Health Effects from Breathing Air Near CAFOs for Feeder Cattle or Hogs

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ABSTRACT. There is concern that livestock operations for fattening cattle and raising hogs known as concentrated animal feeding operations (CAFOs) release substances into the air that have negative effects on the health of persons living nearby. These substances include dust containing endotoxin and other microbial products as well as ammonia, hydrogen sulfide and a variety of volatile organic compounds. Odors from these farms are considered offensive by some neighbors. A variety of medical complaints are reported to be more common in those people who live near CAFOs for raising hogs than in people without this exposure. Respiratory health effects, including symptoms of pulmonary disease and lung function test result abnormalities, have been described in workers employed in CAFOs where hogs are raised. Health effects after inhalation exposure of neighbors to substances released into the ambient air from these farms is less well characterized. It must be noted that CAFO workers may differ from neighbors in terms of their exposures and general health status. The presence of dust and other substances from cattle feedlots also causes some neighbors to voice concerns about the impact on their health but this exposure has been studied less extensively than exposure to substances released from CAFOs where hogs are raised. Further research needs to be done to look for measurable health effects attributable to living near all CAFOs in order to better understand the impact of these farms.

KEYWORDS. Concentrated animal feeding operations, endotoxin, organic dust, hog dust, cattle feedlots, respiratory health

INTRODUCTION

Increasing numbers of cattle and hogs are raised or fattened in intensive livestock operations in North America, Europe and elsewhere. Some people who live near these farms have voiced concerns about human health effects from exposures related to their presence, particularly hog confinement facilities and cattle feedlots.[1,2] There has been a great deal of public debate about the medical, economic and social impacts of this type of livestock farming. Also, the possible impact on human health of these operations has been the focus of a number of research studies.

Intensive livestock operations are often known as concentrated animal feeding operations (CAFOs). CAFOs, and their smaller rela-

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tives, animal feeding operations (AFOs) are defined by the U.S. Environmental Protection Agency (EPA) according to the total number and liveweight of the herd on feed.[3] The majority of the information published about human health effects from breathing the air in and near CAFOs comes from studies conducted on persons who work inside hog confinement barns. Some respiratory conditions and related health problems are more common in these workers than in the general population. As this complex topic is discussed, care must be taken to avoid drawing conclusions about the nature or extent of neighborhood human health effects using only what is known about occupational health problems seen in CAFO employees. For example, hog odor can be quite apparent in the neighborhood as well as inside the barns. However, one cannot assume that the neighborhood exposure is sufficient to cause the same health effects that some workers experience. Assumptions should not be made about neighborhood human health effects from measuring the impact on air quality without (1) directly assessing those effects and (2) measuring the air-quality parameters thought to be associated with them.

The presence of excessive airborne dust in the air is the concern raised most often by persons living near cattle feedlots. Identifying and understanding the human health effects of living near feedlots are complicated by the fact that neither the occupational health effects in feedlot workers nor the neighborhood health effect of these facilities has been formally studied. This paper reviews neighbor health and worker effects of airborne emissions from hog and cattle CAFOs.

THE HOG CONFINEMENT BARN ENVIRONMENT

Hog confinement facilities are buildings in which the hogs spend their entire lives. They are given a feed that consists of ground grain and soybeans. The animal waste is typically flushed out with water, the manure slurry collected and usually stored under anaerobic conditions in one of several possible structures: a pit below the concrete floor of the building, a lagoon, or in a deep basin. This manure slurry is applied to the land as a fertilizer at a later date. Hog confinement barns are complex environments from an air quality perspective. Dust collected within the barns consists largely of feed components but also contains swine fecal matter and dander, bacteria and molds.[4] More than 330 volatile organic compounds and fixed gases have been described from swine facilities using gas chromatography and mass spectroscopy.[5] Most of the gases are present in very low amounts and likely contribute only to the characteristic odor associated with swine confinement operations. Respiratory symptoms in workers have been found to be associated with total and respirable dust concentrations, endotoxin in the dust and ammonia measured in the air of the barns.[6,7,8,9]

