CWD), which is very prevalent in deer and elk (as well as buffalo) in North America, transmissible mink encephalopathy (TME) and many more. Reported clustering of human prion disease cases with suspected CWD transmission have raised concerns that there may be possible transmission to humans, but definitive research is still in progress (Belay et al 2001, Belay et al 2004).

Recently, the emergence of an atypical variant of BSE has been described (Brown et al 2006). This type was found in older animals, and had different clinical signs than typical BSE. In addition, symptoms may be muted or nonexistent until the most terminal stages, although very little data exist on this subject. The frequency of these cases is also unknown, although preliminary testing in Germany and Canada suggests it could be as high as 10% (Buschmann et al 2006).

The general public became aware of BSE in 1996, when testing confirmed that a variant form of the human prion disease, Crutzfeld-Jakob disease (vCJD), could be caused by oral exposure to PrP^{BSE} (Eggenberger 2007, Will et al 1996). CJD is a human prion disease that is 100% fatal, and causes symptoms similar to BSE including tremors and loss of motor control, disorientation and paranoia, and finally fatal neurodegeneration (Eggenberger 2007). The classical form of CJD was first described in the 1920s, long before the first BSE cases were identified. About 10-15% of CJD cases are caused by familially inherited mutations of the prion protein gene, and about 85% of classic CJD cases are considered sporadic, where there is no recognizable pattern of transmission (Belay and Schonberger 2005). vCJD can be distinguished from classical CJD mainly due to the strikingly younger median age at death (28 years) when compared to classical CJD (68 years), as well as differences in the progression of clinical signs, illness duration, magnetic resonance imaging (MRI) findings and neuropathological lesions (Brown et al 1994).

The question of the actual risk of vCJD, via BSE, to humans is difficult to answer. As of June 2007 there have been only 201 cases of vCJD worldwide since it was recognized a decade ago (Beekes, Zerr, and Groschup 2007). However, the emergence of atypical BSE has raised the question of whether so-called sporadic CJD may actually be caused by this less obvious form of BSE (Brown et al 2006). The weight of the devastating effects of this disease, despite its presumed rarity, means that BSE poses a significant preserved risk. The public's awareness of, and outrage over, BSE means that whatever the actual risk may be, BSE must be thoroughly addressed both from an animal and human health standpoint (Brown et al 2006).

D.3. Prevention Measures for Workers

Occupational medical surveillance. Without a proper environmental history, the health care provider may fail to relate a patient's symptoms to CAFO exposure, resulting in misdiagnosis and treatment of CAFO-related respiratory conditions as allergic responses (Merchant and

Reynolds 1999). An in-depth personal and family medical history will include questions on allergies, asthma, heart conditions and hobbies or personal habits (such as smoking) that might complicate the work exposures (Merchant, Thorne, and Reynolds 2005).

It is important to recognize that a worker's response to confinement dusts and gases is variable and that one or more conditions may be occurring simultaneously (e.g. chronic bronchitis, occupational asthma and sinusitis). A worker should be questioned in detail about chief complaints, including questions on how long symptoms have been present and the time relationship of symptoms to work exposure. Work exposure for more than two hours per day and more than six years of total exposure are related to increased frequency and severity of symptoms. Improvement in symptoms over a vacation period with greater than normal symptoms on return to work is an indicator of a work-related condition. The worker should also be questioned on the specific jobs he/she does and on the environmental air quality in the building. Moving and sorting animals and power washing inside the building are tasks that lead to increased exposure to respiratory irritants. The worker should be medically assessed for fit and use of an appropriate respirator.

The use of spirometry in medical surveillance is important and has been well developed through adoption of the OSHA cotton dust standard (Merchant, Thorne, and Reynolds 2005). Reduced flow rates (FEV_1 and FEF) over the work period of 5%-10% are common in workers with symptoms. Less commonly, decreases of 5% or more in volumes (FVC) over the work period may be seen. However, baseline spirometry values are usually normal. A positive methacholine challenge is common but does not necessarily correspond to a cross-shift decline in FEV_1 or respiratory flow rates. Dermal prick tests for suspected feed or swine allergens are usually negative.

Medical surveillance must be accompanied by reducing exposures to dust and gas through management and engineering controls, appropriate use (selection and fitting) of respirators, and/or transfer of workers to a low-exposure work area (Merchant and Reynolds 1999). In most cases, with appropriate use of these modalities, workers can be kept working safely on the job. The local veterinarian or the Cooperative Extension Service should be able to recommend an industrial hygienist or agricultural engineer familiar with CAFO design and exhaust ventilation. Environmental assessments should be conducted and concentrations of dust and ammonia should meet the current research-based recommendations seen in Table 4.1. Monitoring air quality in these buildings is essential to assurance of a healthful work environment. Minimum assessment includes ammonia and total dust (mass) two times yearly, one of which should be in cold weather conditions.

Worker safety. Health hazards associated with confinement houses must be addressed through a hierarchy of environmental controls: 1) decreased generation of dusts and gases by improved management procedures or engineering controls, 2) removal of contaminants once in the air, such as through ventilation, and 3) proper protection of the individual with respirator use. A prevention model for confinement house problems, based on education and industrial hygiene consultation, has demonstrated its effectiveness (Donham *et al*, 1990). Some examples of management practices to reduce the sources of dusts and gases include: 1) delivering feed by extension spouts into covered feeders, rather than letting feed fall freely from automatic delivery systems into open feeders; 2) using extra fat or oil in the feed to reduce dust; 3) sprinkling or misting the environment with vegetable-based oil and washing of buildings with power sprayers every three to four weeks (operators must use respiratory protection during this procedure); 4) using flooring that is more self-cleaning (e.g. plastic-coated wire mesh); and 5) assuring that heating units are clean, vented, and functioning properly. Details of control measures are published elsewhere (Donham, 1991). Effectiveness of control techniques can be assessed by measuring dust and gas concentrations to assure they remain within healthful limits.

Because it is economically impossible to completely eliminate dusts and gases in CAFOs, techniques for removing contaminants from the air of confinement houses are critically important. Ventilation systems must be properly designed and maintained, and ventilation rates adjusted to include consideration of air quality (operators often keep these rates low in winter to conserve heat, causing dust and gas concentrations to rise). A number of engineering techniques, such as using heat exchangers that allow increased ventilation while capturing some waste heat, have been tried with varying degrees of success (Donham, 1993).

A worker in a swine or poultry CAFO with exposures in excess of the levels recommended in Table 4.1 should be advised to wear a NIOSH-certified two-strap dust mask. Persons exposed to houses with high dust or gas concentrations, or workers with respiratory conditions, may need a more protective respirator, such as a half-mask cartridge respirator or powered air-supplying respirator (e.g. air helmet).

Preventing exposure to high concentrations of H_2S from manure pits requires stringent controls. General safety measures include constructing manure pits outside of the confinement building, constructing openings so that lids or other objects cannot fall into the pit requiring a worker to enter the pit for retrieval, and erecting safety guards and warning signage around open pits. Whenever a pit that is under a confinement house is being agitated, people should stay out of the building, ventilation of the house should be maximized, and animals should be removed or observed from outside the building.

Preventing Zoonoses among CAFO workers. A recent review by Collins and Wall (2004) indicates that zoonotic pathogen transmission in confinement facilities can be reduced through numerous measures. These measures include good confinement facility design with proper drainage and barriers to vermin, strict biosecurity policies, pathogen and ill animal surveillance, sound animal husbandry practices, acquisition of safe feed, education of workers, appropriate animal transport preventions, facility cleanliness, the control of animal waste, on-farm animal carcass inspection and laboratory study, vermin reduction programs, and appropriate use of personal protective equipment and hygiene measures among workers. Guidelines for the use of personal protective equipment and hygiene measures currently vary with institutions and with the type of production animals. A number of federal guidelines have been drafted to protect animal production facility workers. Recently NIOSH has drafted an updated review of such guidelines for protecting poultry workers from avian influenza when an outbreak is suspected or detected in a facility (US DHHS, CDC, NIOSH 2007). The draft document recommends educating workers regarding the symptoms and transmission of avian influenza, and encouraging workers to seek medical attention when ill. It further recommends that workers be encouraged to wear appropriate personal protective gear including coveralls, boots, eye protection, and respirators and be appropriately trained to care for this equipment.

For the numerous reasons mentioned above, swine and poultry CAFO workers should be required by their employers to receive annual influenza vaccines. Such vaccination will help to reduce the emergence of novel influenza strains as well as reduce cross-species transmission of influenza viruses (Gray, Trampel, and Roth 2007, Gray and Baker 2007). CAFO workers should also be trained to seek medical attention whenever they develop an influenza-like-illness or infections and to avoid coming to work if ill. Finally, swine and poultry CAFO workers should be included as priority recipients of pandemic influenza vaccines and antivirals should their use be indicated. Saenz et al has demonstrated that administering a moderately effective pandemic influenza vaccine to just 50% of CAFO workers could totally mitigate the increased risk of the workers accelerating pandemic viruses transmission in their communities (Saenz, Hethcote, and Gray 2006).

Bovine spongiform encephalopathy prevention and surveillance. In 1988, two years after the scientific and agricultural communities were alerted to BSE presence in United Kingdom cattle populations (Collee and Bradley 1997), the use of ruminant proteins in ruminant feeds was banned in the UK. This restriction was widened in 1994, banning the feeding of meat-and-bone meal (MBM) to ruminants, but not before nearly half of the UK's herd was affected. By 2001 the European Union instituted a comprehensive ban on the feeding of mammalian MBM to ruminants (WHO 2002), which remains in place today. These bans have been effective in progressively lowering the prevalence of BSE in the UK and in Europe. The United States and several other countries banned certain ruminant protein sources from ruminant feed as a precaution, before BSE had been described in their herds. The US ban went into effect in 1997, outlawing the use of brain matter, spinal cord, eyes and small intestine of ruminants in ruminant feeds (Bren 2004). The efficacy of the ban in the United States is unknown, but BSE has recently been detected in the US cattle population.

