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Exposure of workers to dust and bioaerosol on a poultry farm

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Primary Audience: Researchers, Flock Supervisors, Poultry Workers, Production Managers

SUMMARY

Poultry houses are known for generating excessive dust, which originates from bedding materials, fiberglass insulations, feed, dried fecal materials, and feather particles. Dust may contain microorganisms, including endotoxins, fungi, and bacteria, that may affect living things when inhaled. Dust that contains living organisms is referred to as bioaerosol, and its particle size may range from 0.5 to 100 μm. Respirable dust, which has an aerodynamic diameter of less than or equal to 4 μm, can travel to and be deposited in the gas-exchange region of the human respiratory system. This is of particular concern because of the greater health hazard that it poses. The concentrations of respirable dust and bioaerosol measured with samplers attached to the workers (worker-exposure concentrations) were more than 3 (0.82 vs. 0.26 mg/m^3) and one-and-a-half times (58.46 vs. 33.79 cfu/m^3) higher, respectively, than the concentrations measured with stationary samplers indoors. The respirable dust is still below the permissible exposure limit (5 mg/m^3) set by the Occupational Safety and Health Administration, but beyond the limit for animal buildings suggested by other researchers.

Key words: bioaerosol, dust, worker exposure

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DESCRIPTION OF PROBLEM

Concentrated animal feeding operations greatly contribute to the ability of US producers to meet mounting demands for the production of meat, milk, poultry, and eggs [1]. Approximately 2,204,792 farm workers exist in the United States, with an estimated 260,000 persons working in livestock, dairy, and poultry farm facilities [2]. As livestock and poultry facilities have evolved from small backyard farms to large confined structures, health and environmental issues in and around these facilities have become significant.

Malmberg and Larson [3] reported that inhalation of organic dust may cause an acute inflammatory reaction in the airways and fever in nonsensitized subjects, which is called toxic pneumonities or organic dust syndrome. In addition, a person exposed to a high level of dust may experience increased phlegm production and pulmonary inflammation 4 to 10 h after exposure that can last up to 24 h; conversely, chronic exposure may result in bronchitis and asthma

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[4]. The severity of dust damage to health not only depends on the inhaled concentrations but on the size of the dust as well. Fine (≤2.5 μm in aerodynamic diameter) and coarse particles (between 2.5–10 μm in aerodynamic diameter) have been linked to higher rates of total mortality, mortality from major cardiovascular diseases, and increased rates of morbidity expressed primarily as hospital admission for those populations with long-term exposure to heavier loads of dust. The smaller the particles are, the more intense the damage is, as small particles may be composed of adsorbed organic molecules, bioaerosols, and other materials.

The exposure to and effects of pollutants on the health of workers in animal buildings have not been fully studied. Previous exposure studies in animal buildings primarily dealt with the concentrations of dust measured at stationary locations indoors. Results of stationary sampling with short sampling time correlates poorly with health effects and probably is not a surrogate measure of worker's exposure [5, 6]. In addition, Riegel et al. [7] found that the measured concentrations of endotoxins and bacteria in dust collected using samplers attached to the workers are higher than those measured from stationary samplers indoors. However, the exposure of workers to higher concentrations of dust could be attributed to activities that they do outside of the buildings, such as loading litters into trucks for disposal, unloading new shavings, mowing, cleaning the barns between flocks, and so on. Therefore, relying only on measurements indoors may not be adequate to quantify the real exposure of workers to dust during their entire work hours. The objectives of this study were to quantify the worker-exposure of poultry workers to respirable dust and bioaerosols, and compare those with the measured concentrations at stationary locations indoors. With representativeness of samples being a critical component of exposure assessment studies, this research addresses the importance of adopting the method that will more adequately represent the condition to which poultry workers are exposed.

