

Aerial emissions of particulate matter and microbes from poultry barns and use of shelterbelts and an air ionizer for mitigation

S. Bittman¹, K. Chipperfield², K. Bartlett³, D. Hunt¹, M. Diarra¹, D. Poon⁴, W. Asman⁵, E. Topp⁶, G. Rogstand⁴

¹AAFC, Agassiz, BC

²Sustainable Poultry Farming Group, Abbotsford, BC

³School of Environmental and Occupational Hygiene, University of BC, Vancouver, BC

⁴BCMAL, Abbotsford, BC

⁵Danish Institute of Agricultural Science, Denmark (present address)

⁶AAFC, London, ON

Abstract / Summary

Emission of particulate matter (PM) from agricultural operations in general and livestock buildings in particular is a potential health (pulmonary and cardiovascular) and bio-security concern (potentially transport avian influenza) and public annoyance factor. Small PM (under 2.5 μ) disperses widely and may be most deleterious for health because they can pass to lung alveoli. PM from poultry operations in the lower Fraser Valley of BC is of concern because of the density proximity of poultry barns with residences and food production. This study monitored concentrations and emissions of PM from a broiler operations, as well as abatement by a and electrostatic precipitator and through several cycles using optical and impactor techniques. A modelling study predicted that very small and very larger particles would not be affected by the tree belt. The optical technique gave somewhat higher values than the impactor, especially for small particles and this may be due to amount of hydration. Emissions increased sharply through the bird cycle especially after about 3 weeks. Microbial numbers followed closely the PM values, with counts sometimes overwhelming current techniques. Emission factors for broilers in this study are much greater than standards used in inventories. Concentrations of PM and microbials was far higher in the wind than lee side of the trees due to dispersion, impaction/deposition and dilution. Electrostatic precipitator improved barn air quality especially during the early part of the growth cycle. Preliminary data suggests improving air quality will improve feed conversion efficiency.

Executive Summary

Emission of particulate matter (PM) from agricultural operations in general and livestock buildings in particular is a potential health (pulmonary and cardiovascular) and bio-security concern (potentially transport avian influenza) and public annoyance (odour and visibility) factor. Small particulates (under 2.5 μ) disperse widely and may be most deleterious for health because they can pass to lung alveoli. Particulates may be vectors for other toxic agents including heavy metals or bioactive chemicals such as antibiotics and endotoxins. Particulates may also transport bacteria through the atmosphere over long distances. Since broiler operations are a source of microbes potentially having resistance to one or more antibiotic, the role of particles in dispersion of microbes from poultry farms needs consideration. Concern over cross contamination was greatly heightened in April of 2004 when an outbreak of Avian Influenza spread quickly among farms in the poultry intense area around Abbotsford. Therefore the project was intended to examine emissions of particulates from a typical broiler operation and to relate the particulates to transport of microbes. The project is also intended to assess the use shelterbelts outside the barns of and air ionizer-precipitator in the barns for reducing emissions and dispersion of particulates.

Report edited from original for submission to the BC Sustainable Poultry Farming Group Annual General Meeting, June 2008.

1. Theoretical Basis for Employing Shelterbelts for Entrapment of Particulates and other Materials from Farming Operations: A Scoping Study

The entrapment by the shelterbelt decreases with source height, and distance between the source and shelterbelt (point source) or length of the field upwind of the shelterbelt (area source). Optical porosity of the shelterbelt is related to the proportion of air flow approaching the shelterbelt will be forced to go through the shelterbelt. The vegetation elements (leaves, needles) in the coniferous shelterbelts are small which is better for entrapment, in contrast to deciduous trees that have less efficient larger leaves. RE. Particle sizes: particles with a diameter of less than 6×10^{-6} m are not removed well by the upper respiratory system and may enter the lungs where toxic compounds can be taken up or where they may cause irritation. Particles with a diameter of less than 1×10^{-7} m do not contribute much to the overall particle mass. Particles with a diameter between 1×10^{-7} and 1×10^{-6} m are not removed well by dry deposition and entrapment. Particles with a diameter of 1×10^{-5} and larger are removed relatively well, but in general dry deposition between the point source and the shelterbelt is more important than entrapment by the shelterbelt. The scoping study concludes that it would be possible to design shelterbelts in such a way that they entrap particles and gases somewhat more efficiently than normal shelterbelts do.