A recent French study concluded that, despite the ban on MBM in ruminant feed, cross-contamination at the feed plant or farm may be the most likely reason for the 957 cases of BSE that have been detected in cattle born after the July 30, 1990 ban (Paul et al 2007). These data cannot be extrapolated to the United States, as feed production and practices differ. One can extrapolate that feeding practices wherein feed is bought from a central location (as in the feedlot system), rather than foraged by cattle at pasture, increase the risk of exposure to BSE, simply due to the possibility of cross-contamination within feed production that does not exist in foraged feeding. Since most foraged feeding is supplemented, however, the risk is not zero, even to cattle on pasture.

The World Animal Health Organization (WAHO) outlines two different types of BSE surveillance in their Terrestrial Animal Health Code (WAHO 2006). "Type A" surveillance is practiced by countries to determine the prevalence of BSE within the country's cattle population, and is meant to detect as few as one case in 100,000 cattle. The United States and Japan have surveillance programs that meet or exceed Type A surveillance. In 2006, the US tested 735,000 cattle for BSE, and found 2 cases of BSE, while Japan tested 6 million cattle for BSE, including every animal at harvest, and found 10 cases (WAHO 2007). Once prevalence has been established via Type A surveillance, a country can perform a less costly Type B surveillance to monitor their indigenous cattle population. A country with negligible risk for having BSE, like Australia or Argentina, may also implement a Type B surveillance program. Type B surveillance is designed to detect as little as one case in 50,000 adult animals (WAHO 2006).

Unfortunately, the emergence of atypical BSE, and its detection in the United States in the past few years, reemphasizes the need for all nations to actively monitor their cattle populations and continue to implement risk mitigation, such as the ruminant-to-ruminant feed bans (Brown et al 2006), since this type of BSE may be more prevalent than expected and may not be detected via clinical signals. Brown et. al. suggest that the less rigorous surveillance level that the US dropped to in 2006 is insufficient to assess the threat of atypical BSE (2006). In addition, surveillance of food animal populations is made easier in the UK and many other countries by the national tracking of food animals, something that is not done in the United States.

Another important public health issue in surveillance of BSE is the lack of an internationally accepted test for BSE. Since each nation may use a different type of test to look for BSE in their herd, differing test sensitivity may result in differing abilities to detect BSE (Bowling et al 2007). Research into the best form of testing, from the standpoints of efficacy of detection, ease of use, and cost, as well as other conditions, is ongoing, but an international standard has not been agreed upon.

Beyond surveillance, further research is warranted into the etiology of all prion diseases, and into the actual infectious dose of BSE needed to cause vCJD. The relative rarity of the disease suggests that it may be high compared to the dosage needed to infect another cow with BSE, but there is, as yet, no definitive answer (Bowling et al 2007).

Although the relative risk of contracting vCJD may be low, the steady levels of BSE in Europe, and the discovery of atypical BSE, mean that BSE surveillance and prevention methods is important and must be maintained. More stringent, internationally sanctioned surveillance and animal tracking programs will help minimize the risk of BSE and CJD, as will further research into the etiology of prion diseases.

E. COMMUNITY ENVIRONMENTAL EXPOSURES

E.1. Scope of Airborne Exposures

Exposures to airborne effluents from industrialized livestock facilities, also known as a concentrated animal feeding operation or CAFO, are a complex mixture of particulate matter, bioaerosols, gases and vapors. These compounds arise from feed, animals, manure and microorganisms. Highly noxious odors are associated with vapor phase chemicals and compounds adherent to particles. These agents emanate from livestock facilities, waste storage reservoirs and manure application sites associated with livestock production. All have the potential to migrate from the CAFO to its neighbors or neighboring communities. This section will briefly describe those hazardous agents; their measurement, generation rates, and transport; and the concentrations at which they appear.

Particulate matter and bioaerosols. Particulate matter associated with CAFOs is composed of fecal matter, feed materials, skin cells, microorganisms, and the products of microbial action on feces and feed (Table 4.3.). Components of feed include plant proteins, starches and carbohydrates; feed additives such as vitamins, minerals, amino acids and other supplements; and antibiotics. Bioaerosols, or airborne particles of biological origin, are a major component of the particulate matter from livestock facilities. These include bacteria, fungi, mold and bacterial spores, viruses, mammalian cell debris, products of microorganisms, pollens, and aeroallergens (Table 4.3.).

Table 4.3. Components of CAFO Particulate Matter.
(Heederik et al 2002, Douwes et al 2002)

Microorganisms	**Plant Materials in Feed Dust**
Bacteria	Proteins
Fungi	Starches
Amoebae	Carbohydrates
Viruses	
Products of Bacteria	**Feed Additives**
Spores	Antibiotics
Endotoxins	Vitamins and minerals
Exotoxins	Amino acids
Peptidoglycans	Antiparasitics
Lipoteichoic acid	Heavy metals
Bacteria CpG DNA	Mammalian Cell Debris
Products of Fungi	Animal Dander
Spores	**Aeroallergens**
Hyphal fragments	Plant pollens
β(1-3) Glucans	Storage mite fecal allergens
Mycotoxins	Arthropod allergens

Bacterial and fungal bioaerosols may be of infectious or non-infectious species and are a mixture of viable and non-viable organisms. Their presence as bioaerosols represents a transitional transport from one ecological niche to another. Bacterial products or components exist as bioaerosols and include pathogen-associated molecular patterns capable of acting as ligands for toll-like receptors (TLR) (Thorne and Duchaine 2007). Examples include endotoxins, peptidoglycans, lipoteichoic acids, viruses, and bacterial CpG DNA. Fungal products or components of note include spores, hyphal fragments, mycotoxins and glucans. Arguably the most important non-infectious bioaerosol associated with CAFOs is endotoxin, an amphipathic component of the outer cell wall of Gram-negative bacteria that is ubiquitous in the environment. It is a potent inflammatory agent that produces systemic effects and lung obstruction, even at low levels of exposure (Heederik et al 2007). Inflammatory effects of endotoxin are amplified by a cascade involving a highly regulated suite of accessory molecules (Gioannini and Weiss 2007) including LBP, CD-14, MD-2, TLR4 and NFkB. Livestock confinement units present some of the highest concentrations of endotoxin found anywhere.

Genera of bacteria found in air samples from swine barns include the Gram-negative organisms *Enterobacter, Acinetobacter, Moraxella, Pseudomonas,* and *Escherichia coli,* and the Gram-positive organisms *Enterococcus, Staphylococcus, Streptococcus, Bacillus, Aerococcus,* and *Micrococcus* (Kiekhaefer et al 1995, Cormier et al. 1990). Gram-positive microorganisms (especially Enterococci) represent the majority of bacteria and gram-negative organisms are generally less than 25% of the measured viable bacteria (Clark et al 1983, Heederik et al 1991). Recent research has revealed the presence of Archebacteria in manure lagoons (Nehmé et al 2007). Multiple studies have shown that viable airborne bacteria can be resistant to multiple antibiotics (Chapin et al. 2005; Gibbs et al. 2006) and also resistant to arsenical biocides (Sapkota et al. 2006).

The most commonly found fungi are the mold genera *Aspergillus, Scopulariopsis, Penicillium, Geotrichum, Mucor*, and *Fusarium*. Yeasts found in swine environments include *Candida, Cryptococcus, Toruopsis, Trichosporon, Rhodotorula,* and *Hansenula*. However, variations in housing conditions and feed ingredients can impact the gastric flora of the animals and the microbial ecology of the animal facility. The concentrations of non-culturable aerobic and anaerobic organisms in the particulate matter in swine barns is generally 10 to 100-fold higher than the culturable organisms (Lange et al 1997b, Heederik et al 2002). However, the bacterial genera represented in these bioaerosols have not been adequately studied.

Gases and vapors. Noxious gases and vapors are emitted from livestock facilities, manure lagoons and storage piles, and from sites of manure land application. These compounds arise from the urine and feces, but especially from microbial degradation of manure slurry in storage or as manure compost. Table 4.4 lists some of the volatile organic compounds; vapors and gases; and odoriferous volatile fatty acids, phenolic compounds and nitrogen-containing compounds. Many of these agents are sensory and respiratory irritants. In combination, they are associated with nasal, sinus, and eye irritation; coughing; wheezing; dyspnea and feelings of malaise (Schenker et al 1998). Hydrogen sulfide levels downwind of swine CAFOs have been measured in one hour average samples above 300 ppb. In an extended evaluation of a livestock operation in Minnesota, one site had over 150 exceedances of a 50 ppb, 30-min average concentration (Minnesota Department of Health 2003).

Table 4.4. Gases and Vapors Emanated from CAFOs.

Volatile Organic Compounds	Vapors and gases
Acetaldehyde	Ammonia
Acetone	Hydrogen sulfide
Acetophenone	Dimethyl sulfide
Acrolein	Hydrazine
Benzaldehyde	Sulfur dioxide
Benzene	Carbon dioxide
bis (2-ethylhexyl) phthalate	Carbon monoxide
2-butanone	**Odoriferous volatile fatty acids**
Carbon disulfide	Butyric and isobutyric acid
Carbonyl sulfide	Caproic and isocaproic acid
Chloroform	Valeric and isovaleric acid
Crotonaldehyde	Propionic acid
Ethyl acetate	Phenylpropionic acid
Formaldehyde	Lauric acid
Formic acid	Acetic and phenylacetic acid
Hexane	**Phenolic compounds**
Isobutyl alcohol	Phenol
Methanol	Ethyl phenol
2-methoxyethanol	Cresols
Naphthalene	**Nitrogen-containing compounds**
Pyridine	Ammonia
Tetrachloroethylene	Amines
Toluene	Pyridines
Triethylamine	Indole
Xylene	Skatole
	Trimethylamine
	Tri- and tetra-methyl pyrazines

Sources: Banwart and Bremmer 1975, Cole et al 2000, Donham and Popendorf 1985, Hammond and Smith 1981, Hammond et al 1979, Hammond et al 1981, Hammond et al 1989, Hartung 1985, Hartung 1988, Heederik et al 1990, Merkel et al 1969, Minnesota Environmental Quality Board 2001, O'Neill and Phillips 1992, Ritter 1989, Schaefer 1977, Schenker et al 1998, Spoelstra 1980.

