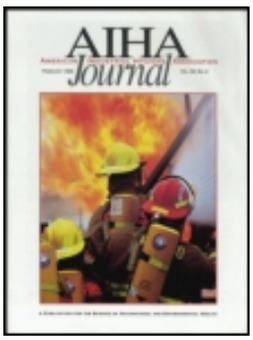

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Environmental Study of Poultry Confinement Buildings

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Environmental measurements were made in three poultry confinement buildings in order to characterize gas and particulate contaminants. Levels of total and respirable dust averaged 4.4 and 0.24 mg/m^3, respectively. Particle size distribution as measured by cascade impactors was similar in the three confinement houses with a mass median aerodynamic diameter of about 15 μm and a geometric standard deviation of about 2.2. Ammonia levels measured in the active areas of the buildings averaged about 25 ppm. Ammonia concentration was quite high, however, in an unused and unventilated portion of one of the buildings ($\bar{x}$ = 170 ppm). CO_2 levels ranged from 0.05-0.1%. Levels of CO, H_2S, NO_2, NO_x, CH_4, mercaptan, formaldehyde, and hydrocarbons were all below the limit of detection for indicator tubes. Concentrations of airborne bacteria and fungi were on average about 1.5×10^5 and 1.0×10^4 colony-forming units/m^3, respectively. Endotoxin analysis was also performed on the total and respirable dust samples. Endotoxin levels (expressed in air concentration) ranged from 0.77 to 61 ng/m^3 for total dust and from 0.71 to 15 ng/m^3 for respirable dust. Endotoxin was also measured on the collection media from the individual impactor stages. Endotoxin was detected in all size ranges with the highest concentration of endotoxin per unit of dust found in the smallest ($<\sim$3.5 μm) size fraction. The endotoxin levels tend to be lower than those previously reported in poultry operations.

Introduction

The raising of poultry in confinement houses developed from an economic need for high production yield utilizing little space, energy and labor. Enclosing and concentrating birds, however, meant concentrating their waste products and contaminants. Potential health hazards to the agricultural worker and livestock arise in the confinement facilities as both are exposed to these agents. The airborne contaminants found in these buildings can be divided into two categories; particulates (both viable and non-viable) and gases.

The non-viable particulate fraction or "dust" is mainly of organic nature and can include particles of manure, litter, feed and dander that can become airborne by animal movement and air flow. The viable fraction tends to be associated with the larger dust particles[1] and can include both bacteria (gram positive and negative) and fungi.[2]

Gases that are associated with animal confinement include ammonia, hydrogen sulfide, methane, carbon dioxide, carbon monoxide and nitrogen oxides. Ammonia, hydrogen sulfide and methane evolve from the microbial degradation of manure. Carbon dioxide is a result of animal and microbial respiration as well as a product of the combustion of fuel used to heat the buildings. Carbon monoxide can result if the combustion of the fuel is incomplete. Nitrogen oxides are also by-products of combustion.

The following is a report of environmental measurements for particulate and gas contaminants taken in three poultry confinement buildings.

Process Description

Sampling was conducted in 3 poultry confinement houses in North Carolina in late spring. Figure 1 is a diagram showing both top and cross-sectional views of the houses.

These long and rather narrow buildings are designed to be energy efficient so that only a portion of the building is used initially when the young chicks are received. As the birds get larger and demand more space, a larger area is partitioned off until finally the birds occupy the full building. Approximately 20 000 birds are confined per building. The concentration of birds per unit occupancy area therefore ranges from about 1.5 to 3.9 birds/ft^2. All buildings had automatic feed and water systems and gas heating.

In the first broiler house surveyed (Building #1), the birds were 30-days old and were occupying the entire building space. Fans designed to turn on when the inside temperature reached 27° C were located down the center of the building. These fans were about 90 cm in diameter and operated at about 10 000 CFM. With the number of fans used, this corresponds to about 3 CFM/bird. Large doors were kept open at both ends of the building to aid ventilation. Smaller doors were also located along the sides of the house but these were closed during the survey. Windows equipped with curtains were positioned along each side of the house. These curtains were kept open. The fans operated continually during our sampling since the temperature ranged between 28 and 31° C. Relative humidity was 50 to 60 percent and winds were light and variable. Wood chips were used as litter and in this house the litter in the front one-third of the building was about a month old while the litter in the back section was about a year old.

