THE OHIO STATE UNIVERSITY EXTENSION

FACT SHEET

Agriculture and Natural Resources

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Air Quality in New Free-Stall Dairy Facilities

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Air quality within dairy barns and air emissions from dairy operations, especially larger free-stall dairy facilities, are attracting increased public scrutiny regarding odor and gas emissions. Odors are difficult to quantify because they are subjective and vary between individuals. Gases are better understood and can be more easily quantified. A better understanding of air quality will help address odor and gas emission concerns objectively and find a satisfactory solution. Furthermore, a comprehensive understanding of air quality is an important first step to maintaining worker and cow health. This fact sheet will facilitate an understanding of air quality through an objective approach to odor and gas emissions from Ohio's dairy farms.

Why care about air quality in dairy facilities?

Air quality is influenced by the concentration of air pollutants in the air. Indoor air quality is affected by the air pollutant emission rate and the effectiveness of building ventilation. It directly affects human and animal health. Typical air pollutants emitted from dairy facilities include:

- gases (ammonia, hydrogen sulfide, nitrous oxide, methane, and carbon dioxide),
- particulate matter (PM), often referred to as dust,
- volatile organic compounds (VOCs), and
- odor.

Different air pollutants have different health effects at various exposure levels. For example, high ammonia levels can cause mucus membrane irritations and respiratory problems. Hydrogen sulfide is a toxic gas that has the potential to cause severe sickness and even death. Hydrogen sulfide is often released from manure storage structures, especially during agitation. Carbon dioxide naturally occurs in the air and is often found at high levels in enclosed buildings. High concentrations can restrict the amount of oxygen in the air. Some of the VOCs may irritate the skin, eyes, nose, and throat.

Odor may cause mood disturbance, and be perceived as a nuisance. This feeling can impact a person's psychological health and affect the quality of his or her life. Technical limitations in measuring odors and the subjective response of humans to odors make it difficult to quantify the impact of odor on one's quality of life.

Particulate matter, or dust, can be a carrier of odor, gas, and bacteria; thus, may be a transmitter of diseases. Various public health studies have associated dust with acute and chronic respiratory diseases and dysfunction, higher rates of mortality, and major cardiovascular diseases among human and animals. Small dust particles (less than 2.5 microns) can be inhaled by animals and humans and often have a more negative effect on respiratory systems than larger particles, which get filtered out more easily by natural respiratory systems.

Occupational Indoor Air Quality Standards

Air quality standards provide maximum levels of various air pollutants that are considered safe for human health. Examples are the national ambient air quality standards and indoor air quality standards. The Occupational Safety Health Administration (OSHA) determines the official occupational indoor air quality standards. The National Institute of Occupational Safety and Health (NIOSH) recommends maximum levels of eight-hour average exposure to various air pollutants in a working environment. Table 1 summarizes the occupational indoor air quality standards for air pollutants that can be found in an animal facility.

Table 1. OSHA and NIOSH occupational indoor air quality standards, air pollutant exposure limit to eight-hour average concentrations.

	NH_3 (ppm)	H_2S (ppm)	CO_2 (ppm)	TSP (mg/m^3)
NIOSH	25	10	5000	4
OSHA	50	20	5000	15

Background of the Study

In 2003 and 2004, two recently built free-stall dairy facilities were studied by researchers at The Ohio State University. The dairy barns, which had six-row free-stalls and 650-700 cows, were located in northwest Ohio and central Ohio, respectively. Both dairy barns were 400 feet long, 108 feet wide and 12 feet high at the side wall. Both were modern dairy barns with a 20-foot wide center drive-through feed alley. Natural ventilation was provided by 12-foot high sidewall curtains with a 2-foot wide open ridge and overhead doors at each end of the service and