Odors. The most significant community concern associated with airborne effluents from CAFOs is odor. The breakdown of feed in the gut of the animals produces organic compounds that have a foul odor. Microbial degradation of manure further produces foul odoriferous compounds. The chemicals that evoke these foul odors are an extreme nuisance and may induce adverse health effects with sufficient exposure (Schiffmann et al 2005; Schiffmann and Williams 2005). Bacteria attack organic matter in order to gain energy for life and growth. Bacteria in manure dehydrogenate these odoriferous compounds producing reduced oxygen species. Sulfur in proteins is broken down to SO_4 ions which are reduced to hydrogen sulfide by sulfate-reducing bacteria. In a similar fashion, when oxidized organic compounds are reduced to organic acids, mercaptans, skatoles or indoles, they become orders of magnitude more noxious.

Some of the most objectionable compounds produced are the organic acids including acetic acid, butyric acids, valeric acids, caproic acids, and propanoic acid; sulfur-containing compounds such as hydrogen sulfide and dimethyl sulfide; and nitrogen-containing compounds including ammonia, methyl amines, methyl pyrazines, skatoles and indoles. Smells associated with these compounds are described as similar to rotten eggs or rotting vegetables (hydrogen sulfide, dimethyl sulfide), rancid butter (butyric acids), or having a putrid fecal odor (valeric acid, skatole, indole).

Emissions of acidifying compounds and greenhouse gases. It is recognized that ammonia emissions from the livestock sector contribute significantly to eutrophication and acidification of the environment. Acidification can put stress on species diversity in the natural environment. Reduction of ammonia emissions from CAFOs requires covering of manure storage tanks and reservoirs and direct injection of controlled quantities of manure slurry into soil during the growing season. Land application of manure without direct injection or during winter months or rainy weather leads to significant runoff into surface waters.

Industrialized livestock production facilities are known sources of greenhouse gases such as methane and nitrous oxide. These gases may contribute to global climate change and are the subject of national and international air pollution control strategies. Methane is produced during the digestive process by ruminants (enteric fermentation) and through manure handling while nitrous oxide arises primarily from the microbial degradation of manure. Their global warming potential, compared to a value of 1 for carbon dioxide, is 62 for methane and 275 for nitrous oxide on the 20-year time horizon. The US EPA Greenhouse Gas Inventory Report data for agricultural inputs is summarized in Table 4.5. Agriculture accounts for 7.4 % of the total U.S. release of greenhouse gases (Intergovernmental Panel on Climate Change 2001).

Table 4.5. US Greenhouse Gas Inventory for Agricultural Emissions.

	Source	Gigagrams	Teragrams CO_2 Equiv.
Methane, CH_4	**Total**	**7674**	**161.2**
	Enteric fermentation	5340	112.1
	Manure management	1966	41.3
	Other	369	7.8
Nitrous Oxide, N_2O	**Total**	**1210**	**375.1**
	Agric. Soil management	1178	365.1
	Manure management	31	9.5
	Other	2	0.5

Source: US EPA, 2007.

E.2. Air Measurements, Methods, Sources

Because of the potential of the air emissions from CAFOs to induce adverse health effects it is important to assess exposures and understand generation rates of effluents, especially including ammonia, hydrogen sulfide, odors, and bioaerosols. There are no federally mandated monitoring programs in the United States and only a small number of states have instituted their own monitoring. Efforts to institute local controls have generally focused on siting, setbacks and zoning rather than compliance with standards for hazardous air pollutants. In 2005, the EPA put forward an administrative consent agreement that allows CAFOs immunity from violations of the Clean Air Act and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) if they pay a small fine and conduct some monitoring. To date this program has not produced scientifically useful datasets. The majority of the monitoring and exposure data available have come from academic researchers interested in characterizing emissions either for studies of occupational and community health or for studies to address emission rates and efficacy of control approaches.

Particulate matter and bioaerosol measurements. The most common approaches to measurement of particulate matter emissions are gravimetric sampling or particle counting. Gravimetric sampling is performed by pre-weighing specialized air sampling filters using a precision microbalance, sampling the environment by pulling a measured amount of particle-laden air through the filter, and then post-weighing the filters and correcting the weight gain for any change in blank unsampled filters. This corrected weight change is then divided by the volume of air that was pulled through the filter to determine the airborne dust concentration in mg per cubic meter of air.

When dust is inhaled by humans or animals, a higher proportion of small particles than large particles will travel deep into the lung and be deposited. Thus, it is prudent to sample selected fractions of the total suspended particulates to gain more insight into the potential for toxic effects on the lung. Categories of selected fractions include the inhalable dust fraction, the respirable dust fraction, PM_{10} and $PM_{2.5}$. The inhalable and respirable fractions have 50% of the particle mass below 100 μm and 3.5 μm, respectively. PM_{10} refers to particulate matter less than

10 µm in diameter and $PM_{2.5}$ is less than 2.5 µm in diameter. In general, finer particulate fractions contain a higher proportion of anthropogenic dust and lower levels of wind-blown soil and plant pollens. Larger particles are more often associated with upper respiratory tract and airway diseases while fine particles produce small airway and alveolar disorders. The inhalable dust fraction is often measured to assess exposures from CAFOs. This is done using gravimetric methods with a sampling device that excludes PM outside of the desired size range. Examples of inhalable dust samplers are the IOM, GPS, PAS6 and Button samplers (deVocht et al 2006, Hauck et al 1997, O'Shaughnessy et al 2007).

Much research has been conducted on methods of assessing bioaerosol concentrations in the agricultural environment (recently reviewed by Thorne and Duchaine 2007, Douwes et al 2007, Heederik et al 2002). The concentration of endotoxin is most often determined using the *Limulus* amebocyte lysate (LAL) assay (Thorne 2000, Spaan et al 2007) on extracts of air sampling filters or on liquid impinger solutions. This bioactivity assay has been extensively developed and refined through optimization studies and international interlaboratory evaluations. The LAL bioassay is based on the exquisite sensitivity of an enzymatic clotting cascade in amebocytes taken from the hemolymph of horseshoe crabs (*Limulus polyphemus*) and related species (Thorne 2000). Samples are typically extracted in sterile, pyrogen-free water with 0.05% Tween-20 with continuous shaking. Extracts are centrifuged and supernatants are analyzed using the kinetic chromogenic LAL assay. To provide the highest quality analysis, a twelve-point calibration curve of standard endotoxin from *E. coli* 0111:B4 and four-point endotoxin determination for samples is performed (Thorne 2000). Assay reagent blank wells serve as reference and control. Quality assurance spiking assays are performed to assess matrix interference or enhancement.

β(1-3)-glucans are cell wall components of fungi that have been associated with mild lung inflammation and immunomodulation (Douwes et al 2003, Rylander et al 1992, Fogelmark et al 1994). β(1→3)-glucans are glucose polymers with variable molecular weight and may appear in triple helix, single helix or random coiled structures. They may account for up to 60% of the dry weight of the cell wall of fungi (Klis 1994; Williams 1994). The assay of β(1-3)-glucans (Douwes et al 1996, Blanc et al 2005) is most commonly performed by sandwich or inhibition enzyme linked immunosorbent assay. Antibodies are produced to recognize specific glucan structures and form the basis of the detection of fungal glucans. An alternative assay that utilizes the factor G pathway of the Limulus assay is also available.

Methods for assessment of culturable organisms rely on collecting bioaerosols using jet-to-agar samplers or using liquid impingers with dilution plating onto agar (Thorne and Heederik 1999). Sampling for pathogenic organisms such as methicillin-resistant *Staphylococcus aureus* (MRSA) uses selective media in jet-to-agar samplers. Cultures are then allowed to grow in incubators and are enumerated to determine airborne concentrations. Individual colonies may be sub-cultured and identified. Impinger collection fluids may be cultured on a variety of media to quantify mesophilic bacteria, thermophilic bacteria, fungi and selective microbial groups (Thorne et al 1992, Kiekhaefer et al 1995, Cormier et al 1990, Lange et al 1997a, Kullman et al 1998). Since many of the airborne organisms are not culturable, it is necessary to employ non-culture based methods. These include use of direct count methods with DNA staining and epifluorescence microscopy, fluorescent in situ hybridization, PCR techniques, and PCR amplification of 16S rRNA coupled with restriction fragment length polymorphism (Thorne et al 1992, Lange et al 1997b, Kullman et al 1998).

Measurements of gases, vapors and odors. Real-time monitors with sufficient sensitivity are available for chemicals such as ammonia and hydrogen sulfide (Bunton et al. 2007) and are in use in state and federal programs and for research. The most commonly employed devices for ammonia monitoring convert ammonia to nitrogen oxide which is detected in real time by chemiluminescence. For hydrogen sulfide monitoring, high quality devices are available that employ a thermal oxidizer to convert hydrogen sulfide to sulfur dioxide which is then detected using pulsed fluorescence. Passive diffusion-based monitors for ambient air sampling of these chemicals are commercially available but require up to 4 weeks of sampling time for sufficient loading and detection. Other compounds are determined using GC-MS or LC-MS methods on air samples collected in impermeable bags or by extraction or purging from porous collection media. Some vapors, such as ammonia, exist at significant concentrations in both the vapor phase as well as adsorbed to particulate matter. For quantification of these compounds, it is necessary to assay for both the solid and vapor phase concentration.

Methods are well established for characterization and quantification of the odor threshold of an air sample using olfactometry (ASTM 2004). Odor thresholds are quantified using an olfactometer and a panel of smellers. These panelists are non-smoking adults that are carefully selected and trained according to ASTM. They sniff a two-fold serially diluted odor sample as it is discharged from one of three ports. The other two ports deliver clean air. The panelist must select which of the randomly assigned ports is the sample and declares whether the selection is based upon recognition, detection, or a guess. The panel then samples the odor at a two-fold higher concentration. Analysis of results from the panel utilizes the triangular forced-choice method in an ascending concentration series. This method carries a high per-sample cost.