2. Emissions of particulates from poultry housing

All PM fractions in the barns and exhausted from the barns increased dramatically through a production cycle. Diurnal spikes in PM may be related to increase bird activity due to feeding, light cycle and farmer entry in barn. The large PM₁₀ ($>1000 \mu\text{g m}^{-3}$ in last week of cycle) far exceeded (10X) the smaller PM_{2.5} particles by weight, but were much less numerically. The periods of maximum concentrations generally corresponded with maximum emissions showing that the high concentrations are due primarily to production of particles rather than reduced ventilation. There is indication that reducing PM in barns improves bird performance and this has prompted the participating farmer to purchase an ionizing device. Particle concentration is greatly reduced by the tree shelterbelt and there is evidence of large amounts of PM deposited on the trees. Only one tree in the shelterbelt has died over 2-3 years, and because this tree was not a prime recipient of emissions, other factors may have been involved.

3. Aerial transport of microbes associated with PM of varying sizes

The microbial density in the air leaving the barns was slightly lower than the air tested inside the barn. Quantities declined further through the tunnel although dilution was kept to a low level since the tunnel prevented most (not all) mixing with outside air. There is indication, although data is limited, that there is a greater decline in microbes on larger than on small particles when comparing the air near the exhaust and air past the shelterbelt. This suggests that some of the larger particles were dry-deposited or entrapped by the trees. The possibility of entrapment of the small particles is much lower than for the larger particles and would require high airflow rates. This would require that the tunnels were made much smaller (ducts) or that the trees were moved very close to the buildings. The latter might not be very practical since unrestricted access is needed on all sides of the barns. The presence of antibiotic resistant bacteria was detected in the in the PM emitted from a broiler barn.

In conclusion, this study succeeded in developing a relationship with the poultry industry that has raised their awareness of the issue of emission of PM in to the environment and the possible direct benefits (feed efficiency) and public benefit (fewer conflicts) of reducing emissions. The project validated methodology for quantifying PM (size ranges <1 to $>10\mu$) in air within broiler building. This has led to detailed information on effect of growth stage and seasonal emission patterns and has contributed towards calculating an emission factor for use in inventories. Static precipitators will reduce emission of

PM and microbes from barns but they are less effective during periods of high PM and re-suspension of PM during cleaning needs consideration. There is evidence that trees receiving barn air will help entrap PM and reduce dispersion to the environment. Because the PM was shown to be associated with large numbers of microbes, the reduction of PM will also reduce microbial release into the environment. Some of these microbes have resistance to one or more antimicrobials. Much of the work must be considered preliminary or provisional due to the new technology being undertaken.

Technical Report

Background

The lower Fraser Valley of BC, and in particular the Abbotsford Uplands near the City of Abbotsford, is a region of increasing production of poultry products and an increasing human population. As a result there is increasing proximity poultry operations, especially broilers and layers, with habitations, areas of recreation and work, and fields for production of specialty crops (especially small berries for the fresh market). This is giving rise to conflict between rural and urban populations over issues such as dust, odour and flies that originate with the poultry operations. In addition, there is conflict between various agricultural sectors and even between and among poultry farmers themselves due to concerns over aerial cross contamination among farms.

Concern over cross contamination was greatly heightened in April of 2004 when an outbreak of Avian Influenza spread quickly among farms in the poultry intense area around Abbotsford. Fig. 1 shows the location of small and commercial poultry operations and the location of the infected flocks. The pattern and rapidity of infection has led to the conclusion that the spread was likely caused by windborne pathogens. Figure 2 shows a typical LFV broiler operation with exhausting waste air into the surroundings.