MATERIALS AND METHODS

This study was conducted during the spring and summer of 2009 (April to July) in the Broiler Research Center (**BRC**) at the Walter C. Todd Agricultural Research Center of Stephen F. Austin State University. One of the 4 tunnel-ventilated buildings at BRC was used for indoor measurements. This farm produces 110,400 commercial broiler chickens in 7 wk for one flock. Including the preliminary tests, the study covered 2 flocks: flock 37 and 38. The center raises about 5.5 flocks each year, with 14 to 21 d of down time between flocks. Wood shavings were used as bedding used at BRC, as wood is an abundant resource in east Texas.

Area Sampling for Respirable Dust and Bioaerosol

The building was tunnel ventilated with ten 52-in fans and one 48-in fan (Figure 1). It had 29 adjustable drop-down inlets and 2 cooling pads on opposite ends to cool the air that was drawn into the house during warm weather. Three ventilation schemes were used in this building—minimum, tunnel, and transitional—to maintain a temperature range of 70 to 88°F and RH between 40 and 60%, depending on the growth stage of the chickens. Three forced-fan heaters [8] were located on one side wall in the house that put out 250,000 BTU/heater and 16 infraconic radiant heater brooders [9] that generate 16,000 BTU/brooder.

Area sampling was when stationary samplers consisting of respirable cyclones [10] connected to personal sampling pumps [11] were used to measure the concentrations of respirable dust (particles with diameter of ≤4 μm) at a height of about 1.5 m at 6 sampling locations in the building (Figure 1). The cyclone has a cut-point of 4 μm at a flow rate of 2.5 L/min. Cut-point diameter is the aerodynamic diameter of the particles collected at 50% efficiency or where half of these particles are captured on the filter and the other half are not. Based on results of preliminary experiments in which 3 types of filters (gelatin, glass fiber, and Teflon) were tested side-by-side for dust loading and growth of microorganism colonies, Teflon filters [12] were determined to be best suited for mass concentration and microorganism colony quantifications (data not shown); thus, Teflon filters were used in the measurements. Filters were conditioned in a desiccator (RH = 20 to 30%; temperature

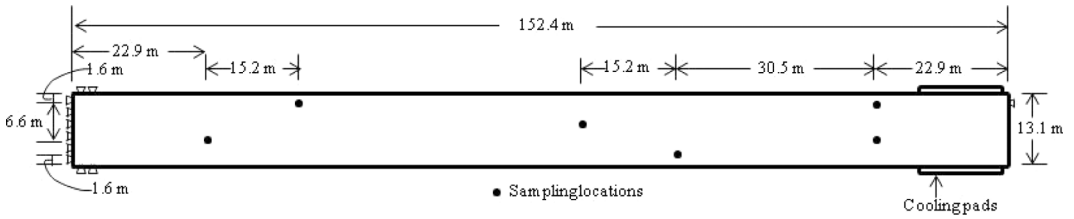

Figure 1. Location of stationary samplers inside one of the poultry buildings at the Walter C. Todd Broiler Research Center at Stephen F. Austin State University. The building had 11 fans: 6 on one end wall, 4 on the adjoining sidewalls, and 1 on the opposite endwall. Not drawn to scale.

= 25 ± 2°C) 24 h before and after sampling. All pumps were calibrated before use using a primary flow calibrator [13]. Sampling indoors lasted for about 20 h to ensure that a measurable amount (≥1 mg) of dust was collected on the filters. The total number of sampling events was 16 d. Every sample was analyzed for dust mass concentration and colony growth. An analytical balance [14] with a resolution of 0.1 mg was used in weighing the filters before and after sampling to get the weight of respirable dust.

The bioaerosol component of dust was quantified following the procedure outlined in Predicala et al. [15]. The filters were loaded onto R2A agar plates after the mass concentration of dust has been determined. The samples were then incubated at 30°C for 3 d. After incubation, the colony-forming units of microorganisms were counted with a hand-held electronic colony counter [16].