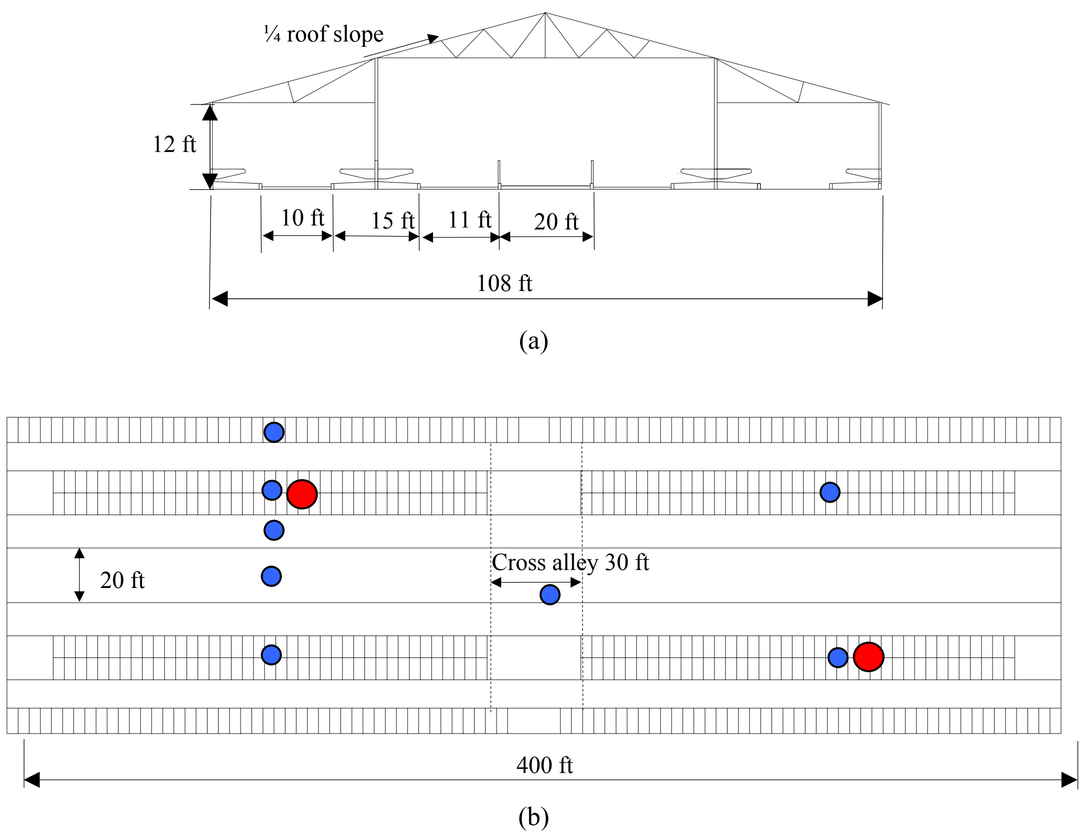

Figure 1. Cross section (a), floor plan, and sampling plan (b) of the modern six-row free-stall dairy barn (blue dots denote the gas and indoor environment sampling locations and the larger red dots denote the odor sampling locations).

feed alleys. Cooling fans and water misters were located along the drive-through feed alley. The free stalls were sand bedded. Alley scrappers were used to bring manure to the center cross alley where a gutter cleaner carried the manure to the settling basin. Liquids then flowed into an earthen manure storage basin.

Air pollutants studied during a one-year period at each facility included ammonia, hydrogen sulfide, carbon dioxide, dust, and odor. For each dairy barn, gas concentrations and air temperatures at each row of the free-stalls, at the walking alley, at the central feed alley, and at the center cross-alley were measured to see how air quality varied within each barn. In addition, odor levels were measured at the upward and leeward ends of the barn (figure 1).

Since air quality is affected by weather conditions, animal facility design and management practices, weather data, indoor temperature, relative humidity, and air velocity were also monitored. Additionally, manure management practices, cattle numbers, and milk production data were acquired from the dairy producers.

Indoor Air Quality of the Dairy Barns

Table 2 summarizes the indoor air quality and environment of the dairy barns. The ammonia concentrations ranged from 0.3 to 3.0 ppm, the hydrogen sulfide concentrations ranged from 2 to 31 ppb, and odor levels averaged 100 OU per cubic meter in the dairy barns. Carbon dioxide concentrations ranged from 349 to 513 ppm. Dust concentrations, measured in total suspended particles (TSP), ranged from 0.16 to 1.5 mg per meter during the study. All air quality measurements were well below the maximum exposure levels defined in the OSHA and NIOSH indoor air quality standards.