Added to this concern, is the recent findings that particulate matter is not only a nuisance in obstructing visibility and spreading dirt, the smaller particles may be toxic. Particles less than 2.5 μ m are thought to bypass respiratory filtration and lodge in the alveoli of the lungs. Here the particles cause inflammation which leads to increased blood clotting (e.g. Nurkiewicz et al 2006). There is epidemiological evidence for the close relationship between air pollution events and cardiovascular illness. The Greater Vancouver Regional District is maintaining an inventory of particulates from all sources including agriculture (<http://www.gvrd.bc.ca/air/pdfs/2000EmissionInventory.pdf>).

It is not well known, but there is concern that the particles may be vectors for other toxic agents including heavy metals or bioactive chemicals such as antibiotics. Attached to fine PM, these chemicals may have direct access to the exchange sites in the lungs.

Particulates may also transport bacteria through the atmosphere over long distances. Since broiler operations are a source of microbes potentially having resistance to one or more antibiotic, the role of particles in dispersion of microbes from poultry farms needs consideration.

It should be pointed out that the maximum amount of ventilation from poultry buildings occurs during warm weather. This is also the time when people are most likely to be outside, when wet deposition due to rain is most rare, and when the fruit crops are being picked and eaten. It is the non-visible fine particulates that are most likely to be transported to neighbouring properties.

Therefore the project was intended to examine emissions of particulates for a typical broiler operation and to relate the emissions to transport of microbes. The project is also intended to consider the use of an air ionizer in the barns and shelterbelts outside the barns for reducing emissions and dispersion of particulates.

Nurkiewicz, T.R., Porter, DW, Barger, M. et al. 2006. Systemic Microvascular Dysfunction and Inflammation after Pulmonary Particulate Matter Exposure

PART 1. THEORETICAL BASIS FOR EMPLOYING SHELTERBELTS FOR ENTRAPMENT OF PARTICULATES AND OTHER MATERIALS FROM FARMING OPERATIONS: A SCOPING STUDY

Entrapment of ammonia, odour compounds pesticide sprays and pathogens by shelterbelts: overview of current knowledge and recommendations for future research

Scoping paper by Willem Asman, Danish Institute Agricultural Sciences.

An overview is given over the processes that play a role in the entrapment of gases and particles by shelterbelts close to agricultural point and area sources. The report focuses on ammonia and particles, but some information is also given that is relevant for gaseous pesticides and odour compounds as well as pesticides, odour compounds and pathogens that are associated with particles.

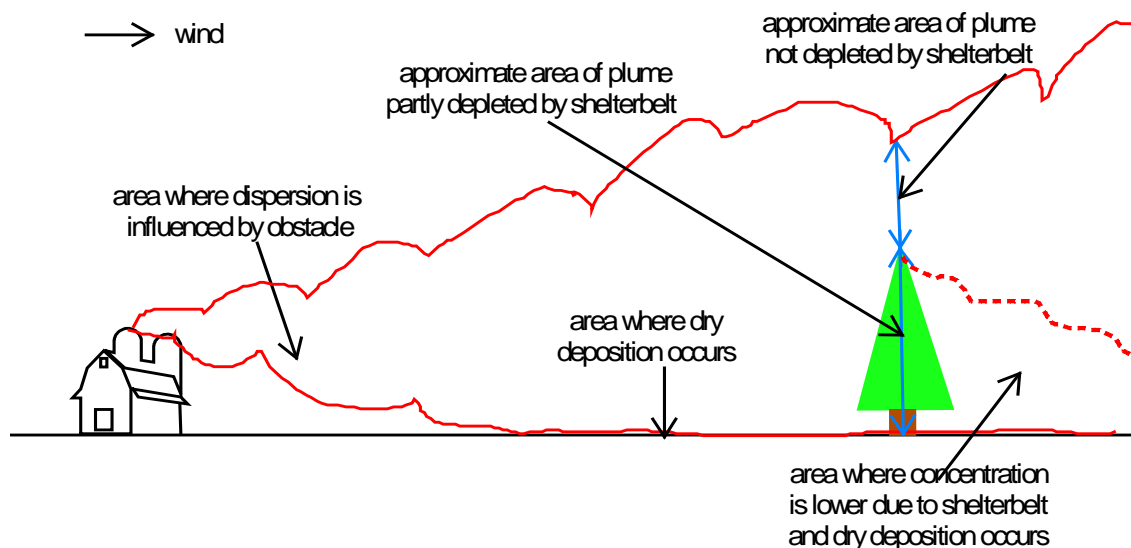


Fig. 1 Schematic showing emission transport and deposition of PM from animal housing facility located near a shelterbelt (from Asman 2007).