Worker-Exposure Sampling for Dust and Bioaerosol

In worker-exposure sampling, the samplers were attached to the workers' lapels near their breathing zones during the entire sampling period, as shown in Figure 2. Four workers were present at the farm. All 4 volunteered to participate in this study; however, only 2 wore 2 samplers each during each sampling event. The cyclone was connected to a sampling pump that was enclosed in a belted noise-reducing cover to minimize noise. Each pump weighed about 450 g, whereas the cyclone was about 40 g. The working hours spent on the farm varied from 170 to 520 min. Workers spent about 40 to 90 min in all 4 poultry buildings at the BRC to pick up dead chicken and check the equipment. The rest of their time was spent working outside the buildings but within the farm. Samplers were worn while they were in the farm so the respirable dust the workers collected came from a variety of sources indoors and outdoors.

The workers were trained on how to use the samplers before the start of the study. The samplers were placed in secured, clean, and sanitized containers by the workers after completing their measurements and were collected at the end of the day by the investigators for analysis in the laboratory. The workers were not required to record the start and end times of the measurements, as the actual run time of the pumps were automatically recorded. The collected filters were analyzed for dust mass concentration and colony growth following the same procedures used for filters collected from the stationary samplers indoors.

Figure 2. Two respirable cyclones were worn by each worker. Each cyclone was connected to a pump enclosed in a noise-reducing cover. Color version available in the online PDF.

Data Analysis

The mass concentration of respirable dust was the mass of dust divided by the volume of air sampled. The mass of dust was the difference between the weights of the filter before and after sampling. The volume of air was the product of the sampling airflow rate and the sampling time. As for the bioaerosol concentration, it was calculated as the number of colony-forming units of the microorganism divided by the volume of air sampled.

The randomized complete block ANOVA was used to determine if a significant difference existed between the means of the concentrations of respirable dust and bioaerosols indoors and those collected by the workers. The sampling method was considered as a fixed factor and each sampling event (day) was considered a random factor, which was used as a block. To determine whether differences existed among each sampling event for indoors and worker exposure of dust and bioaerosol concentrations, the repeated measures design was used. Repeated measures provided information on how the concentration varied with time. Data analyses were completed using the statistical software SAS [17].

RESULTS AND DISCUSSION

Comparisons of the Environmental Conditions and Poultry Data in All Buildings

Due to the limited number of samplers available for indoor measurements, area samplings were conducted in just one building. However, personal samplers were carried by the workers in all 4 buildings. Because all 4 buildings were located side-by-side and the same management practices (manure, feeding, ventilation, and so on) were applied throughout, the assumption was that the environmental conditions inside were also similar and all 4 buildings were essentially the same. To confirm this assumption, environmental conditions (temperature and RH), and the weight and mortality of birds in all 4 buildings during 2 flocks (flocks 37 and 38) were collected and compared. In the comparisons, the one-way ANOVA was used. All chickens in the 4 buildings had the same growth level.

The air temperatures in all 4 buildings during both flocks did not vary significantly ($P > 0.05$). The average temperature in all 4 buildings during flock 38, however, was about 4°F higher (84.3 vs. 80.3°F) than during flock 37, as shown in Table 1. The mean temperature levels in all 4 buildings varied from 72.3 to 88.3°F during flock 37, whereas they varied from 78.3 to 90.2°F during flock 38. In the building that was tested, the temperature varied from 73.1 to 86.8°F during flock 37 and from 78.3 to 88.4°F during flock 38. The temperature setting in the building was varied from d 1 to 49 to provide proper temperature for different growth levels of chickens. When the chickens were younger, a higher temperature was needed to keep them warm. The air temperature in the building was reduced as the chickens became bigger.