Dust in swine confinement barns is rich in bacteria and other microbes.[10,11] Endotoxin is a highly inflammatory substance found within the external cell membrane of Gram negative bacteria, which are abundant in manure. Endotoxin is the substance that has been most consistently associated with impairment of lung function in workers.[12] The presence of ammonia results from metabolism of urea in hog urine by the enzyme urease. Available evidence suggests that dust, ammonia and endotoxin act together to cause the airway disorders described above, as reviewed elsewhere.[12] Concern has been raised in several states in the U.S. by concerned citizens about the human health effects in workers and neighbors of hydrogen sulfide, a malodorous gas that comes from anaerobic manure storage facilities as well as from a number of other sources, such as the petroleum industry.[1] Hydrogen sulfide is a very toxic gas when present in hog barns at high concentrations ($\geq$ 500 ppm by volume), which is an unusual event. Short-term exposures at this level have caused death in swine confinement workers. A severe, life-threatening exposure to hydrogen sulfide has also been associated with reactive airway dysfunction syndrome, a form of asthma, in a worker with heavy exposure to hydrogen sulfide.[13] However, published studies do not support the idea that hydrogen sulfide causes respiratory disease in persons working in hog confinement facilities under ordinary conditions, when the levels are in the range of 2-3 ppm or less.[5,14,15] Hydrogen sulfide levels in swine confinement barns do not appear to be predictors of respiratory outcomes in workers.[7]

The dust emitted from the barns has not been completely characterized and has not become the focus of regulation. In contrast, gases released from hog confinement barns and lagoons into the ambient air have received more attention. Hydrogen sulfide (H_2S) can be detected at the property line of these farms in some instances and has been the subject of current or proposed ambient air quality standards in more than half of the states in the U.S., including Minnesota, Nebraska and Iowa.[16,17] Ambient air quality standards for ammonia are likewise being considered in various livestock-producing areas of North America, most notably in the province of Alberta, Canada.[18] There is an ammonia standard in place in North Carolina that can be applied to production agriculture and several other states have ammonia standards as well.[19]

The regulation of odors from hog confinement facilities and other CAFOs is a controversial topic. Recently, a group of experts was unable to reach consensus concerning the control of odors from CAFOs.[20] Some experts favor specific air quality standards limiting airborne concentrations of odor, NH_3 or H_2S at the CAFO property line. Regulatory action at the state level might be similar to that which is used to enforce the National Ambient Air Quality Standard.[21] Others favor measuring odor at residences or in public-use areas and using dispersion modeling tools to factor in the impact of frequency, duration and concentration of exposure to odor at the residence, thereby avoiding extensive monitoring.

THE CATTLE FEEDLOT ENVIRONMENT

Cattle feedlots, as we are using the term, consist of outdoor unvegetated corrals or pens in which cattle are confined, fed and watered. Pens usually have unpaved, earthen surfaces on which manure excreted by the animals accumulates over time. In arid, semi-arid or temperate regions where long-term evaporation exceeds the sum of effective precipitation (rainfall or snowmelt that remains on the pen surface instead of running off) and the moisture excreted by the animals in manure and urine, the accumulating manure will dry out over time. If compacted by machinery or hoof action, this manure consolidates into a firm surface layer. Manure that is not well consolidated, however, becomes a reservoir of "parent material" for fugitive dust, which is generated and suspended in air primarily by the shearing action of the bovine hoof on the unconsolidated manure.[22] Because fugitive dust emissions from the feedlot surface are closely tied to animal behavior, and because cattle feedlots are typically open to the environment, concentrations of airborne dust downwind of feedlots vary both diurnally and seasonally.[23] Peak concentrations of feedlot dust generally coincide with the evening spike in cattle activity combined with neutral or stable atmospheric conditions at ground level.[23] Neutral or stable conditions are characterized by low wind speeds and little to no thermal mixing. These peak concentrations are known to decrease visibility on nearby roadways and to create nuisance conditions at downwind receptors.[24]

Ongoing research across the United States and Australia is confirming that the emission of odorous trace gases (e.g., volatile fatty acids, phenols, organic sulfides, amines, NH_3 and H_2S) from cattle feedlots is likewise episodic and is closely associated with rainfall events and warm temperatures. That association is a direct result of the incomplete, microbially mediated, temperature-dependent, anaerobic digestions that occurs when excessive moisture displaces oxygen from the pore space of the surface manure layer in a cattle feedlot. Although emission rates of those gases are as yet gross and variable estimates, their ground-level concentrations downwind of open feedlots seldom approach established health-based standards or guidelines.[25,26,27,28]