The report gives also information on the dry deposition that occurs downwind of sources before the shelterbelt is reached, because this dry deposition reduces the amount that can be entrapped by the shelterbelt.

A model was developed for the entrapment of ammonia and other gases by shelterbelts and an existing model was used to describe the entrapment of particles (Raupach et al, 2001). These models were combined with a two-dimensional atmospheric transport model (Asman, 1998) that includes dry deposition to describe the transport of released material to the shelterbelt.

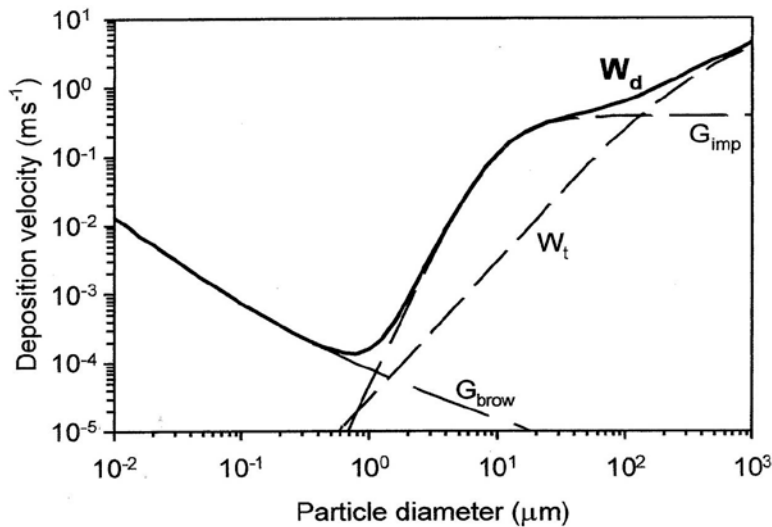


Fig. 2 Modelled deposition velocity of particles ranging from 10⁻³ to 103μm as affected by by various processes: W_d = dry deposition velocity, G_{br} = Brownian motion, W_t = gravitational settling G_{imp} = impaction (from Asman 2007)

The entrapment by the shelterbelt increases with:

- The height of the shelterbelt.
- Stability of the atmosphere.
- Wind speed (for particles).
- Particle size (for particles with diameter $> 1 \times 10^{-7}$ m).