Buildings #2 and #3 were located on one farm. These buildings both housed one-week-old chicks which were partitioned off in the front third of the building. These two buildings were in fact identical in all respects with the exception that the litter was only one week old in building #2 whereas the litter in building #3 has been used for over a year. In the occupied area of these buildings doors were kept closed and window curtains were kept down. One fan (90 cm 10 000 CFM) was located on one of the side walls to provide

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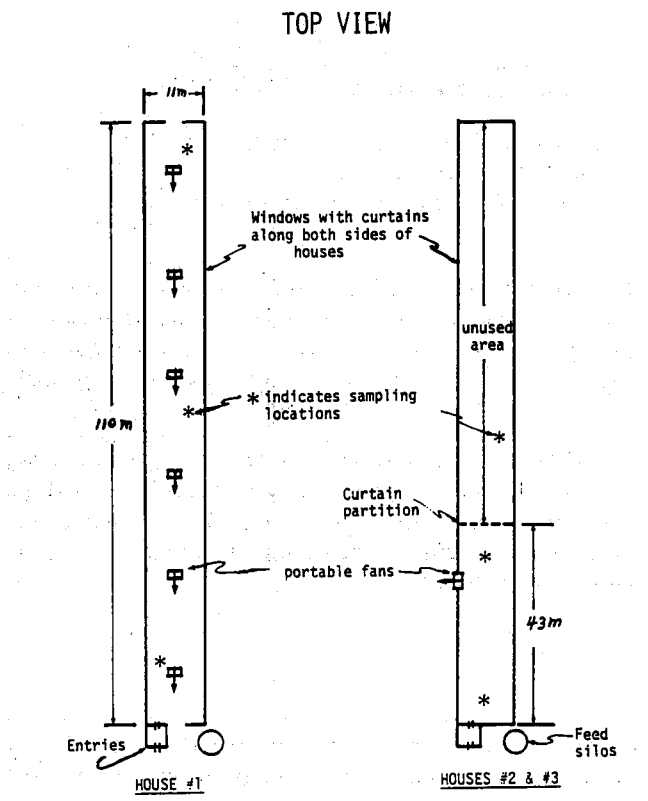

Figure 1 — Confinement house diagram.

general ventilation. Sampling was conducted on the same day in these two buildings. Temperatures were warm, 24-33° C; relative humidity ranged from 50 to 80 percent; and winds were light and variable.

Methods

Particulate Sampling

Total dust samples were collected in areas within the confinement building using DuPont P-4000 pumps to draw air at a flow rate of 2 L/ min through FWSB filters (Mine Safety Appliance). The filters were mounted in 3-piece 37 mm cassettes and sampling was performed open faced. Filters were weighed to the nearest 0.01 mg before and after sampling using a Cahn model 4700 electrobalance. The respirable dust samples were collected by drawing air at 1.7 L/ min first through a 10 mm nylon cyclone and then through a pre-weighed FWSB filter. DuPont P-4000 pumps were again used as the air mover.

Particle size distribution of the dust was measured by using a recently described cascade impactor[3] fabricated from 37mm cassette pieces (Figure 2). A flow rate of 2 L/ min was maintained through the impactors using DuPont P-4000 pumps. At this flow rate, the effective cut-off diameters are 20, 15, 10 and 3.5 μm. Glass fiber filters were used as collection media for the four stages and for the back-up filter. Sample times for the impactor samples as well as for the total and respirable dust samples ranged from about 4 to 6 hours. Sampler inlets were set up about 1.8 m from the floor to approximate a human breathing level and were placed in areas in the front, middle and back sections of the confinement buildings. These sampling locations are indicated by an asterisk on Figure 1.

A portion of the total dust, respirable dust and impactor samples were analyzed for endotoxin. These filters were first extracted with 5.0 or 10.0 mL sterile, non-pyrogenic water (Travenol Laboratories, Inc., Deerfield, IL) by rocking at room temperature for 60 minutes. Sterile, non-pyrogenic plastic ware was used during all phases of the endotoxin analysis. The fluid was centrifuged at 2200 RPM (1000 g) for 10 minutes, and the gram negative bacterial endotoxin content of the supernatant fluid was quantified in duplicate by a spectrophotometric modification of the *Limulus* amebocyte lysate gel test (Pyrostat; Millipore Corp., Bedford, MA) as previously described.[4] Blank, unused filters were treated similarly and used as controls.