NEIGHBORS' CONCERNS ABOUT ODOR AND DUST FROM CAFOS

Workers rarely complain about the odors from cattle feedlots or hog confinement barns. However, odors associated with both cattle feedlots and hog confinement facilities can be perceived as offensive by people who live nearby or drive by these facilities on public roadways.[29] Some of these individuals allege that the odors have adverse health effects as

well as a negative impact on their quality of life.[30] The characteristic odors from CAFOs are caused by a number of contributing compounds, including volatile organic compounds (VOCs), NH_3 and H_2S.[31] These odors are complex, resulting from fresh manure and its aerobic and anaerobic fermentation. Those processes result in the release into the air of VOCs, including fatty acids, alcohols and aromatic ring compounds containing carbon, sulfur and/or nitrogen.[32,33,34,35]

Dust emissions from cattle feedlots have also been an increasing concern for rural communities.[36] Dust concentrations can cause limited visibility on public roadways. Although feedlot dust has not been associated with an increased incidence of vehicle collisions overall, the risk continues to be a concern. This is especially true for feedlots located on the prevailing, windward side of high-traffic roadways. A recent chain-reaction motor vehicle accident in Nebraska with multiple fatalities was attributed to feedlot dust blowing across a road.[37] Feedlot dust concentrations are usually highest in the early evening and lowest in the early morning.[23] Odor intensity measured as dilutions to threshold (DT), appears to increase with increasing dust concentrations.[38] Published 24-hour averaged dust concentrations of PM_{10} and total suspended particulate (TSP) immediately downwind of cattle feedlot corrals have approached 1,200 and 430 micrograms per cubic meter for TSP and PM_{10} respectively, as reconstructed from sequential, short-term (3 to 6 hour) monitoring data.[38] Absolute PM_{10} concentrations and therefore compliance with National Ambient air Quality Standards for PM_{10} depended heavily on which monitoring instrument was used.[21]

Odors clearly have important effects on humans. For example, results from recent studies using imaging of the brain indicate that odors have the ability to influence emotion.[39] The study of human reactions to odors is complicated by the large variation between individuals in the ability to perceive odors.[40] Also, persons who describe themselves as having heightened sensitivity to odors may not have enhanced ability to detect and identify odors but rather report more negative symptoms when exposed to odors they find unpleasant.[41] They may state that their ability to breathe is affected by certain odors, but it has been difficult to document objective negative effects on lung function from offensive odors.[42,43] Odors are described either in terms of concentration, offensiveness or hedonic tone.[44,45] Thus, there are a number of variables to be considered when determining the impact of the presence of livestock odors.

Quantifying livestock odors in a reproducible, technically feasible way has proven to be difficult. Investigators have worked to quantify odors from livestock facilities as a first step toward controlling them, using both trained panelists (e.g., dynamic, forced-choice olfactometry) and electronic odor sensors.[46,47] At this point, olfactometry is still the gold standard in odor assessment although newer methods show promise.[48]

STUDIES ON HEALTH EFFECTS IN CAFO NEIGHBORS FROM INHALATION EXPOSURES

The effect of feedlot dust on rural communities has not been extensively studied although it has been a source of complaints voiced at community meetings and to local health departments. Communities have also responded negatively to a variety of odor sources, both agricultural and industrial as well as those related to municipal activities such as sewage treatment.[49] Some CAFO neighbors allege that odors from feedlots and hog barns represent a risk to human health. While it is clear that many persons consider these odors to be unpleasant, the health implications of this exposure are not yet fully understood.

A small number of studies have been published that specifically address other human health effects of living near large hog confinement facilities. The first of these papers describes the findings of Schiffman and colleagues, who studied 44 neighbors of large-scale hog operations in North Carolina using the Profile of Mood States psychological testing tool. Results from testing the hog-farm neighbors were compared to findings from a group of rural residents who did not live near hog confinement facilities.[50] Persons living near the swine operations reported significantly more tension, depression, and anger than did

the control subjects. They also reported less vigor, more fatigue and more confusion. The authors concluded that these differences could be explained by neighborhood exposure to hog odors, although they did not measure actual exposures or estimate the likelihood of exposure as a function of distance and direction from the hog confinement facilities.