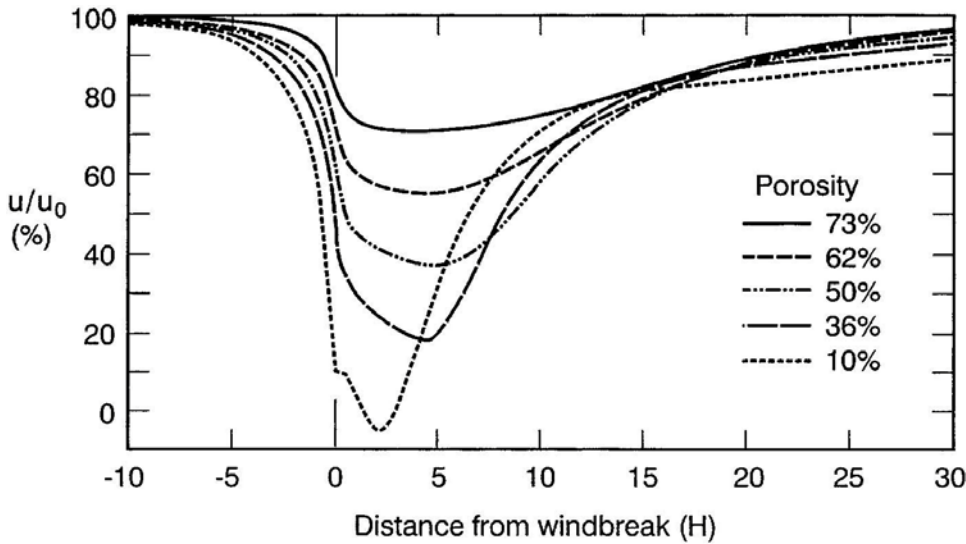


Fig. 3 Effect of optical porosity of tree shelterbelt on wind velocity

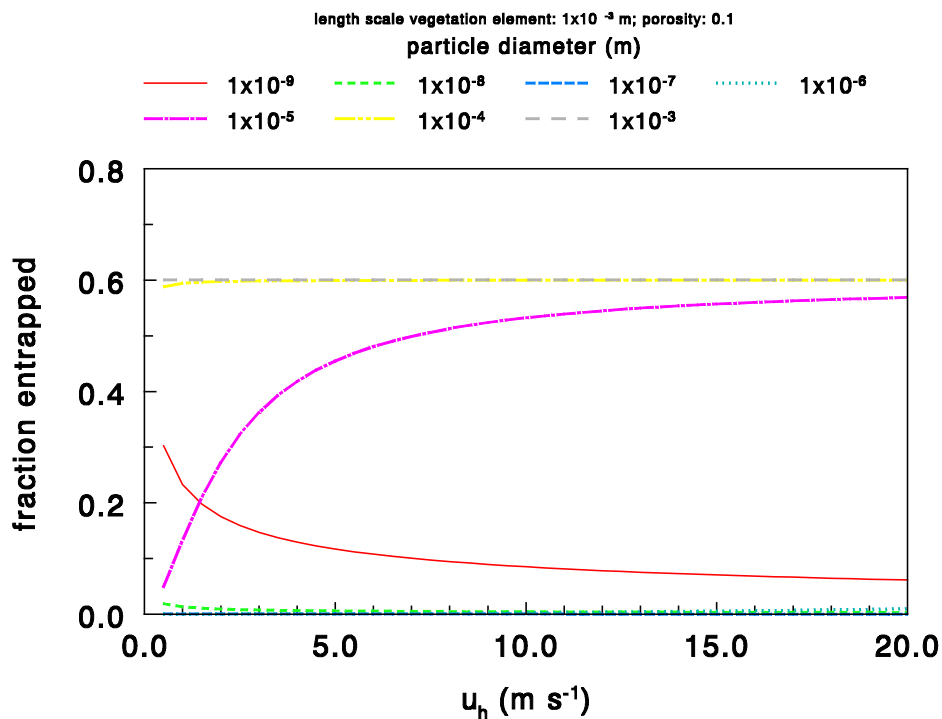


Fig. 4 Proportion of PM entrapped by a shelterbelt as affected by wind speed and particle size

The entrapment by the shelterbelt decreases with:

- Source height.
- Distance from the source to the shelterbelt (point source) or length of the field upwind of the shelterbelt (area source).
- Optical porosity of the shelterbelt. The smaller the porosity the larger fraction of the air flow approaching the shelterbelt will be forced to go through the shelterbelt.
- Typical length of the vegetation elements (leaves, needles) in the shelterbelt. Coniferous trees that have small needles entrap more efficiently than deciduous trees that have larger leaves.
- Wind speed (for gases).
- Surface resistance and molecular mass (gases).

Research in the UK indicates that it would be possible to design shelterbelts in such a way that they entrap gases and particles somewhat more efficiently than normal shelterbelts do.

Gases

At maximum 37% of the emission of a ground level point source of ammonia can be dry deposited before the plume reaches a shelterbelt that is located 200 m downwind. Then another 11% can be removed by a 10 m high shelterbelt. In this case it is assumed that there is no resistance for uptake of ammonia by vegetation. If it is assumed that there is a small surface resistance for uptake of ammonia, only 28% of the emission is dry deposited between the ground level point source and the shelterbelt and only 3% of the emission is entrapped by a 10 m high shelterbelt.