Gas Sampling

Ammonia concentration in the buildings was measured using Draeger long-term indicator tubes. DuPont P-4000 pumps were used to draw air through these tubes at nominally 15 mL/ min. These tubes were read immediately after sampling and by dividing the tube reading by the sample volume the average concentration over the sampling period was estimated. Sampling times ranged from about 30 to 120 minutes.

Samples were also collected for the following contaminants using Draeger short-term indicator tubes: NH_3, CO, CO_2, H_2S, NO_2, NO_x, CH_4, mercaptan, formaldehyde and hydrocarbons. These samples were typically collected in general areas of the confinement buildings although a few were collected close to the floor.

Microbial Sampling

Microbial samples were collected with Andersen viable 6-stage samplers (Andersen Samplers, Inc., Atlanta, GA) operated at 1 CFM. Samplers were placed in central areas of

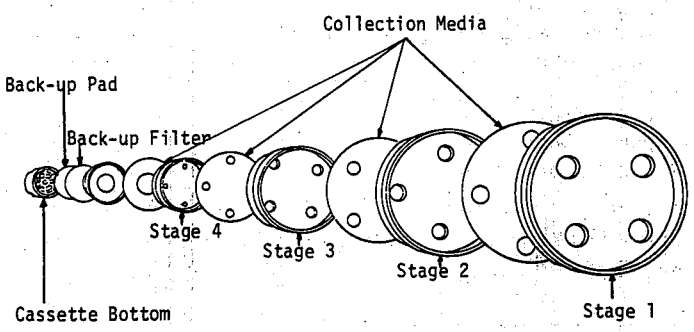

Figure 2 — Exploded view of "cassette" impactor.[3]

the confinement buildings approximately one meter off the floor. Plastic petri dishes containing tryptic soy agar with cycloheximide (TSA) or rose bengal-streptomycin agar (RBS) were used in the samplers to measure bacteria and fungi, respectively. The RBS samples were protected from direct sunlight and kept at room temperature. After collection, the TSA samples were put on ice to slow the growth of bacteria during transport from the field (~24 hours). At the laboratory the samples were incubated under normal atmosphere at 27° C. Both bacteria and fungi were counted under magnification so that multiple colonies under any given jet could be resolved thus eliminating the need for "positive hole" correction. Counts were made approximately 48 hours after collection of the samples.

In addition to the 6-stage Andersen measurements, samples of bacteria and fungi were also collected in the same areas using a modified method where only the last stage of the Andersen sampler is used to collect microbes directly onto a single culture plate.[5] Since this sampling system is more prone to overloading, these samplers were run for 30 seconds while the 6-stage sampler was operated for 2 minutes.

Results and Discussion

Particulate Sampling

Dust levels were highest in Building #1 with total and respirable dust averaging about 10 and 0.5 mg/m^3, respectively (Table I). This was expected since the birds in this house were larger and more active and thus able to generate more dust. The gradation of dust concentration within this building (lowest in back to highest in front) is also as expected since the fans directed air from the back to the front thus concentrating both gases and particulates in the front of the building. The dust data from all of the houses show a small and rather constant ratio of respirable to total dust of about 5 percent. The exception is the unused sections of Buildings #2 and #3. The levels reported in these areas however were quite low and in fact the concentrations in the unused section of Building #2 were close to our detection limit.

TABLE I
Total Dust, Respirable Dust and Ammonia Concentrations Measured in Poultry Confinement Buildings

Building	Location Within Building	Total Dust (Mg/m^3)	Resp. Dust (Mg/m^3)	Ammonia (ppm)
#1				
30-day old birds	Front	11	0.62	13
	Middle	9.2	0.39	9.2
	Back	7.6	0.42	-
#2 (new litter)				
7-day old birds	Front	2.5	0.11	-
	Middle	1.4	0.04	6.0
	Unused Area	0.02	0.02	-
#3 (old litter)				
7-day old birds	Front	2.8	0.11	-
	Middle	4.6	0.31	75
	Unused Area	0.14	0.11	170[A]

[A]Mean value from 7 measurements.

The dust levels (both total and respirable) were higher in building #3 than Building #2. Since all variables except age of litter were the same in these houses, it is thought that the old litter, which is essentially dried manure, may be more friable than the new wood chips and thus more "dusty".