Thu, Donham and colleagues conducted a study of 18 Iowa residents living within a 2-mile radius of a 4,000-sow hog confinement facility. These rural residents were compared to a group of demographically similar rural residents who did not live near large livestock facilities.[51] Measurements consisted of self-reported symptom histories. Their findings included several clusters of symptoms more commonly in the confinement facility neighbors than in rural residents who did not live near hog confinement facilities. The authors divided the symptoms into clusters as follows: Cluster 1 symptoms included sputum, cough, shortness of breath, chest tightness and wheezing; Cluster 2 complaints were nausea, dizziness, weakness and fainting; Cluster 3 consisted of headaches and plugged ears; Cluster 4 included runny nose, scratchy throat and burning eyes; and "other" symptoms were muscle aches, hearing problems, skin rash and fever. Cluster 1, 2 and 3 symptoms were statistically more common in hog facility neighbors than in control subjects. Cluster 4 symptoms were reported by more hog farm neighbors than control residents ($p = .12$) but the difference between the two groups was not as great as for Cluster 1-3. Symptoms in the "other" category were not more common in hog farm neighbors. A medical assessment was not done to look for objective physiologic measures of ill health in either population. Questionnaires were administered to look for evidence of depression and anxiety. Both the hog confinement neighbor and comparison populations scored in the normal range on the depression and anxiety surveys.

Wing and Wolf surveyed several rural communities, one of which was near a 6000 head hog operation and two of which were near large dairy operations.[30] Another community studied was near no large livestock farms. The 155 participants were not told that the reason for the survey was concern over the health effects of living near large-scale livestock facilities. Symptoms that were significantly increased in persons living near the hog operations included the following: headaches, runny noses, sore throats, excessive coughing, fatigue, diarrhea and burning eyes. Quality of life, as measured by the number of days residents were not willing to open their windows or go outside in pleasant weather, was significantly reduced in those who lived near a hog operation compared to both of the other groups. As with the other studies, the authors did not conduct a physical assessment of the subjects or perform exposure monitoring to corroborate their findings.

In summary, there is evidence from a small number of published research studies that people living in the neighborhood of large-scale hog facilities are more likely to have a variety of medical complaints. These complaints range from respiratory problems to burning eyes, sore throats, nausea and diarrhea, fatigue, headaches and plugged ears. Some but not all of these symptoms are like those of the hog confinement workers, who receive a much more intense exposure to the dust and odors associated with this industry. At this time, there are no published studies in which scientists have attempted to find exposure-corroborated, physiologic evidence of negative health effects in populations of neighbors of hog facilities. Neither healthy subjects, nor potentially more vulnerable subjects such as asthmatics or persons with chronic obstructive pulmonary disease, have been assessed in this way. It is conceivable that odors from CAFOs could worsen their symptoms and lung function, but this has not been demonstrated. Psychological symptoms, including tension, depression and anger were more common in hog facility neighbors studied by the group of researchers that looked at psychological aspects of the neighborhood health issue. Quality of life does appear to be affected by the presence of the unpleasant odors associated with this industry.

RESPIRATORY HEALTH IN HOG CONFINEMENT BARN WORKERS

Studying worker health effects can be useful for developing a better understanding of the respiratory conditions for which the CAFO

neighbors might be at risk. One can expect the workers' exposures to be similar in terms of the substances inhaled but much more intense than that of the neighbors. Therefore, studying the workers can contribute to the understanding of potential health effects in CAFO neighbors. However, the healthy worker survivor effect is likely a factor in this environment.[52] This effect could indirectly cause the health effects on neighbors to be underestimated. Specifically, vulnerable groups such as children or anyone with underlying cardiopulmonary disease could be more severely affected than workers that are healthy and who have demonstrated their ability to tolerate this environment. Also, there is evidence that exposure to this environment results in an adaptation to the inflammatory response by the chronically exposed worker.[12,53] It is unclear how the adaptation phenomenon applies to the understanding of the neighborhood effect.

Health effects of working in the hog confinement barn have been studied extensively by investigators in North America and in Europe using symptom surveys and lung function testing.[8,9,54-70] It has been known for some time that working in hog confinement facilities causes chronic or intermittent lower respiratory tract symptoms in approximately one-third of workers. These respiratory symptoms consist of cough with or without production of phlegm, chest tightness, wheezing and shortness of breath with heavy exertion. Depending on the constellation of symptoms displayed and the results of pulmonary function testing, the worker may suffer from chronic bronchitis, the asthma-like syndrome, or exacerbation of preexisting asthma.[71] Rarely, a true allergy to hogs develops in the workers. This hog allergy can be associated with allergic asthma.[11,72] It is said that exacerbation of underlying asthma can also occur secondary to hog barn exposures, although the extent of this problem is not well documented. The respiratory impairment directly attributable to this work is usually not severe if the workers suffer from the asthma-like syndrome or chronic bronchitis. However, lung function test values below the normal range are commonly seen in workers with respiratory complaints. Even a small decrease in lung function can result in shortness of breath with exertion in workers who perform heavy physical labor.