A simple non-standardized method used in field screening studies is called scentometry. This method is dependent upon the detection of odor at various dilutions of the air by a single individual and can be highly variable. Efforts to develop instrumentation to mimic human olfaction remain experimental. Some studies employ GC-MS techniques to analyze 12 compounds that are most important components of CAFO odorous emissions. These are listed in Table 4.6. along with their CAS numbers, and odor thresholds (Cheremisinoff 1975, Schiffmann et al 2001).

Table 4.6. Odorous Compounds Measured by GC-MS and Their Odor Thresholds.

Compound	CAS #	Odor Threshold, ug/m^3
Indole	120-72-9	0.2
Methyl mercaptane	74-93-1	2.1
Skatole	83-34-1	3.1
Dimethyl sulfide	75-18-3	5.9
Trimethyl amine	75-50-3	5.9
p-Cresol	106-44-5	8.3
iso-Valeric acid	503-74-2	10.5
n-Butyric acid	107-92-6	14.5
n-Valeric acid	109-52-4	20.4
Dimethyl disulfide	624-92-0	47.9
Propionic acid	79-09-4	110
Benzaldehyde	100-52-7	186
Carbon disulfide	75-15-0	302
Acetic acid	64-19-7	363
Phenol	108-95-2	427

Rates of gaseous and vapor emissions from industrial livestock operations. Researchers have sought to measure generation rates of hydrogen sulfide and ammonia from livestock operations in order to understand their environmental impact and to provide data for modeling airborne transport. Recent estimates for H_2S and ammonia emissions from livestock operations and manure storage lagoons have been reported. In Table 4.7, emission factors are specified in grams per day per animal unit (mg/day•AU). These data illustrate that swine CAFOs are the biggest source of hydrogen sulfide while broiler operations produce the most ammonia per animal unit.

Table 4.7. Hydrogen sulfide and ammonia emission factors for livestock operations.

Operation	**Emission Factors, grams/day•AU**	
	Hydrogen sulfide	**Ammonia**
Swine CAFO, average	20	40.5
Swine CAFO, cold months	6.3	
Swine CAFO, warm months	34.1	
Swine Lagoon, Apr-Oct	5.5	43.3
Dairy Operation	0.0332	16.4
Cattle Feedlot	0.115	31.3
Chicken Broilers	0.0587	200

1 AU (animal unit) = 2.5 swine >25kg, 0.7 dairy cow, 1 feedlot cattle, or 200 broiler chickens

Sources: Baek et al. 2003; Demmers et al. 2001; Fulhage 1998; Grelinger 1998; Groot Kooerkamp et al. 1998; Hoeksma et al. 1993; Hutchinson 1982; Lim et al. 2003; Misselbrook et al. 1998; Ni et al 2000; Ni et al 2002; USDA 2000; Wathes et al. 1997, Zahn et al. 2001; Zhu et al. 2000a.

E.3. Air Dispersion Modeling

The Clean Air Act Amendments of 1977 first required the US EPA to use air quality simulation models (Jacobson et al 1999). Since that time, these “dispersion models” have been developed to include the effects of advection (transport) and dispersion (including dilution by the wind and dispersal due to turbulence) and may also include considerations of plume rise, wind shear, and chemical and physical transformations (including removal mechanisms) (Turner 1979). Air dispersion modeling relies on knowledge of local meteorological conditions and source emission rate, and may include topography and building information. The general class of dispersion model accepted by the EPA for regulatory efforts relies on the assumption that the contaminant disperses from a source with a concentration profile defined by a normal or “Gaussian” curve.

This model assumes that the atmosphere is diffusive. The most widely used regulatory model approved by the EPA has been the Industrial Source Complex (ISC) Model. The ISC model is a steady-state Gaussian plume model suitable for a wide range of industrial applications and special cases. However, following a 1999 meeting of the American Meteorological Society/EPA Regulatory Model Improvement Committee (AERMIC), the EPA introduced state-of-the art modeling concepts into its air quality models. The new AERMIC Dispersion Model, known as AERMOD, replaced the ISC standard regulatory model as of December 2006.

Attempts have been made to use air dispersion models to estimate concentrations of both odor and contaminants downwind of CAFOs. These studies are complicated by three important factors: there may be several sources of a contaminant; the emission rate from each source is difficult to precisely determine; and the regulatory models do not typically include provisions for the degradation and deposition of gases in transport downwind from the source. The Minnesota Pollution Control Agency recently used the ISC short-term (ISCST) model to evaluate ambient concentrations of ammonia and hydrogen sulfide resulting from the cumulative effect of 60 feedlots located in a region in West-Central Minnesota (Pratt 1998). The model predicted exceedences of the state's hydrogen sulfide standard (30 ppb half hour average) up to 4.9 kilometers from the source with the highest emissions. Predicted ammonia concentrations exceeded the state's proposed Health Risk Values of 1000 $\mu g/m^3$ at distances up to 1.6 miles from the highest emitting source.

While there has been a great deal of research on effluent plumes from livestock facilities, most of the measurements that have been made have assumed that the emissions travel horizontally near the ground and that the sources are continuous. Many of these researchers have further assumed that conventional Gaussian diffusion models are appropriate to describe the downwind dispersion of the plume from the facilities (for example, Piringer and Schauberger, 1999). For ventilated facilities, the primary source of effluents is often assumed to be the exit aperture of the ventilation fans (Demmers et al 1998, 1999). Similarly, measurements made with fourier transform infrared spectrometers are often made over several transects across the assumed path of the effluents. A bivariate Gaussian shape is assumed and fitted to the available data so as to reconstruct the details of the distribution in the plume and the shape (for example, Hashmonay et al 1999a, 1999b; Price 1999; Childers et al 2001; Harris et al 2001a). Modifications to the Gaussian plume model that better represent agricultural sources have been investigated (for example, Gassman 1995; Keddie 1980). A detailed discussion of transport from ground level agricultural sources can be found in Smith (1993).

The AERMOD model may have particular applicability to emissions from animal agriculture by including the air boundary layer above surface releases, ie., manure storage basins (Jacobson et al 1999). Koppolu et al. (2002) compared results obtained from AERMOD and STINK (a research-grade, Gaussian plume model from Australia) after modeling the dispersion of low-weight volatile fatty acids (odor compounds). They found better agreement between model results and measured values when using AERMOD. The authors caution that the choice of model averaging time will influence accuracy where a time of 1 hour provided the best agreement.

Other studies have focused on the dispersion of odor primarily for the purpose of determining setback distances between CAFOs and local residences (Heber 1997, Jacobson et al 2001, Zhu et al 2000a, Guo et al 2005). Gassman (1992) reviewed literature on odor modeling using the Gaussian-plume method and concluded that the method was best applied on a relative basis for comparing differences between different facilities. Gaussian plume models that have been widely used for odor dispersion modeling include AUSPLUME (EPAV 2000), ISC3 (US EPA 1995), and STINK (Smith and Watts 1994). Studies have shown varying degrees of agreement between model results and odor measurements (Carney and Dodd 1987, Li et al 1994, Gassman 1992, Guo et al 2001). Guo et al (2005) have developed a model specifically for determining offset distances from animal production sites. They found that their model, OFFSET, accurately represented average odor intensity over a neighborhood but they recognized that high variations in measured odor exist over a small space scale that are difficult to predict.

Another class of plume model that has recently been applied to the dispersion of contaminants from CAFOs appears to have promise over the conventional Gaussian model. These Gaussian "puff" models are non-steady state models that depend on high-definition meteorological data and can account for an intermittent release rather than assuming a steady, continuous stream by simulating pollutant releases as a continuous series of puffs. The Gaussian puff model, INPUFF-2, has been used predict odor dispersion (Zhu et al 2000b) and the puff model, CALPUFF, has recently been used to model ammonia and hydrogen sulfide in the vicinity of a CAFO (Minnesota Pollution Control Agency 2003). Some of the attributes of CALPUFF are especially pertinent to conditions associated with CAFOs: variable wind directions, calm-wind algorithm, buoyant area and line sources, non-uniform land patterns, and multi-facility applications. Because the worst-case scenario for high concentrations near a facility occurs during calm-wind conditions, this feature, in addition to its ability to simulate intermittent releases, makes

CALPUFF especially relevant. A recommendation was made to the State of Minnesota to use the ISC model for single facilities and the CALPUFF model for multi-facility applications (Earth Tech 2001) and the USEPA has adopted CALPUFF as the preferred model for assessing long-range transport of pollutants (US EPA 2003).

The science of modeling air pollution has advanced and recent developments with application to industrialized livestock sources make modeling an essential methodology for permitting, siting and regulatory decision making (Thorne 2007).

E.4. Waterborne Exposures, Methods, Sources

Exposures to waterborne hazards from industrialized livestock facilities include excess nutrients and chemical and biological contaminants (Burkholder et al 2007, Lee et al 2007). These pollutants are released into surface waters (and to a lesser extent, to ground waters) and can contribute to the eutrophication of streams, rivers, and estuaries (Mallin 2003). Besides the handling and management of manure, the storage of animal feed, handling of carcasses, and disposal of excess or expired pharmaceutical chemicals may also contribute to the release. Animal manure, including liquid and solid wastes, is stored on site at CAFOs and applied to agricultural lands as a needed fertilizer (Keeney and Gilbert, 2000; Mallin and Cahoon, 2003). Failure of the manure storage systems may result in massive pulse inputs to surface waters (Mallin, 2000). Chronic inputs result from normal operations that require direct release of animal manure to terrestrial surfaces. In most agricultural areas, land application of animal manure is both a convenient waste disposal method and a source of nitrogen and other nutrients for row crops. Environmental exposure to contaminants associated with animal manure is therefore an inevitable product of CAFO development. This section will briefly describe the major chemical and biological contaminants, the common methods for measurement, and the potential risks to human health.