Is the source height changed from 0 m to 10 m at maximum 4% of the emission of a 10 m high point source can be dry deposited before the plume reaches a shelterbelt that is 200 m downwind. Another 12% will be entrapped by a 10 m high shelterbelt. So in the case of a higher source the dry deposition is less important. If it is also assumed that there is a small surface resistance for uptake of ammonia, both dry deposition and entrapment become even less.

So it is important that the distance between the source and the shelterbelt is not too large.

For other gases than ammonia (gaseous pesticides, odour compounds) the dry deposition and entrapment will be less than for ammonia.

Particles

Particles with a diameter of less than 6×10^{-6} m are not removed well by the upper respiratory system and may enter the lungs where compounds can be taken up. Particles with a diameter of less than 1×10^{-7} m do not contribute much to the overall particle mass. Particles with a diameter between 1×10^{-7} and 1×10^{-6} m are not removed well by dry deposition and entrapment. For particles with a diameter of 1×10^{-5} and larger are removed relatively well, but in general dry deposition between the point source and the shelterbelt is more important than entrapment by the shelterbelt.

Pathogens and part of the odour compounds are associated with particles, but it is not known with which size they are associated. As dry deposition and entrapment are highly dependent on the particle diameter, nothing is known on the dry deposition and entrapment of pathogens and odour compounds associated with particles.

2. EMISSIONS OF PARTICULATES FROM POULTRY HOUSING

MATERIALS AND METHODS

Site Layout - -For further detail see Appendix 1

Overall site layout was comprised of a Quonset wind tunnel structure with approximate dimensions of 11 feet x 30 feet placed perpendicular to the barn, allowing dust to travel its full length. The height of each monitoring tunnel at its peak was about 10.5 feet. Each tunnel was designed to channel exhausted barn air from a 24 inch and 36 inch fan located at about 3 to 4 feet above ground elevation.

Two rows of Cedar trees (*Thuja plicata* 'Excelsa') spaced about 8 feet x 8 feet were placed in an arc configuration from the outlet of the tunnel. Tree height varied from about 11 – 15 feet. Distances from the end of the tunnel to the first row of trees varied from about 10 feet to 14 feet depending on measurement location within the arc or at the tunnel outlet. The second row of trees was located about 8 feet further from the tunnel along the same arc line as the first row.

Surrounding the tunnel horizontal outlet area encompassing the trees and area between the tunnel and trees was a wing wall projecting from each side of the tunnel outlet of about 8 feet high and 28 feet long. This wing wall consisted of 'landscape fabric' of low air permeability (same material covering the tunnels) immediately near the tunnel outlet for a length of 36 Feet and then 'snow fence' was used (about 60% porosity) to the end of the wall (13 Feet). As well, vertical air movement from tunnel outlet air was minimized through the use of 'snow fence' ceiling (60% porosity) which spanned from the tunnel outlet to each side of the wing walls out to and including the second row of trees.