Hog confinement workers who smoke cigarettes are at risk for developing changes in measures of lung function at lower exposure thresholds than nonsmokers.[7] Some of those workers, including persons without a history of cigarette smoking, meet the criteria for chronic obstructive pulmonary disease, which is commonly known as COPD.[73] Approximately 6% of the U.S. population suffers from chronic obstructive pulmonary disease, the term used to describe emphysema and chronic bronchitis.[74] The majority of this disease burden is attributed to cigarette smoking, but occupational factors, including agricultural exposures, are also important.[75]

Nasal symptoms are also common in swine confinement workers. Up to 74% of workers have been described as reporting nasal stuffiness, sinusitis symptoms and other nasal complaints.[54] Olfactory function defined as the ability to recognize odors using a scratch-and-sniff odor identification tool, was described as being compromised in women, but not in men, who work in hog confinement barns in a recently published study.[76] Other evidence of impairment in nasal function has not been identified in persons who work in this setting. However, neutrophilic nasal inflammation has been documented in normal volunteers exposed to the swine confinement barn. Interestingly, there is evidence for adaptation of the nose over time to these exposures.[53] Burning of the eyes and a sore throat are also reported by some workers. The constellation of nasal, eye and throat symptoms are known as the mucous membrane irritation syndrome.

A number of other health problems are associated with work in hog confinement barns. Some workers develop a flu-like illness called organic dust toxic syndrome (ODTS) from heavy exposure to organic dust in their work.[69,77] Symptoms of ODTS include fever, chills, headache, muscle aches, malaise, fatigue and dry cough. This illness usually lasts for several days and is rarely life threatening. There is evidence that having had ODTS makes people more sensitive to having respiratory symptoms such as cough and chest tightness with subsequent exposures to organic dust such

as grain dust or hog dust and that it contributes to the presence of chronic bronchitis.[68,78]

Hydrogen sulfide is a gas that has the odor of rotten eggs and is present in low amounts in the hog barns under ordinary conditions. When amounts of H_2S rise to very high levels secondary to agitation of a manure pit under the floor of the barn, inhalation of this gas can be fatal to workers.[79] Reactive airways dysfunction syndrome, a form of occupational asthma, has been described in a hog confinement worker after exposure to a high level of H_2S.[13] Inhalation of low amounts of hydrogen sulfide by workers has not been shown to be associated with respiratory effects.[7] Interestingly, a recent study has suggested that communities presumably exposed to long-term, low-level H_2S from industrial sources might be at increased risk of respiratory and central nervous system complaints.[80]

In conclusion, hog confinement workers clearly are at risk of developing chronic or intermittent respiratory disorders. While these disorders are not usually life-threatening, they can interfere with their ability to perform their work and may be reason for workers to leave the industry. The substances that cause these problems include hog dust, endotoxin and NH_3. Hydrogen sulfide, while quite malodorous, has not been conclusively associated with the presence of chronic respiratory disease in workers or the public although it causes death from acute, high-level exposures.

RESPIRATORY HEALTH IN CATTLE FEEDLOT WORKERS

A limited amount of information has been published about occupational health problems in cattle feedlot workers.[12,81] The information available at this time about worker health pertains mainly to non-respiratory problems and does not contribute to the understanding of health concerns of feedlot neighbors. Studying the workers' respiratory health status may provide an opportunity for better understanding the potential health effects of the dust from these feedlots.

FUTURE DIRECTIONS

Our understanding of how many persons living near hog confinement operations or cattle feedlots consider their health to be negatively impacted or who have changes in their health status that can be quantified by physiological testing is still quite limited. There is an urgent need to document the health status of subjects in larger samples of hog confinement facility and cattle feedlot neighbors and to make careful comparisons with rural residents who do not live near such facilities. Such research projects should use objective measures of health as well as subjective information obtained by asking persons about symptoms of illness. Moreover, it is essential to compare the prevalence of symptoms and signs of human illness with accepted measures of actual exposures to specific air pollutants made in the neighborhood. Until this research has been done, we will not have a true understanding of the human health implications of constructing more hog confinement facilities, cattle feedlots or other CAFOs. Also, we will not know how to monitor existing CAFOs to assess their potential for causing human illness in the neighborhood.

These studies represent a very important step in addressing the neighborhood health effects aspect of the CAFO debate. However, much more work remains to be done before there are enough data about the human health neighborhood effect of large-scale hog and cattle facilities in order to draw firm conclusions that could have a permanent impact on the industry, its neighbors and its stakeholders.

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