Exposures to waterborne chemical and biological contaminants in surface waters. Waterborne chemical contaminants that may be associated with CAFOs include nitrogen and phosphorus, veterinary antibiotics and hormones, pesticides, and heavy metals. Nitrogen and phosphorus are essential nutrients for plant growth. Antibiotics are used to prevent and treat bacterial infections for animals held in close quarters and, along with the heavy metal arsenic, are routinely added to animal feed as a growth promoter. Pesticides are used to control insect infestations and fungal growth. Heavy metals, especially zinc and copper, are added as micronutrients to the animal diet.

Nitrogen and phosphorus are major constituents of manure (and all animal waste) and required additives for many row crops. Application of manure to agricultural soils is a low-cost alternative to chemical fertilizers that are energy intensive and expensive to produce. Whether in synthetic or manure form which the USDA has found larger CAFOS apply at unsustainable rates (Arbuckle and Downing, 2001). As a result, surface waters in the Midwest experience high concentrations of these nutrients that are directly linked to the percent of the watershed dedicated to agricultural production (U.S. Department of the Interior, 1999). In Iowa, surface water concentrations of nitrate nitrogen are among the highest in the nation (Goolsby *et al*, 1999). High concentrations of nutrients in surface waters cause excess algal and bacterial growth and subsequent reductions in oxygen concentrations(Rabalais *et al*, 1996).

The spatial distribution of CAFOs on the agricultural landscape is statistically associated with higher concentrations of nitrate in rivers and streams. Weldon and Hornbuckle (Weldon and Hornbuckle, 2006) showed that CAFOs contribute more nitrogen to surface waters than expected from a mass balance analysis. A mass balance analysis of 17 watersheds in Eastern Iowa show that most of the nitrogen applied to the watersheds is applied as chemical nitrogen (mostly anhydrous ammonia). Manure application is a small input, as is human and nonagricultural wastewater effluent. Nevertheless, measurements of nitrate in rivers and streams show a strong correlation between high nitrite water concentrations and high density of CAFO facilities on the landscape.

Pharmaceuticals are commonly found in surface waters (Teeter and Meyerhoff 2003, Daughton and Ternes 1999). Human wastewater and landfills that handle human waste have been strongly implicated as sources of pharmaceuticals such as antibiotics, pain relievers, caffeine, and hormones, clearly related to human use. Some compounds are produced primarily for animal treatment but their presence in the environment and can be used as indicators. Tylosin is a widely used macrolide antibiotic for therapeutics and growth promotion in swine, beef cattle, and poultry production. It has not received as much research attention, despite significant potential for release (Burkholder et al 2007). Tylosin, a fermentation-derived macrolide antibiotic, is an example of a veterinary pharmaceutical that decays rapidly in the environment but can still be found in surface waters of agricultural watersheds (Song *et al*, 2007).

Measurement Methods. Nitrate and nitrite in surface waters are measured routinely by EPA method 353.2, a colorimetric method that requires a filtered sample be passed through a column containing granulated sorbent. The resulting solution (now converted to nitrate) is analyzed by derivitizing to form a colored dye which is measured colorimetrically. Measurement of nitrogen in other forms is completed using methods referenced in the Table 4.8.

Table 4.8. River sample measurements, test methods and uncertainties.

Measurement	**Method (IDNR sites)**	**Uncertainty in Measure**
Total Kjeldahl Nitrogen	TIM 786-86T	+/- 14%
Nitrate plus Nitrite	EPA 353.2	+/- 10%
Ammonia Nitrogen	TIM 780-86T	+/- 14%
Organic Nitrogen	Calculated	Calculated
Total Nitrogen	Calculated	Calculated

Measurement of veterinary pharmaceuticals in natural waters typically requires that waterborne compounds are extracted to a solvent phase using solid-phase extraction (SPE) or with liquid-liquid extraction (LLE). Both extraction methods strive to concentrate the pharmaceuticals to solvent-phase concentrations that can be detected using mass selective methods. The most common instrumentation for detection is high-performance liquid chromatography with mass spectrometry and ion electrospray (HPLS/MS-ESI(+)) (Kolpin *et al*, 2002). This method typically uses select ion monitoring (SIM) to increase analytical sensitivity and the internal standard method. When the compounds are at higher concentrations, such as those used in experimental studies of chemical fate and transformation, HPLC with ultraviolet absorbance detection can be used (Hu and Coats, 2007).

F. COMMUNITY HEALTH EFFECTS

F.1. Populations Vulnerable to Air Pollutants

For many reasons, permissible exposure limits for air pollutants are significantly lower for communities than for the same agent in the workplace. A community comprises an entire population, including children with still developing organ systems, and therefore vulnerable lungs, brains, and immune systems. In addition, childhood asthma is one of the most common diseases of childhood ranging in prevalence from 10-20%, and not necessarily lower in rural areas than urban centers (ISAAC 1998;Chrischilles et al 2004). Communities, especially in rural areas, include a large number of the elderly many of whom have pre-existing conditions including, most commonly, those with chronic heart disease and also with chronic bronchitis, emphysema and adult onset asthma. All those living in communities are potentially exposed to any air pollutant for up to 24 hours a day, seven days a week—unlike workers who have limited durations of exposure, but at much higher concentrations. Also community residents are less able to relocate to no or low-exposure communities, whereas workers have more flexibility in where they live and where they work.

F. 2. Air Exposure Health Effects

Adverse health effects arising from exposure to CAFO air emissions fall into two categories: 1) respiratory symptoms, disease and functional impairment, and 2) neurobehavioral symptoms and impaired function. The impact on health of those living in proximity to CAFOs has been the subject of increased epidemiological research.

Respiratory health outcomes. A large number of chemicals and mixtures of chemicals have been well-documented components of CAFO emissions. Information regarding adverse health effects, especially adverse respiratory health outcomes, have come from studies of occupational, experimental, and non-CAFO community exposures, many of which were made among selected populations of workers or healthy volunteers. Important documented community respiratory exposures fall into three broad categories and include ammonia, hydrogen sulfide, and particulates including bioaerosols. Adverse respiratory outcomes associated with relatively high occupational exposures have been addressed in Section C of this report and have been summarized in detail elsewhere (ISU-UI CAFO Report 2002).

Ammonia is an important component of animal waste and a well-recognized human toxin. Water soluble, ammonia is rapidly adsorbed in the upper airways, damaging airway epithelia and leading to irritation of the skin, eyes, nose and sinuses. Ammonia may reach the alveoli via adsorption to respirable particles found in complex mixtures arising from CAFOs, an important consideration in a research-based recommended occupational exposure limit of 7 ppm (See Table 4.1). Similar occupational exposures (9 ppm) were observed among soda ash workers who reported increased symptoms of coughing, wheezing, and nasal, eye, throat and skin irritation (Holness et al 1989). The EPA has found that animal agriculture operations are responsible for almost three-fourths of ammonia air pollution in the United States (Harris et al 2001b). EPA has recommended a long-term MRL of 300 ppb for community exposures.

Hydrogen sulfide is one of the most recognized gases arising from the storage, handling and decomposition of animal wastes. Smelling like rotten eggs, this gas is both an irritant and an asphyxiant. For community exposures, EPA has recommended a reference concentration for long-term exposure of 7 ppb.

Several experimental, occupational and non-CAFO community studies have provided insight regarding adverse health effects from low-level exposures to hydrogen sulfide. Members of a mobile monitoring team from the Texas Natural Resource Commission who were evaluating hydrogen sulfide downwind from an oil refinery reported eye and throat irritation, headache and nausea following exposures of 0.09 ppm (30 minute averages) over a period of five hours (Texas Natural Resources Conservation Commission, 1998). A US Public Health Service study of a general population exposed to levels of H2S in excess of 0.3 ppm reported shortness of breath, eye irritation, nausea, and loss of sleep (USPHS 1964). A community study of chronic exposure to hydrogen sulfide and TRS (total reduced sulfur) compounds (H2S annual means of 0.006 ppm and daily means of 0.07 ppm), found that both asthma and chronic bronchitis were somewhat more prevalent, that eye and nasal symptoms were more frequent and that these symptoms were dose related (Jaakkola et al 1991). Haahtela et al (1992) studied community residents exposed to four-hour peak concentrations of 0.095 ppm and daily means of 0.025 and 0.030 ppm on two days of exposure, compared with control days with four-hour peak concentrations of 0.00007 and a 0.002 ppm, and reported eye and throat irritation and cough more frequently during the peak exposure days. Both Jaakkola and Haahtela concluded that the WHO guideline of 0.10 ppm for a 24-hour average did not provide adequate protection. Partti-Pellinin et al (1996) studied a general population exposed to TRS levels up to 0.1 ppm over a 24-hour period and reported more cough, respiratory infections, and headaches than was found in the reference community. On days when 1-hour daily or daily mean TRS levels exceeded 0.028 ppm, headaches, depression, tiredness and nausea were more frequently observed. Campagna et al (2001) studied the effects of hydrogen sulfide and TRS levels associated with hospital visits for respiratory diseases among children and adults and observed an increase in asthma the day following peak community exposures to TRS among children, and an increase in all respiratory disease visits following peak exposures for both TRS and hydrogen sulfide.

Particulates are important components of the complex mixture of chemicals arising from CAFOs. Particles between 4 and 10 microns settle in the upper airways while particles less than 2.5 microns may reach small airways terminal bronchioles. Community exposures to particulates have been studied extensively in urban air pollution studies and have been associated with asthma, bronchitis, and impaired lung function among children (Peters et al 1999). In addition to the direct inflammatory effects of inhaled particles, respirable organic dust contains inflammatory agents and may convey inflammatory gases and chemicals deeper into the lung thereby enhancing their toxic effects.