Spatial Distribution of Air Quality Inside the Dairy Barns

The study measured little variation in air quality at different locations within the each facility. In addition, the temperature and relative humidity within the barn were similar to the outside conditions and did not vary significantly at indoor locations. However, air velocities at the different locations varied greatly. The data show that these dairy barns with natural ventilation provide a uniform environment for dairy cows. Human and cow health are not a concern based on the data collected from these facilities.

Seasonal Variations in Air Quality

Seasonal variations in hydrogen sulfide concentrations changed from month to month but not in a specific pattern. In general terms, ammonia concentrations increased as temperatures increased to the point where ventilation had to be maximized then ammonia levels dropped. Odor and carbon dioxide concentrations did not significantly vary from month to month. Dust concentrations in Barn #1 were significantly higher in August when supplemental cooling fans were in operation, than in March and June when the building was naturally ventilated only. However, in Barn #2 dust concentrations were not significantly different due to the wet weather in that year. Because of the natural ventilation systems, indoor temperatures had distinct seasonal variations as weather conditions changed

Table 2. Indoor air quality and environment of the two dairy facilities.**

Average Air Quality Parameters	A Northwest Ohio Dairy Barn				A Central Ohio Dairy Barn			
	March	June	August	Average	March	June	August	Average
Odor (OU m^{-3})	105	79	117	100^{0A}	109	142	87	112^{0A}
CO_2(ppm)	465^{1a}	$449^{1a, b}$	513^{1a}	476^{1A}	349^{1c}	$379^{1b,c}$	366^{1c}	365^{1B}
NH_3 (ppm)	$2.1^{2a,b}$	3.0^{2b}	$1.4^{2b,c}$	2.2^{2A}	0.3^{2c}	2.9^{2b}	$1.3^{2b, c}$	1.5^{2A}
H_2S (ppb)	4^{3b}	12^{3b}	31^{3a}	16^{3A}	26^{3a}	2^{3b}	4^{3b}	11^{3A}
TSP (mg m^{-3})	0.9^{4b}	0.8^{4b}	1.5^{4a}	1^{4A}	0.2^{4c}	0.2^{4c}	0.16^{4c}	0.2^{4B}
T (°F)	53^{5e}	78^{5c}	86^{5b}	72^{5A}	54^{5d}	87^{5a}	78^{5c}	73^{5A}
RH (%)	79^{6b}	54^{6e}	57^{6e}	63^{6A}	84^{6a}	61^{6d}	74^{6c}	73^{6B}
Air velocity (m/s)	0.4^{7b}	1.4^{7a}	1.1^{7a}	1^{7A}	1^{7a}	1.2^{7a}	1.2^{7a}	1.1^{7A}

**Data with different superscripts are statistically different and vice versa from March to August. Indoor relative humidity varied depending on weather conditions and indoor temperatures. Indoor air velocity was affected by outdoor wind speed and supplemental cooling fans. These cooling fans created statistically high airflow within the dairy barn. As long as the cooling fans were in operation, the indoor airflow of the dairy barns showed no large seasonal variations.

Knowledge of seasonal variations can provide specific guidance on dust management needs and strategies for air quality management in hot months. There is no specific concern for ammonia, hydrogen sulfide, and odor levels in these facilities. Indoor environment of dairy facilities follow changes in weather conditions as expected. Cooling fans in the dairy facilities are very effective in providing sufficient airflow around the dairy cows and is necessary for natural ventilated facilities.

Daily and Diurnal Variations in Gas Concentrations

Hydrogen sulfide concentrations over a 24-hour period fluctuated consistently around mean seasonal values with occasional peaks (figure 2). The peak concentrations may be associated with manure scraping activities. The average daily hydrogen sulfide concentrations were not statistically different from each other for most days in a month or within each day, but were different from month to month.

High air temperature is likely to result in high ammonia concentrations, but increased barn ventilation will decrease barn ammonia concentration. The hourly mean ammonia concentrations within a day were not statistically different between the early-morning hours (2400 h – 0600 h), the morning hours (0900 h – 1200 h) and afternoon hours (1300 h – 1700 h). However, daytime (0900 h – 1700 h) and nighttime (2000 h – 0800 h) average ammonia concentrations varied significantly.