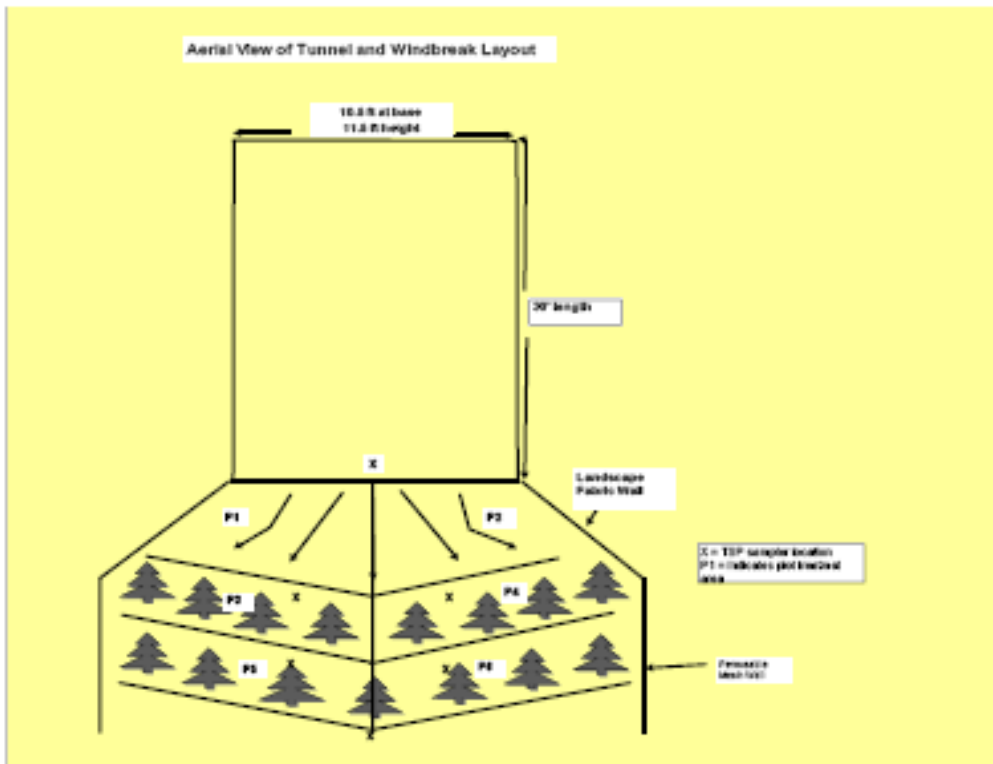


Fig. 5. Diagrammatic representation of tunnel shelterbelt arrangement used in this study

PM emissions is estimated as the product of overall barn ventilation rate and particulate matter concentrations:

$$E(x) = Q_{vent} * C(x)$$

where $E(x)$ is the emission rate of the x -fraction of particulate matter (μg or particles min^{-1}), Q_{vent} is the overall barn ventilation rate, and $C(x)$ is the mass concentration or particle number count of particulates in the x -fraction.

Ventilation determination

This report assumes airflows of $136 \text{ m}^3 \text{ min}^{-1}$ for each 24" fan and $184 \text{ m}^3 \text{ min}^{-1}$ for each 36" fans, at every fan stage. These airflows were based on extensive testing with balometer (Model APM 153, Alnor TSI Inc., Shoreview, MN). Table 1 provides estimated overall barn ventilation rates.

Table 1. Estimated barn ventilation rates at each fan stage, for both study barns

Fan stage	Ventilation ($\text{m}^3 \text{ min}^{-1}$)
1	0
2	544
3	728
4	912
5	1096
6	1648
7	1832

Fan activity was recorded minutely with an induction current switch-based system, as described by Muhlbauer et al. (2006). Twenty-minute averages of estimated barn ventilation rates were then calculated. Since fan activity data collection was incomplete for the control barn, data for the ESCS barn was used to estimate control barn fan activity. The relative difference between the two barns' average estimated ventilation rates was used as a correction factor to estimate ventilation rates for the control barn when control fan activity data was missing.

Alternative measures (to validate fan activity data): cumulative timers and manual checks.

Table 2. Effect of distance from barn and height on air velocity in wind tunnel

		Distance from fans (m)			
		3.1	4.6	9.2	13.8
Height (m)	2.5	4.9	2.1	1.3	1.4
	1.2	2.3	1.8	1.3	1.4
	0.6	0.1	1.3	1.5	1.3
	1.2	2.5	1.4	1.6	1.0
	1.2	2.0	0.1	1.6	1.5

Dust concentrations

Continuous sampling. Grimm (Model 1.108, GRIMM Technologies, Inc., Douglasville, GA) sampled every minute at location A (Fig. 10), 1.6 m high, for periods of typically two to three days throughout the cycle. Between periods of sampling both barns, the Grimms alternated barns. In addition, there were periods of sampling one barn (location), when a randomly-selected Grimm was placed on top of the other to compare the Grimms against each other or alternative particulate measurement devices.