Relative humidity plays an important role in dust and bioaerosol concentrations. Lower humidity and higher temperature in the house result in higher concentrations of microorganisms in the air [18]. Significant differences ($P < 0.05$) were observed in RH among the 4 buildings during flocks 37 and 38. Relative humidity fluctuated from d 1 to 49, varying from 45 to 84% for flock 37 and from 52 to 87% for flock 38. The average RH was about 64 and 68% for flocks

Table 1. Comparison of average environmental conditions in all 4 buildings at the Broiler Research Center of Stephen F. Austin State University for flocks 37 and 38

	Flock 37		Flock 38	
Parameter	*P*-value	Mean	*P*-value	Mean
Temperature, °F	0.59	80.3	0.71	84.3
Humidity, %	<0.001	63.6	<0.001	68.0
Water consumption, gal	0.61	1,194.1	0.96	1,235.4
Weight of birds, lb	0.98	2.13	0.93	2.21
Mortality	0.13	15	0.39	18

37 and 38, respectively, close to the desired RH of 60%.

Chicken activity has a significant effect on dust concentration, and their level of activity could be represented by their water consumption. No significant differences ($P > 0.05$) were observed among the 4 houses in terms of the water consumption for both flocks 37 and 38. The average water consumption in the 4 buildings for flock 37 ranged from 8 to 2,529 gallons. For flock 38, the average water consumptions in the 4 buildings ranged from 5 to 2,410 gallons. Based on no significant differences being observed among water consumption in the buildings during the 2 flocks, the chicken activity may have been similar. Based on the results of the comparisons of the environmental conditions, water consumption, mortality, and chickens weight, it could be concluded that all 4 buildings were similar. Also, due to the limited number of samplers available, using one building in the data collection was deemed to be sufficient.

Comparisons of the Area and Worker-Exposure Sampling for Respirable Dust

The random block design was used to test if significant differences existed between the concentrations of dust and bioaerosols measured at stationary locations indoors (area sampling) and at the samplers attached to the workers (worker-exposure sampling). Sampling type was the fixed-effect factor and each sampling event was a block. The area dust concentrations were significantly lower than the worker-exposure dust concentrations ($P < 0.05$). As shown in Table 2, respirable dust concentrations varied from 0.03 to 1.03 mg/m^3 with an average value of 0.23 mg/m^3 indoors and from 0.07 to 4.07 mg/m^3 with a mean of 0.82 mg/m^3 for worker exposure. The average worker-exposure dust concentration was 3 times higher than the dust concentration indoors. Ellen et al. [19] obtained higher respirable dust concentrations in the poultry houses that they monitored, ranging from 1.4 to 6.5 mg/m^3. In addition, their measured maximum dust concentrations were more than 6 times higher than the measurements in the current study. This large discrepancy in the maximum value can be attributed to the fact that their samplings were conducted mostly during the day, when the animals were more active, and also during winter, when the ventilation rates were low. In the current study, none of the average indoor or worker-exposure measurements exceeded the threshold value for respirable dust of 3 mg/m^3 recommended by the American Conference of Governmental Industrial Hygienists [20]; however, the values did exceed the recommended exposure limit of 0.16 mg/m^3 recommended by Donham et al. [21].

The area dust concentrations fluctuated from d 1 to 49 for both flocks. As shown in Figure 3, the initial dust concentration was high due to the resuspended dust brought about by intense activity in the building with new chicks being brought in. Conventional wisdom was that the dust concentration will continue to increase as the birds become bigger, as they tend to generate more particles emanating from their feathers and resuspend more dust from their disturbance of the litter. Because the mass concentration fluctuated throughout the growing period, results may indicate that majority of the resuspended dust was not of a respirable fraction. Similarly, no uniform pattern emerged for the measured worker-exposure concentrations (Figure 3). The

Table 2. Worker-exposure and area concentrations of respirable dust and bioaerosols

Item	Lower 95% confidence limit	Upper 95% confidence limit	Mean	Minimum	Maximum	SD
Worker exposure						
Respirable dust	0.56	1.08	0.82	0.07	4.07	0.87
Respirable bioaerosols	41.7	75.2	58.5	0	259.3	57.1
Indoors						
Respirable dust	0.19	0.26	0.23	0.03	1.03	0.18
Respirable bioaerosols	28.0	39.6	33.8	2.3	128.0	27.4