Bioaerosols arising from high concentrations of microorganisms are also important components of CAFO emissions, the most important of which are endotoxins. Endotoxins are ubiquitous in the environment, but present in very high concentrations in organic dusts from grain elevators or feed milling operations, and also from CAFOs. Endotoxins are now recognized to be important components of these agricultural exposures and have been associated with airway inflammation resulting in occupational asthma and bronchitis manifest most commonly by symptoms of cough, chest tightness and less frequently shortness of breath. While several studies have now found lower levels of atopy and asthma among children raised on farms and therefore exposed to bioaerosols (a finding attributed to the hygiene hypothesis), there is also evidence that higher levels of ambient exposure to endotoxin in homes may result in increased rates of asthma. Park et al (2001) reported that infants who had at least one asthmatic/atopic parent, were at increased risk to wheezing if the home had high levels of endotoxin. Douwes et al (2000), in a community study of household dust, found that endotoxin dust concentrations were associated with increased peak flow variability among asthmatic children. Michel et al (1991) reported that asthmatic patients with higher levels of home endotoxin exposure developed more symptoms and required more intensive medical treatments than those living in homes with lower endotoxin levels. In a separate study, Michel et al (1992) confirmed that asthma severity correlated with endotoxin exposure. Rizzo et al (1997) found that endotoxin content of home dust correlated significantly with symptom scores in asthmatic children.

Community studies of respiratory symptoms and asthma now show a clear association with proximity to CAFOs, confirming a previous assessment that CAFO emissions constitute a health hazard resulting in elevated rates of respiratory symptoms and asthma (ISU-UI CAFO Report 2002). Early studies of residents living in proximity to CAFOs reported increases in respiratory symptoms of cough, chest tightness and shortness of breath (Thu et al 1997), and burning eyes, sore throat and coughing (Wing and Wolf, 2000). These studies were relative small and likely affected by recall bias. The pattern of symptoms was, however, noted to be similar to that observed among CAFO workers, but less prevalent and less severe—both consistent with lower dose exposures expected in the community setting.

While not a study of CAFO exposure, Chrischilles and colleagues reported a high prevalence of wheeze (19.1%) among children ages 6-14 enrolled in all 10 school districts in two non-contiguous, highly agricultural Iowa counties. The prevalence of doctor-diagnosed asthma

(13.4%) was also high and, like wheeze, similar to prevalence rates in urban studies of childhood asthma (ISAAC 1998). Among those who wheezed, farm and non-farm children were equally likely to have been given a diagnosis of asthma and had comparable morbidity—unlike several European, Canadian and Australian studies of children which showed a protective effect of growing up and living on a farm, a finding attributed to the hygiene hypothesis (Braun-Fahrlander et al 1999, Downs et al 2001, Ernst and Cormier 2000, Kilpelainen et al 2000, Riedler et al 2000, Riedler et al 2001, Von Ehrenstein et al 2000, Wickens et al 2002). National differences in the scope and intensity of livestock production are thought to be the likely explanation for these differences between US and non-US studies (Merchant et al 2005).

Four larger epidemiological studies have now demonstrated strong and consistent associations between CAFO exposures and asthma. Merchant and colleagues (2005), in a county-wide, prospective study of 1000 Iowa families, reported a high prevalence of asthma outcomes among farm children living on farms that raise swine (44.1%) and raise swine and add antibiotics to feed (55.8%), despite lower rates of atopy and personal histories of allergy. A limitation of this study was that most of these children lived on family-owned CAFO farms and many (an undocumented proportion) worked doing chores or were exposed as bystanders to occupational-level CAFO exposures. The authors called for greater awareness of asthma risk among children living and working on CAFO farms, for greater awareness of asthma risk and diagnostic standards among rural health care providers, for implementation of farm-based prevention measures and for more population-based studies to assess environmental and genetic determinants of asthma among farm youth exposed to CAFOs.

Sigurdarson and Kline (2006) studied children from kindergarten through fifth grade in two rural Iowa schools, one located one-half mile from a CAFO and the other distant from any large-scale agricultural operation. Children in the school proximate to the CAFO had a significantly increased prevalence of doctor-diagnosed asthma (adjusted odds ratio, 5.71; p=0.004), but no difference was noted in the severity of asthma between the two populations. Potential biases, among children living close to the CAFO, included children who were more likely to live on a farm (occupational-level CAFO exposure was not assessed) and more children lived in houses where parents smoked; neither of these confounders were thought to explain the increase in asthma prevalence. The authors noted that physicians responsible for medical care of these two groups of children differed and therefore physician bias in asthma diagnosis could not be ruled out.

Mirabelli and colleagues published two papers arising from a study of 226 North Carolina schools ranging in distance from 0.2 to 42 miles from the nearest CAFO (Mirabelli et al 2006a, 2006b). Sixty six schools were located within three miles of a CAFO or CAFOs and livestock odor was noticeable outside 47 schools and inside five schools. The prevalence of livestock odor was found to vary by racial and economic characteristics, (Mirabelli 2006a). Using data fromadolescents ages 12-14 regarding allergies, medications, and household environments (n=58,169), a sample of schools (n=265) and public information about North Carolina CAFOs (n=2343), and a survey of qualitative estimates of odor for each school, the authors were able to generate estimates of exposure measured in distance (miles) from CAFOs (Mirabelli 2006b). The prevalence of wheezing in the last year was slightly higher at schools likely to be exposed to CAFO effluent. Among students with histories of allergies, the prevalence of wheezing within the past year was 5% higher at schools located within three miles of a CAFO, compared to schools greater than three miles away, and 24% higher at schools in which livestock odor was noticeable indoors twice per month or more, relative to schools with no odor. Children living within three miles of a CAFO also had significantly more doctor-diagnosed asthma, used more asthma medication, and had more asthma-related emergency room visits and/or hospitalizations in the last year than children living more than three miles from a CAFO. While this is a large, well controlled study, results may have been influenced by selection bias in the communities in which the schools were located. The study is also vulnerable to systematic error that would be introduced if students with asthma or asthma symptoms changed their living environment or behaviors because of exposures arising from CAFOS or because of medical treatment for asthma symptoms; however, these influences would have enhanced rather than reduced asthma outcome rates.

Radon and colleagues (2007) conducted a 2002-2004 survey among all adults (18-45) living in four rural German towns with a high density of CAFOs. Questionnaire data were available on 6937 (68%) of eligible adults. Exposure was estimated by collecting data on odor annoyance and geo-coding data on the number of CAFOs within 500 meters of the home. Analyses were limited to those without private or professional contact with farming environments to control for occupational health effects. The prevalence of self-reported asthma symptoms and nasal allergies increased with self-reported odor annoyance; the number of CAFOs was found to be a predictor of self-reported wheeze and decreased FEV1. While odor varied from day-to-day, reasonable test-retest reliability of the question on odor annoyance in the home environment was reported (kappa=0.51). Sources of bias in this study include a somewhat dated (2000) registry of CAFOs and possible exposure misclassification.

These recent, large and well-controlled studies are consistent in finding associations between proximity to CAFOs, asthma symptoms and doctor-diagnosed asthma, but they all use proxies for environmental exposure to CAFO emissions. Validated dispersion models that take into account CAFOs numbers, density, and emission measurements as well as meteorological conditions, are important research needs to better define environmental health risks . Nevertheless,, these collective studies provide reason to increase community awareness of asthma risk proximate to CAFOs, to better inform rural doctors of standards for asthma diagnosis and reported association with CAFOs and to pursue local and state environmental measures to minimize asthma risk to children and adults living in proximity to CAFO exposures.

Neurobehavioral outcomes. Volatile organic compounds are important components of the thousands of gases, vapors, and aerosols present in CAFOs and over 24 odorous chemicals, often referred to as odorants, have been identified (Cole et al, 2000). Valeric acids, mercaptans, and amines are particularly odorous, even in miniscule concentrations. Ammonia and hydrogen sulfide are also pungently aromatic. Many of these compounds are known to be neurotoxic in sufficient concentration. It is therefore not surprising that the few studies that have examined neurobehavioral effects among residents living in proximity to CAFOs have documented increased rates of neurobehavioral symptoms and depression.

Schiffman and colleagues (1995) studied North Carolina residents who lived in the vicinity of intensive swine operations (n=44) and compared findings among this group to matched control subjects who did not live near to CAFOs. While this small study is subject to selection bias, using a validated Profile of Mood States, the authors found more negative mood states (factors included tension, depression, anger, reduced vigor, fatigue, and confusion) among those living proximate to CAFOs. Greater total mood disturbance was also reported by those living near swine operations. How odors from CAFOs may result in these symptoms was the subject of a Duke University workshop that explored possible paradigms by which odor may result in neurobehavioral health effects (Shiffman et al 2000).

Kilburn (1997) in a study of chronic (non-CAFO) occupational exposures to hydrogen sulfide, found that such exposures among selected subjects may lead to neuropsychiatric abnormalities including impaired balance, visual field performance, color discrimination, hearing, memory, mood and intellectual function. Also, Legator reported abnormal results from neurobehavioral testing among people with chronic exposures estimated to range from 0.1 to 1.0 ppm (Legator 2001).

It is recognized that there is great variability between odors arising from CAFOs, and that odorous gases may be transformed through interactions with other gases and particulates between the source and the receptor (Peters and Blackwood 1977). There remains a need to combine quantitative measures of odors with environmental measures of a suite of odorants in well-designed, controlled studies of neurobehavioral symptoms and signs in community-based studies.

F.3. Water Exposure Health Effects

The presence of excess nutrients, including nitrate, in surface waters can cause growth of cyanobacteria and other microorganisms that may be harmful to people with depressed or immature immune systems (Koplin et al 2002). Methemoglobinemia (blue baby syndrome) is a rare but serious illness in infants caused by the conversion of nitrate to nitrite in the body which can interfere with the oxygen-carrying capacity of blood. Chronic exposure may lead to diuresis, increased starchy deposits and hemorrhaging of the spleen (Ward *et al*, 2005)Hu and Coats 2007) and has a positive correlation to the incidence of bladder cancer (Weyer *et al*, 2001)Carpenter et al 1998). The US EPA sets allowable limits for nitrate of 10 mg/l in public drinking water supplies and requires tertiary treatment or amendment with ground water before distribution (U.S. Environmental Protection Agency, 2002)US EPA 2002).