There are no specific standards for this type of dust. The OSHA standard for nuisance dust is 5 and 15 mg/m^3 for respirable and total dust, respectively. The values reported here are well below these standards. It should be noted, however, that the nuisance dust standard is intended for "inert" dust so that its application here may be inappropriate.

The impactor data (plotted on log probability paper) are presented in Figures 3 and 4. The size distribution of the dust in all three buildings is quite similar. By estimating a line through the points, the mass median aerodynamic diameter (MMAD) is about 15 μm and the geometric standard deviation is about 2.2. Therefore, most of the mass of this dust is represented by particles that are non-respirable as was indicated also by our total and respirable dust sample results. A qualification that should be made is that the "respirable" dust sampler was designed to preferentially sample that fraction of a dust which can contribute to the development of pneumoconiosis; *i.e.*, the fraction of the dust which is able to penetrate and remain in the alveolar region of the lung.

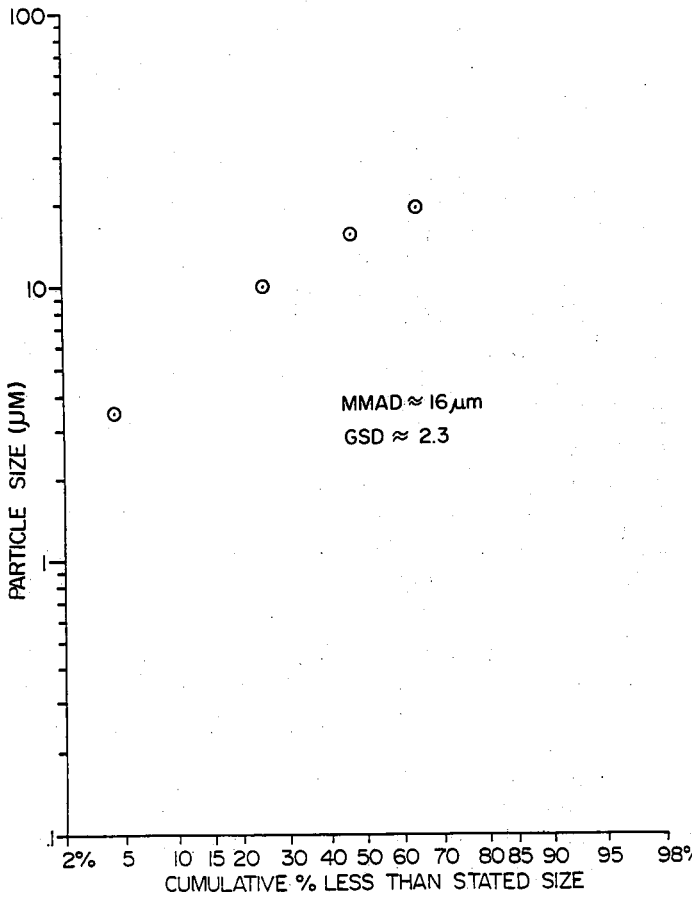

Figure 3 — Particle size distribution (Building #1, 30-day old chicks).