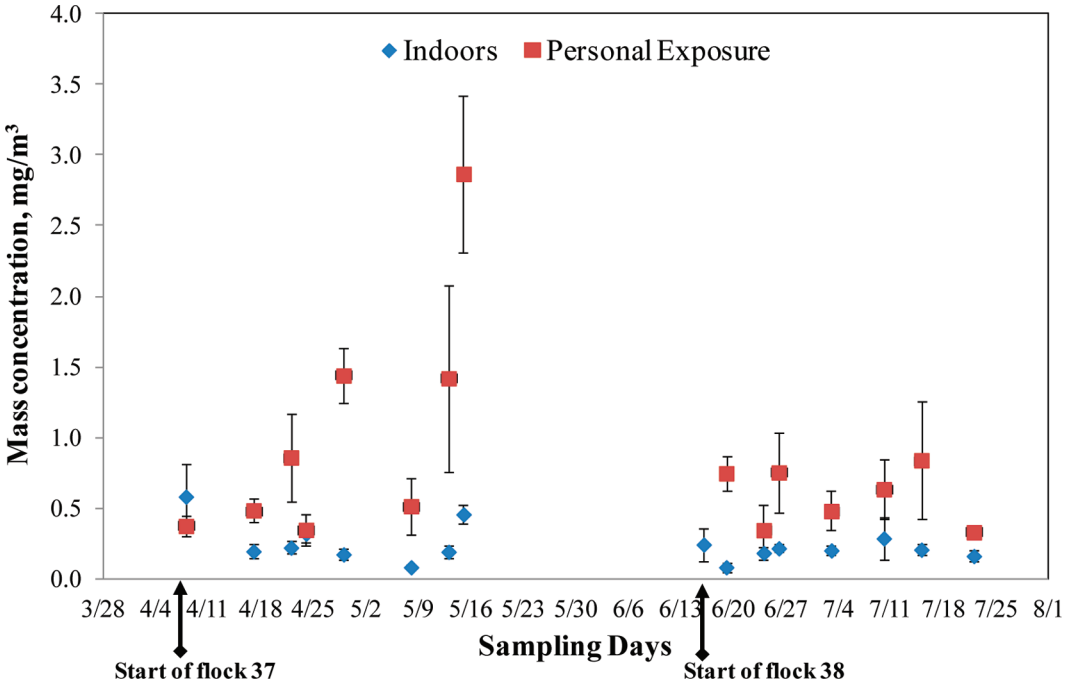

Figure 3. Variation in respirable dust concentrations measured indoors and for worker exposure from April to July 2009. Error bars represent SEM. Color version available in the online PDF.

measured worker-exposure concentrations were generally higher than those of the area measurements, suggesting that measuring the concentrations at stationary locations indoors may underestimate workers exposure level to contaminants such as respirable dust.

Comparisons of the Area and Worker-Exposure Bioaerosol Concentrations

The bioaerosol concentration indoors was significantly different from the worker-exposure concentration ($P < 0.05$). However, no significant differences in bioaerosol concentrations were observed among the sampling events. As shown in Figure 4, the average area bioaerosol concentrations indoors for flock 37 were higher than for flock 38 and fluctuated throughout the whole flock season. During flock 37, the area bioaerosol concentrations ranged from 5 to 128 cfu/m^3, whereas the worker-exposure concentration ranged from 2 to 259 cfu/m^3. During flock 38, area bioaerosol concentrations were somewhat steady from day to day. The indoor concentrations in flock 38 ranged from 6 to 103 cfu/m^3, whereas the worker-exposure concentrations varied from 17.5 to 176.8 cfu/m^3. The worker-exposure bioaerosol concentrations increased from d 1 to 49 for both flocks, which was correlated with the increase in weight of the birds. According to Scheff et al. [22], the acceptable range of values for total bacteria in most indoor environments is from 100 to 1,000 cfu/m^3. The measured respirable bioaerosol concentrations in this study never exceeded 300 cfu/m^3. Studies on bioaerosol measurements in poultry buildings are limited. Hinz and Linke [23] reported a total bioerosol concentration of 7.7×10^6 cfu/m^3 in measurements done in poultry-caged layers.