The presence of veterinary pharmaceuticals in surface and ground water has not been linked to acute effects in humans. However, the potential for subtle effects of chronic exposure has been noted. Daughton and Ternes (1999) were among the first to warn that the constant release of these compounds results in chronic exposures to aquatic organisms that may cause effects commonly attributed to much more persistent compounds. A review by Fent et al (2006) concludes that chronic effects to humans from exposure to low levels of veterinary pharmaceuticals are unlikely. However, this paper and references therein note the almost complete lack of definitive toxicological data on subtle chronic effects for these compounds, especially for human effects.

F.4. Zoonotic Pathogen Exposure to Communities

Communities both nearby and distant from CAFOs are subject to zoonotic pathogen infections from agents that circulate among CAFO livestock. Transmission to communities may occur through several means:

Meat Product Processing - Zoonotic pathogens may be transmitted to communities through meat processing or inappropriate food preparation. As previously described, numerous zoonotic pathogens have been transmitted in this fashion, especially Campylobacter, Salmonella, and Listeria species as well as enterohemorrhagiv E. coli. Once detected, such meat product contaminations have led to widespread recalls of food products that have spanned wide geographical areas.

Waste Contamination – As described above, CAFO waste products have great potential to contaminate the environment of nearby communities and the humans residing in these areas. This may occur through contaminated ground water, fomites, or aerosols.

CAFO Worker Transmission - CAFO workers may serve as a bridging population in sharing animal pathogens with their close human contacts in their communities (Gray et al 2007a, Gray and Baker 2007). Gray et al (2007b) recently found evidence that spouses of swine workers who denied having direct contact with swine had markedly elevated antibodies against swine influenza viruses compared to nonswine-exposed university controls. These data suggest possible secondary transmission or fomite transmission of swine influen virus to the spouses. In a similar fashion, reports from the Netherlands (de Neeling 2007) and Canada (Khanna T 2008) have suggested that pig workers and pig farms may be a source of methicillin-resistant staphylococcal aureous transmission to surrounding communities. There is also evidence that animal workers may play a role in the transmission of antimicrobial-resistant strains of bacteria to communities (Levy 1976). This may occur through gene transfer from an animal pathogen to a human pathogen (Shoemaker 2001) or through direct transmission from an animal strain to man.

Rodent, Bird, and Insect Vectors – Nondomestic animal, birds, and insects may also contribute to the community spread of zoonotic pathogens from CAFOs. This is particularly true for bacterial pathogens but recent evidence also suggests vectors have a role in viral pathogen transmission. For instance, a report from Japan has suggested that blow flies may play a role in highly pathogenic avian influenza virus transmission (Sawabe et al 2006). Another paper implicated mosquitoes as possible mechanical transmitters (Barbazan 2008). Animal studies well-described in other chapters of this report document the potential for rodent, bird, and insect vectors to transmit CAFO pathogens through direct contact (mechanical transmission) or through ingestion and excretion in waste. While rodents and insect vectors have very limited activity ranges, birds that enter a CAFO have the potential to share animal pathogens with other animals and humans quite remote from the affected CAFO.

All of these observations and the fact that 75% of human emerging pathogens originate from animals argue for better assessment and surveillance of zoonotic pathogens in the CAFO environment (Taylor, Latham and Woolhouse 2001; Woolhouse ME, Gowtage-Sequeria S. 2005).

G. PREVENTION STRATEGIES

G.1. Infectious Disease Agent Surveillance and Reporting

The detection and reporting of zoonotic pathogens in CAFOs depend upon appropriate pathogen surveillance, effective laboratory identification of pathogens, and effective laws regarding the reporting of diseased animals and the presence of pathogens. Federal authorities from the US

Department of Agriculture and the Occupational Safety & Health Administration have limited access to CAFO facilities and must often rely upon voluntary industry pathogen surveillance programs and the cooperation of management. In CAFOs there is considerable opportunity for the emergence of novel pathogens that may impact a nation's public health. There is also incentive for industry management not to self-report problems as disease reporting can result in economic disaster for animal agriculture and food production businesses. Delays in reporting zoonoses have undoubtedly contributed to zoonotic pathogen distribution in food products and increased human pathology.

Essential to more accurate and timely surveillance of infectious diseases arising from livestock operations is a national animal identification system to be implemented at the point of sale. Having federal meat inspectors working inside meat production facilities has greatly decreased contamination in meat products, but CAFO facilities are less scrutinized and pathogen transmission is sometimes first detected when animals are brought to market. Greater incentives for pathogen reduction in CAFOs must be created to reduce zoonotic pathogen risk to consumers. Longitudinal integrated safety assurance programs in some developed countries have been quite promising and led to encouraging success stories. For instance, the recent withdrawal of antimicrobials in some Northern European countries has reduced the prevalence of multi-drug resistance pathogens and yet not reduced animal growth or otherwise negatively impacted the flocks and herds (Collins and Wall 2004).

G.2. Best Management Practices

One mechanism to reduce environmental release of, and human exposure to, CAFO effluents is the promulgation or recommendation of specific technologies and process management techniques for the production of livestock and poultry in CAFOs. These best management practices (BMPs) encompass manure management and water contamination control, air emission control, biosecurity and pathogen control, and animal carcass handling and disposal.

Implementation of BMPs is limited by a number of factors. First, their consideration is often guided by what industry engineers regard as economically feasible in terms of retrofitting existing facilities with minimal capital outlay and operating cost. This evaluation of economic feasibility usually does not consider costs incurred to neighboring communities, such as adverse health effects, loss of enjoyment of property, contamination of surface waters, and higher costs of drinking water treatment for downstream communities. Second, opportunities for implementing BMPs for new CAFO construction are lost because few perceived incentives exist for adoption of enhanced systems. Third, state and federal policies in the US typically rely on voluntary conservation programs and incentive payments (Kara et al 2007), although filing nutrient management plans may be required. In Europe mandatory BMPs have been used extensively over the past decade in countries such as The Netherlands and Denmark as a means to reduce emissions of hazardous air pollutants and odors, greenhouse gases, and nutrients into surface waters. They have also been implemented to control transmission of veterinary infectious diseases and for enhancement of livestock animal welfare.

Nutrient BMPs are designed and employed to eliminate discharge of animal waste into surface waters and into groundwater; to reduce emission of ammonia, hydrogen sulfide and odors; to reduce production and prevent release of disease-transmitting vectors and pathogenic bioaerosols; and to eliminate pollution of soils, surface water and groundwater with nutrients, heavy metals, steroidal hormones, antibiotics, and ectoparasiticides (Williams 2007, Khan et al 2007). BMPs for nutrients should employ environmentally superior technology that requires separation of the liquid fraction from solids to reduce effluent volume (Williams 2007). The solid portion is then treated as a commodity; minus the liquid fraction it can be economically transported for use as biomass or for further processing. One type of processing, anaerobic digesters, are especially applicable for dairy operations. They effectively control odors while yielding methane, which can be used as a local source of energy (Iowa DNR 2004). Actively managed composting can also be effective for processing solids. Bulking agents such as straw, sawdust, wood chips or recycled paper are added to balance carbon and nitrogen content and the manure degrades aerobically. In addition to dealing with the waste, front-end actions can also reduce some emissions from CAFO buildings. Dietary manipulations can reduce production of odorous effluents and phosphorous in manure (US EPA 2007), but these are often a further departure from a more natural animal diet which is part of BMPs for animal welfare.

Lagoon and spray field systems, designed to provide long-term storage and reduce waste volume by evaporation and volatilization, cannot be a component of BMPs. They create problems of odor, hazardous air pollution, greenhouse gas emissions, and potential transmission of infectious bioaerosols. The loss of nitrogen to the environment makes it unavailable for recycling as plant fertilizer. Manure slurry systems without spray fields can be better managed, but still are less desirable than solid systems. In the transition to BMPs, slurry systems should employ 1) covered manure reservoirs with adequate capacity to store 12 months of accumulated manure slurry, 2) planting of winter cover crops, 3) incorporation of manure slurry into the soil by injection when a crop or winter cover crop is growing, 4) soil testing and 5) equipment calibration for proper nutrient application rates. Application practices should strive for nutrient equilibrium, where nitrogen and phosphorus applications are balanced with crop utilization. Record keeping requirements include analysis of nutrient slurry for nitrogen and phosphorus content and spatial data to guide where application to fields is needed and at what rates (LPES 2001). Setbacks for the operation itself and the manure storage reservoirs should be employed to reduce offsite transmission of bioaerosols, odors and vapors. Setbacks for manure injection are also needed to separate manure from inputs to water (well, sinkhole, cave, surface water) and from dwellings or public use areas (LPES 2001). Manure should never be applied to slopes steeper than 20 percent, on frozen ground, or when it is raining. Pumping slurry from covered storage reservoirs to tanker trucks must be continuously monitored by operators.

Impermeable and permeable covers can be applied to manure reservoirs to reduce emission of particulates, odors, ammonia, hydrogen sulfide, and methane. Impermeable covers such as polyethylene will last approximately 10 years. Permeable covers can reduce emissions by acting as a biofilter, and can be constructed of waste textiles, straw, corn stover, and/or leka rock. The disadvantage is that they typically last one year or less.

Effective implementation of BMPs for control of odor and air emissions from livestock buildings must consider waste handling and processing techniques, site selection, building design, operational characteristics, and active ventilation of building exhaust through biofilters. Biofiltration systems typically employ a ducted air-handling system with effluent airflow passed through a deep-bed wood chip and straw biofilter or wetted-wall corrugated cellulose biofilter. Biofilters support the growth of microorganisms that utilize noxious gases and vapors in the effluent stream as a source of nutrients. A wood chip biofilter can last for three to five years and then be composted and the unit recharged with fresh woodchips. However, it requires more space than the vertical cellulose biofilter. These biofilters can reduce particulate matter, hydrogen sulfide, ammonia and odorous vapors by as much as 90% (Danish Pig Production 2006, Iowa DNR 2004).