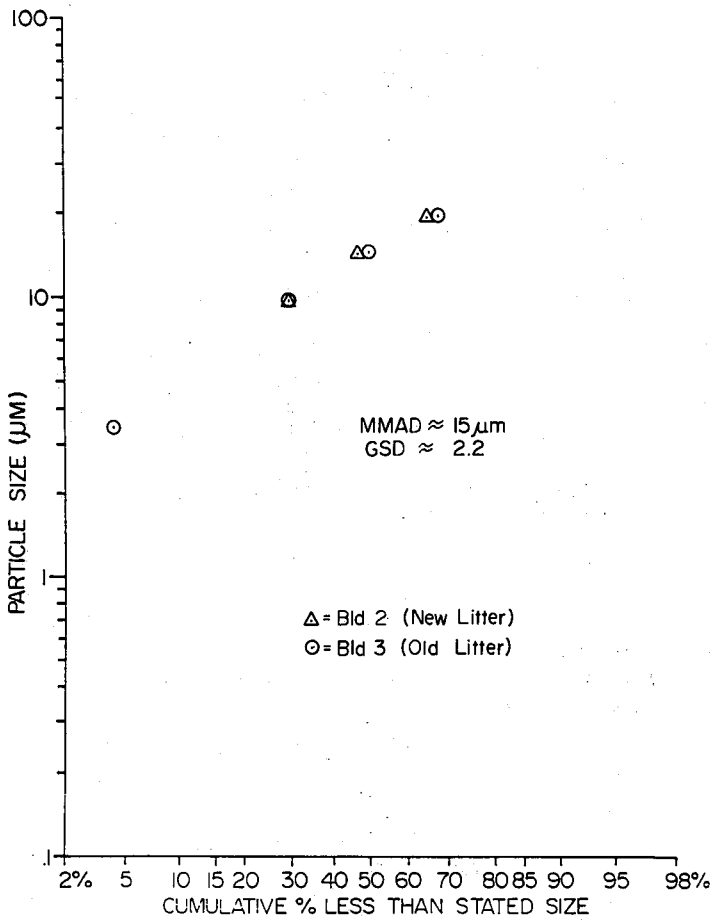

Figure 4 — Particle size distribution (Buildings #2 and #3).

The biological activity of the confinement building dust may be quite different and larger particles may be able to elicit a response.

The concentrations of total dust found in this study ($\bar{x}$ = 4.4 mg/m^3) are intermediate when compared to levels reported in two previous studies. Both Carlsson[6] and Clark, *et al.*[2] reported dust levels in poultry confinement houses in Sweden. Carlsson found total dust levels of 9 to 17 mg/m^3 in the broiler houses which he surveyed. Clark, *et al.*, investigated houses where the birds were raised "on wire" (in suspended wire cages) as opposed to "on litter". The average total dust level found in this study was 2.3 mg/m^3.

Table II gives the results of the endotoxin analysis on both the total and respirable dust samples. Levels of endotoxin are expressed both in terms of the amount of endotoxin per unit of dust on the filter (ng/mg) and in terms of air concentration (ng/m^3).

All filters which were analyzed contained quantifiable amounts of endotoxins but the degree of contamination varied between buildings. Average endotoxin levels in the total dusts ranged from 6.4 to 16 ng/mg. The endotoxin contamination of the respirable dust fractions was higher ranging from 20 to 40 ng/m^3. The highest average level of endotoxin per unit of dust for both total and respirable dust was measured in Building #2. When endotoxin is expressed in terms of air concentration, the pattern is reversed and higher levels are recorded for total dust (24-59 ng/m^3) compared to respirable dust (3.8-9.8 ng/m^3). This is simply due to the much higher levels of total dust found at these facilities.

TABLE II
Endotoxin Content of Airborne Dust

		Average Endotoxin Concentration			
		Total Dust		Respirable Dust	
Building	n	Dust (ng/mg)	Air (ng/m^3)	Dust (ng/mg)	Air (ng/m^3)
#1 30-day old birds	3	6.4	59	20	9.8
#2 (new litter) 7-day old birds	1	16	24	40	4.5
#3 (old litter) 7-day old birds	3	12	36	30	3.8

Endotoxin was found in each size fraction of the aerodynamically fractioned dust (Table III). Both impactor samples show the same trend of rather uniform endotoxin contamination in the size fractions within the 3.5 to 20 μm range. Dust which was collected on the back-up filter, and therefore represented particles < ~3.5 μm, contained a greater amount of endotoxin per mg of dust than did the other size fractions. However, because the fraction of dust which was collected on the back-up filter constituted the lowest amount of dust, it accounted for the lowest level of endotoxins when expressed in air concentration. This is consistent with the endotoxin analysis on the total and respirable dust samples.

Endotoxin levels found in these houses are lower than those reported for poultry confinement units in the southern part of Sweden. Clark *et al.*[2] reported average endotoxin levels of 310 ng/m^3 for total airborne dust in three poultry confinement units whereas the levels which we report average approximately 44 ng/m^3. Likewise, the airborne dust from the units studied by Clark contained endotoxin contamination of 120 ng/mg and the airborne dust from the units in our study contained an overall mean of 10 and 27 ng/mg for total and respirable dust respectively. By comparison with another aspect of the poultry industry, that of poultry processing, Olenchock *et al.*[7] reported endotoxin levels of 24 to 108 ng/mg for total dust and 25 to 65 ng/mg for respirable dust. A single sample of settled dust from a poultry confinement house yielded a concentration of 11.4 ng/mg in a study reported by Thedell, *et al.*[8]

The wide range of reported endotoxin levels is expected in such a non-standardized industry. Variables such as type and age of litter, geographical location, age and type of birds, and ventilation would all be expected to affect both dust and endotoxin concentration.