Based on linear correlation of the bioaerosol concentrations and RH, a weak correlation ($r = 0.24$ for worker exposure and 0.28 for indoors) was observed between the parameters. In general, higher RH in the building is associated with higher bioaerosol concentration. Similar to the respirable dust fraction comparisons, based on Figure 4, worker exposure of bioaerosol was higher than the area concentrations, suggesting that measuring exposure by attaching personal samplers to workers will yield more representative results compared with area measurements.

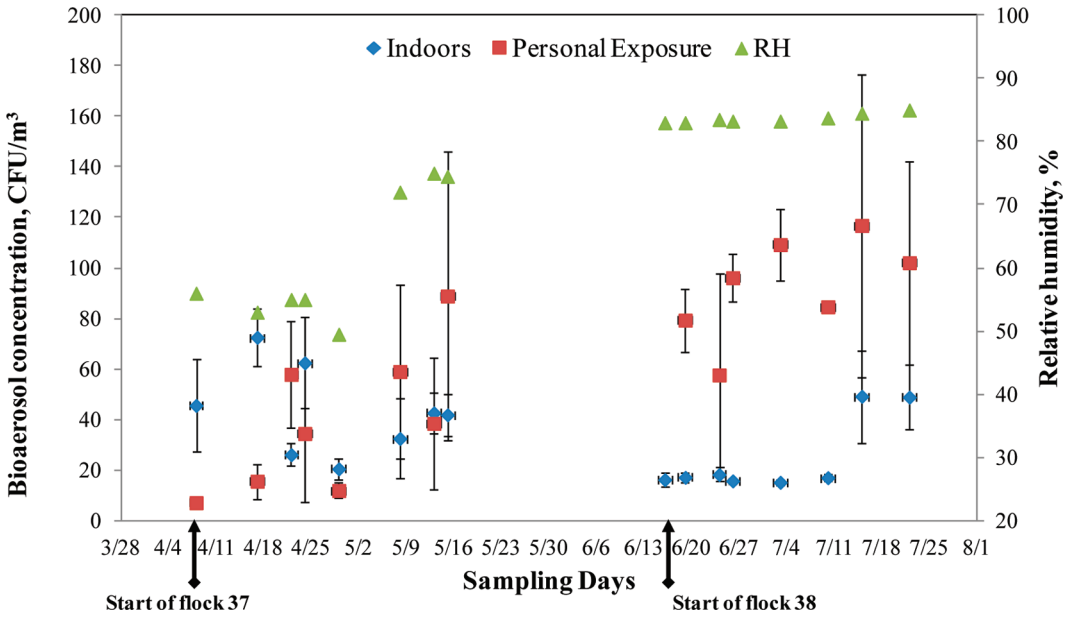

Figure 4. Variation in respirable bioaerosol concentrations measured indoors and for worker exposure from April to July 2009. The average RH during days of sampling is also shown. Error bars for the dust and bioaerosol concentrations represent SEM. Color version available in the online PDF.

CONCLUSIONS AND APPLICATIONS

1. The concentrations of respirable dust and bioaerosols obtained using personal samplers were usually higher than those measured using stationary samplers indoors. The higher measurements in personal samplers could be attributed in part to dust resuspension due to increased bird activities when disturbed and to their exposure to dust outside the buildings. This confirms the results of similar studies done in an indoor environment. Therefore, to determine the true exposure of poultry workers to dust and other pollutants, personal samplers may yield more representative measure.
2. Respirable dust fractions in a poultry house can exceed the more stringent limit proposed by other researchers, but not the recommended threshold by American Conference of Governmental Industrial Hygienists.
3. The measured respirable bioaerosol concentrations in this poultry house were lower than the published results by other researchers.

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