CO_2 concentrations fluctuated more widely during nighttime (2000 h – 0800 h) than daytime (figure 3). The most significant variations of hourly readings occurred at peak concentrations ranging from 400 to 600 ppm, which happened mostly near midnight of each day.

These results indicated that nighttime indoor air quality is significantly different from daytime air quality.

Summary

In this representative dairy facility study conducted by The Ohio State University, it was found that air quality inside the new large, free-stall dairy facilities falls within OSHA and NIOSH indoor air quality standards.

Spatial variations of indoor air quality within these facilities was very limited probably because of the natural ventilation systems. Based on this study, newer dairy barns with natural ventilation can provide a uniform and healthy air quality environment for workers and dairy cows.

Gas and particulates concentrations in dairy facilities vary based on temperature, ventilation, and weather conditions. Odor and carbon dioxide do not vary seasonally, but dust and ammonia concentrations do. Wet weather conditions suppress dust concentration. Indoor temperature and humidity vary seasonally as weather conditions change. Indoor air velocity was predominantly affected by weather

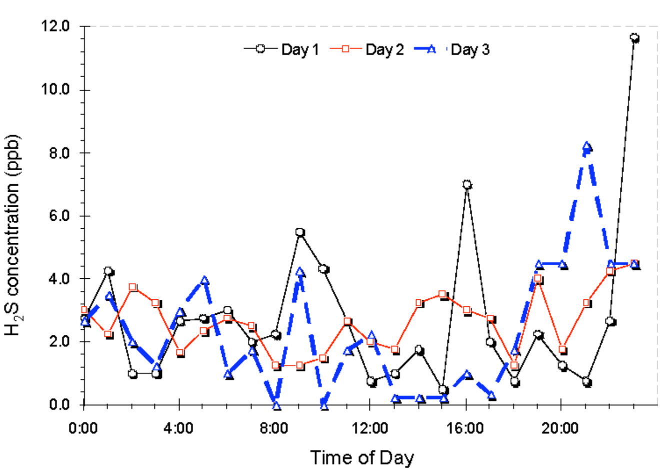

Figure 2. Daily variation of hydrogen sulfide concentration in dairy farm 2 in (a) March and (b) June of 2004.

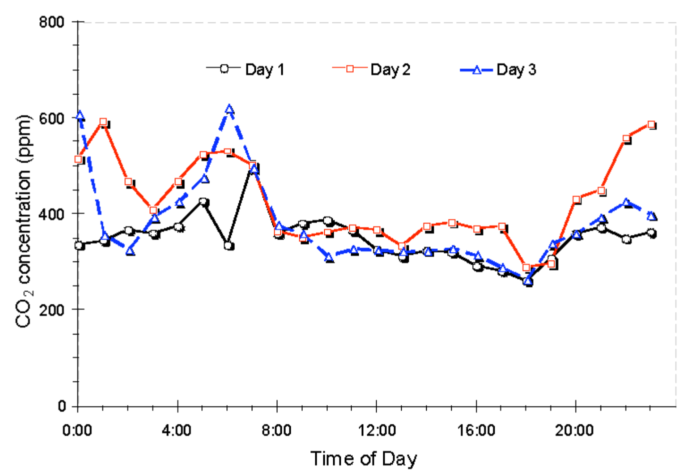

Figure 3. Daily variations of indoor carbon dioxide concentrations in dairy farm 2 in August 2004.

conditions and operation of supplemental cooling fans in these barns. In hot months, more management of indoor air quality of the dairy barns may be needed to control dust concentrations. Supplemental cooling fans are effective in providing sufficient airflow around the dairy cows and are a necessary addition to natural ventilation.

Daily hydrogen sulfide concentrations fluctuated consistently with occasional peaks, which may be associated with manure scraping activities. Ammonia concentrations varied daily between daytime and nighttime. CO_2 concentrations during the day did not vary statistically, but varied significantly near midnight of each day from 400 to 600 ppm. Nighttime indoor air quality should be monitored, because it is significantly different from daytime air quality.

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