Levels of airborne endotoxins have been implicated as a causative agent for disease found in cotton workers[9] and have been associated with symptoms including cough, headache, nausea, chest tightness, diarrhea and fever.[10,11] Although there are no proposed standards for a "safe" level of endotoxin exposure, Rylander and Haglind reported a reaction threshold of about 500 ng/m^3 for decreases in lung function measured over a 4-hour exposure period.[12] This

TABLE III
Endotoxin Content of Aerodynamically Fractionated Dusts

Building	Impactor Stage	Effective Cut-Off Diameter (μm)	Dust Weight (mg)	Endotoxin Concentration Dust (ng/mg)	Endotoxin Concentration Air (ng/m^3)
#1 30-day old birds	1	20	1.49	6.46	21.10
	2	15	0.83	5.49	10.00
	3	10	0.90	6.18	12.19
	4	3.5	0.99	5.82	12.63
	BF[A]	-	0.20	12.60	5.53
#3 (old litter) 7-day old birds	1	20	1.32	6.86	13.84
	2	15	0.63	5.79	5.58
	3	10	0.78	6.72	8.01
	4	3.5	1.02	9.67	15.08
	BF[A]	-	0.16	15.25	3.73

[A]Back-up filter.

TABLE IV
Results of Indicator Tube Measurements Taken in Poultry Confinement Buildings (Values in ppm Except Where Indicated)

Building	Location Within Building	Compound[A]	n	$\bar{X}$	SD
#1 30-day old birds	General Area	NH_3	8	5.9	3.2
	1" from floor	NH_3	2	20	11
	General Area	CO_2 (%)	6	0.05	0.01
#2 (new litter) 7-day old birds	General Area	NH_3	5	2	0
	1" from floor	NH_3	1	3	-
	General Area	CO_2 (%)	4	0.10	0
#3 (old litter) 7-day old birds	General Area	NH_3	4	13	7.3
	1" from floor	NH_3	2	20	14
	Unused area of bldg.	NH_3	1	150	-
	General Area	CO_2 (%)	4	0.10	0

[A]Samples were also taken for the contaminants listed below but all were less than the limit of detection which is given in parenthesis for each tube.

CO (5 ppm)	CH_4 (0.5%)
H_2S (1 ppm)	Mercaptan (2 ppm)
NO_2 (0.5 ppm)	Formaldehyde (0.5 ppm)
NO_x (0.5 ppm)	Hydrocarbons (0.1%)

threshold was observed for students exposed to cotton dust in an experimental card room.

Gas Sampling

The levels of ammonia measured with long-term indicator tubes ranged from 6.0 to 170 ppm (Table I). The highest value was the average of samples taken in the back area of Building #3. This was the area that was both sealed off and unventilated. Farmers do not usually spend any time in this portion of the building. Levels of ammonia were lowest in Building #2; this was expected since the ammonia is produced from decomposing manure and, as mentioned before, the litter in this building was essentially clean wood chips. The OSHA standard for ammonia is 50 ppm. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that levels be kept below 25 ppm. Both values are based on "personal" time-weighted average exposure measurements over a working shift. The measurements reported in this study are from "area" samples thus they are not directly comparable to these limits. The farmers estimated that they spent approximately two hours per day in the confinement buildings. If we assume that the exposure for the balance of the 8-hour shift is zero, then the estimated 8-hour TWA to ammonia would be about 1/4 of the reported values. For the highest value in a working area (75 ppm), this corresponds to an estimate of about 200 ppm which is lower than the OSHA standard and ACGIH recommendation. NIOSH recommends that ammonia levels be

kept below 50 ppm as determined by a 5-minute sampling period. This is usually referred to as a "ceiling" standard. Using this criterion, there is a potential for overexposure in Building #3.

These standards and recommendations were aimed at protecting against irritation to the eyes and respiratory tract. Varying levels of irritation were experienced however by the survey crew and farmers during the survey. In Building #1 the irritation was perceived as low. There was essentially no irritation in Building #2. In the active area of Building #3, the irritation was moderate but irritation was severe in the unventilated area.