BMPs to reduce infectious disease transmission should restrict the movements of veterinarians, employees, vendors and equipment from one facility to another without first undergoing decontamination. Ideally, livestock should not be fed blood, tissue, or feces from other livestock or poultry, including bone and blood meal. Poultry and swine operations should be separated from one another by a distance sufficient to guard against vector-borne or airborne transmission of infectious agents.

BMPs for animal welfare are currently mandated by the European Union and are developing in the United States. BMPs suggest that livestock should be free from discomfort, distress, hunger, injury and disease. These objectives are is promoted through housing systems that provide bedding and forage material for environmental enrichment and more natural animal behavior, reduced stocking density (i.e. more space per animal), discontinued use of gestation crates for sows, use of solid or narrow slatted floors, use of more natural feeds, and improved air quality (EFSA 2007).

BMPs will only be effective if they are widely implemented. Reported experience with voluntary BMPs is mixed; some believe they are readily adopted and effective, but considerable evidence suggests they have minimal impact in the absence of enforcement or the threat of regulatory action. Research to improve BMPs and efforts to encourage the industry to adopt BMPs are ongoing. Many US state and federal agencies and agricultural extension services have extensive outreach efforts promoting BMPs. Unfortunately, many of these efforts focus on "good" management practices out of concern that many "best" management practices require higher upfront and operating costs. If the livestock industry is to reduce its environmental and human health impacts, we must consider the full range of BMPs and include a full accounting of the costs in the analysis.

G.3. Laws and Regulatory Strategies

Agriculture has had a special relationship with environmental regulations in the United States since Dust Bowl times (Egan 2006). It has generally been assumed that farmers would see their self-interest in preserving soil and caring for water quality, and neighborliness would control the odors from livestock operations. This view of farming has led to government cost share programs as the main way to control soil loss and water pollution from agriculture. Air pollution was not considered an agricultural issue when federal laws were strengthened in the 1970s. (Minnesota Environmental Quality Board 2001)

In addition to there being fewer regulations to protect the environment, CAFO neighbors receive less protection from the agricultural operations' various emissions. Some states have attempted to blunt individual legal action against agricultural operations through "right-to-farm" laws.

These laws are based on the principle that “existing farm operations should not become nuisances due to the later development of non-agricultural uses in the surrounding area” (Hamilton 1998). As agriculture evolved to an industrial scale, regulations and freedom from complaints from neighbors hardly changed. Right-to-farm laws would protect CAFOs even if they arrived in the neighborhood later than other rural residents and whether or not they cause harm to established farmers. (Delind 1995).

The evolution of livestock farming to an industrial scale has changed the scale and type of pollution from the industry. Merkel in remarks to this Commission reported that a single dairy operation in Oregon produces more ammonia in a year than the largest industrial emitter (Merkel 2006). Still this industrial reality has been slow to change the approach of governmental environmental controls on agriculture, which continues to be given leniency under major federal environmental laws (Merkel 2006).

CAFOs have been given an amnesty program from prosecution under the federal Clean Air Act (Federal Register 2005). The Administrative Consent Orders (AFOs) between the EPA and the industry cover more than 6,000 operations that have been given the option of signing an AFO and receiving immunity from past and present violation of several federal environmental laws. In exchange for amnesty the industry agreed to allow the EPA to monitor a small number of operations to determine how the industry is to be regulated (Merkel 2006).

The main regulation of point sources of water pollution under the Clean Water Act has missed large and small livestock operations. The Government Accountability Office found that three states, each with more than 1000 large animal feeding operations, had not issued any discharge permits and that eight other states with at least this number of operations issued permits that did not include all required elements. According to the GAO, EPA officials stated that they had historically paid little attention to state programs to which they had delegated authority to issue water permits (US GAO 2003).

In 2007, the livestock industry is attempting to be permanently relieved from compliance with two federal acts, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) better known as Superfund and the Emergency Planning and Community Right-to-Know Act (EPCRA). Hearings were held as recently as September 2007 on whether to weaken legislation that has been used by cities to attempt to make CAFOs contribute to the cost of improving water treatment or to require CAFOs to improve their waste discharges. Agricultural organizations have claimed that these laws are unnecessary because state and local regulation is adequate to protect the environment and neighbors from the emissions from CAFOs (Dove 2007).

Local regulation is severely limited in the state of Iowa mainly because the state legislature has preempted county government from controlling location and emissions from CAFOs. It is common for higher levels of government to constrain (or preempt) lower levels to keep laws consistent. However, when the federal government preempts the states it generally allows the states to go beyond the federal requirements. In the case of environmental legislation, state governments occasionally prevent local governments from passing stronger environmental health standards (Minnesota Environmental Quality Board 2001)

The state of Iowa, the leading state for the production of pork and eggs, serves as an example of how CAFOs are regulated by county action, state action and local action. A series of Iowa Supreme Court cases have established that the state legislature can limit any local government action on where CAFOs are located or whether there can be limits on their discharges. The Iowa Supreme Court held that all agriculture, including an animal feeding operation, is exempt from any county zoning (Kuehl v. Cass County 1996). Humboldt County later attempted to put controls on CAFOs as a proper application of "home rule" authority but lost in the Iowa Supreme Court (Goodell v. Humboldt County 1998). In the face of this state preemption, a Worth County ordinance sought to regulate CAFO operators based not on home rule, but on the county's ability to protect public health. This ordinance was also struck down as being void and unenforceable because it was contrary to state law. The opinion of the court was that "Our legislature intended livestock production in Iowa to be governed by statewide regulation, not local regulation. It has left no room for county regulation" (Worth County Friends of Agriculture v. Worth County 2004).

Iowa legislators provided an opening for local advice and limited consent when the Master Matrix went into effect in 2003. The Master Matrix is a scoring system that forces an operation to adopt measures such as greater separation distances and more stringent manure practices. However, if the operation attains a minimum score on the Master Matrix, permits will be approved by the DNR, even if there is public opposition to the operation and the county recommends against it (Stormont 2004). Of Iowa's 99 counties, only 16 have not adopted a resolution to accept the Master Matrix as of September 2007 (Iowa DNR 2007).

Iowa passed the first major statewide law that placed restrictions on CAFO operators in 1995, attempting to balance protection of Iowa's environment and neighbors with continuation and expansion of the hog industry (Braun 1995). Manure management plans were required of the large producers. CAFOs were required to be separated from neighbors and public use areas to reduce conflicts over air emissions and odor. A 2002 Iowa law extended the separation distances, reduced the size of operations needing construction permits, instituted the Master Matrix, and included limits on air quality for the first time. The 2002 law for the first time called for emission limits on hydrogen sulfide. Both laws successfully constrained local government from legislating CAFOs.

The Iowa state legislature has also attempted to limit an individual's right to take a CAFO to court. Protection of agricultural operations from individual nuisance action has been attempted by many state courts but several states have ruled that these so-called right-to-farm laws give only limited protection from nuisance action (Hamilton 1998). In 1998 the first of livestock's nuisance immunity provisions fell in the Bormann case (Bormann v. Board of Supervisors in and for Kossuth County), which applied to a very few acres organized as special agricultural districts. Beginning in 2001 Iowa district court judges ruled in several cases that Iowa law protecting CAFOs against nuisance suits in all areas of the state is unconstitutional (Iowa Civil Liberties Union, Perkins and Beeman). In October 2002 a case by neighbors against a CAFO owner was decided with a judgment for the plaintiff of $1 million for actual damages and $32 million for punitive damages (Blass et al v. Iowa Select Farms, LP). The case was settled out of court in 2003. Finally, in 2004, the Iowa Supreme Court declared all nuisance immunity laws covering

CAFOs unconstitutional (Gacke v. Pork XTRA, LLC, 2004). Nuisance suits may prove to be a powerful incentive for CAFO owners to reduce emissions in Iowa and other states (Herriges 2003).

North Carolina, which ranks second in pork production, has taken a different regulatory approach from that of Iowa. A law passed in 1991 that exempted large-scale hog farms from local zoning regulations led to the state's meteoric rise in hog production. Limits were placed on the location of new hog buildings in 1995 and, in 1997, the first moratorium was imposed on the construction of farms with more than 250 hogs or the expansion of existing large farms. A second moratorium was imposed in 1999 which applied to farms not using environmentally superior technologies. A four-year extension of the moratorium was imposed in 2003 (Duke University, Center on Globalization, Governance & Competitiveness).

Another novel action in North Carolina was the agreement in 2000 between Smithfield Foods, Premium Standard Farms and the Attorney General of North Carolina to provide millions of dollars to universities in the state to develop environmentally superior technologies (ESTs) for managing hog waste. A great deal of research was done but none of the ESTs evaluated were determined to be economically feasible for existing farms. However, five technologies were found to be applicable to new facilities (Duke University, Center on Globalization, Governance & Competitiveness). Legislation was proposed to impose ESTs and eliminate both lagoons and spray fields in the state but all proposals failed in the most recent session of the North Carolina legislature (Dove 2007).

In 2007 a cost share program to upgrade lagoons was passed by the North Carolina Legislature. The law bans construction or expansion of lagoons and sprayfields but existing lagoons are not required to be closed. In addition, failing lagoons can be replaced if they are upgraded and are not located in the 100-year flood plain. Cost sharing of payments of 75% to 90% is available for farmers to install new systems on existing facilities (Environmental Defense 2007). This program demonstrates again that agriculture is treated differently from other industry. Meeting environmental standards is voluntary and anything required to change a system that has been shown to be inadequate requires a payment by the public in order to be improved. While the new law is hailed by Environmental Defense as a vast improvement, CAFO activist Rick Dove sees it as more of the same inadequate governance (Environmental Defense 2007, Dove 2007).

The policies adopted by the two leading hog states fail to adequately address the impacts of CAFO emissions on public health. A portion of the public health community reacting to the inadequacy of earlier policy addressed the problem as follows:

> 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 (American Public Health Association, 2004).

The APHA approach presumably would spur more innovative animal production methods to lower impacts on air emissions, water quality, and the effectiveness of antibiotics (Osterberg and

Wallinga, 2004). However, CAFOs in major farm states continue to be regulated as if the industrial revolution in agriculture had not happened.

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