The ventilation in the buildings tends to lower ammonia levels even though its main purpose is to maintain optimum temperature for the birds. In the colder months, the buildings are closed up and ventilation was decreased to conserve heat. This would result in higher contaminant levels. Since our study was done during warm weather, it probably represents the best conditions expected at these confinement houses.

The short-term indicator tube results are given in Table IV. For ammonia, the values are in general agreement with the long-term tube results; *i.e.*, lowest in Building #2, highest in #3 and intermediate in #1. As expected, levels are higher when measured close to the litter. CO_2 levels range from 0.05 to 0.10 percent throughout the buildings. These values are lower than both the NIOSH recommendation (1 percent) and the OSHA standard (0.5 percent) for CO_2. Again, these values are not directly comparable to standards. These data do suggest, however, that CO_2 is not a problem during the warm months when the buildings are ventilated.

Samples taken for CO, H_2S, NO_2, NO_x, CH_4, mercaptan, formaldehyde and hydrocarbons were all below detectable levels. Limits of detection for these compounds are given in Table IV.

Microbial Sampling

Levels of airborne bacteria and fungi are recorded in Table V. N_6 refers to the single stage sampler and A_6 designates the standard Andersen 6-stage sampler. Fungal levels were similar in Buildings #1 and #3 but an order of magnitude higher in Building #2. It seems likely that the fresh wood chips in this house provided a more favorable environment for fungi.

TABLE V
Concentration of Microorganisms in Confinement Buildings (Levels Reported in CFU/m^3)

	Bacteria		Fungi	
Building	N_6	A_6	N_6	A_6
#1 (30-day old birds)	3.6×10^5	3.6×10^5	4.5×10^3	2.5×10^3
#2 (new litter) 7-day old birds	1.2×10^5	7.0×10^4	2.3×10^4	2.4×10^4
#3 (old litter) 7-day old birds	7.4×10^4	-	2.5×10^3	2.5×10^3

Airborne bacterial levels were highest (3.6×10^5 CFU/m^3) in Building #1 and this may be due in part to the higher dust levels measured here since these organisms tend to be associated with particulate. The majority of bacteria as well as fungi collected in the 6-stage Andersen impactor were deposited on the upper (1 to 4) stages. Although no identification for specific bacteria was performed, gram staining revealed that >90 percent of the bacteria in Buildings #1 and #3 were gram positive cocci (spherical bacteria). In building #2, >90 percent were gram negative rods which corresponds to the highest average endotoxin per unit of dust found in this building.

When comparing the N_6 method to the A_6 procedure the agreement is either quite good or the N_6 sampler yields higher values. We have observed this in other side-by-side sample runs using the 2 methods[5] and feel that the reason may be due to less wall losses with the N_6 method since the organisms are directly impacted onto a single culture plate.

As with endotoxin there are no specific standards or recommendations for "safe" levels of exposure to airborne bacteria and fungi. The levels of airborne fungi measured in this study ($\bar{x}$ ~1.0×10^4 CFU/m^3) were much higher than those reported by Clark, *et al.*[2] ($\bar{x}$ ~7.0×10^2 CFU/m^3). This may be due to the fact that in this study the birds were raised on litter (wood chips) while in Clark's study the birds were raised in wire cages. Levels of bacteria were in better agreement between the two studies with a range of 7.4×10^4 to 3.6×10^5 CFU/m^3 measured in this study compared to 1.2×10^5 to 6.8×10^5 CFU/m^3 (Clark's study). The variable percentage of gram negative bacteria found in our study (low in Buildings #1 and #3, high in Building #2) was also observed previously. In most of the poultry confinement houses surveyed by Clark, the percentage of gram negative bacteria was low ($\bar{x}$ ~8 percent) but in one house it was estimated to be about 80 percent.[2] Perhaps there is a biological succession occurring within these facilities which could account for these variable results.

Summary

Environmental measurements were made in three poultry confinement buildings. Total and respirable dust, various gases, endotoxins and microorganisms were quantified.

Measured levels of contaminants were usually below current standards and recommendations. The exception is ammonia where overexposure to the NIOSH recommendation of 50 ppm (ceiling) could occur in one of the buildings. For those agents sampled where no standard or recommended "safe" exposure level exists our results were compared to those from previous studies. Airborne bacteria and endotoxin levels tended to be lower and fungal levels higher than results from previous studies.

Acknowledgements

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