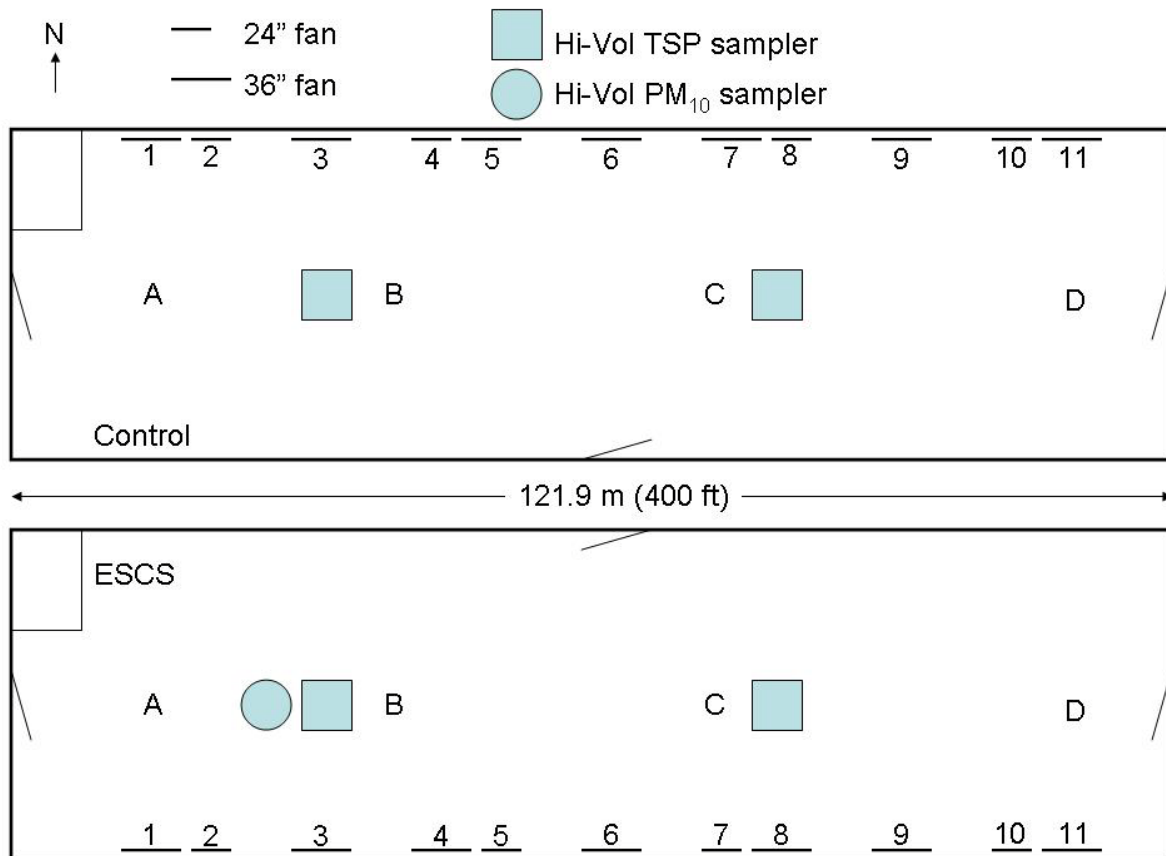


Fig. 6. Schematic showing ventilation fans and sampling locations in two broiler barns used on PM study. Tunnels cover fans 1 and 2 and fans 10 and 11 of the control barns.

Twenty-minute averages are presented, with outliers removed. An outlier was a value more than three standard deviations from the mean of a subset of 60 measurements taken within 30 minutes of the outlier or within 60 minutes if the outlier was taken during the first or last 30 minutes of a continuous sample.

Intermittent, paired sampling. At several points throughout the cycle, one Grimm sampled particle number count and the other sampled mass concentrations along the length of the barns. Barns were sampled in pairs, so that one barn was sampled immediately after the other. There were two minutes of sampling at each of four locations in a barn, and one minute was allotted to moving the Grimms to the adjacent location (Figure 1). The following were randomly selected: the Grimm on count/mass mode, the first barn in each pair, the Grimm on top/bottom, and the starting location for each sample pair.

Sampling interval was six seconds. Eleven-minute averages of dust concentrations and barn ventilation rates were calculated. Data was not evaluated for outliers. The reported time of sampling is within 20 minutes of starting in the first barn and ending in the second barn.

Barn ventilation rates

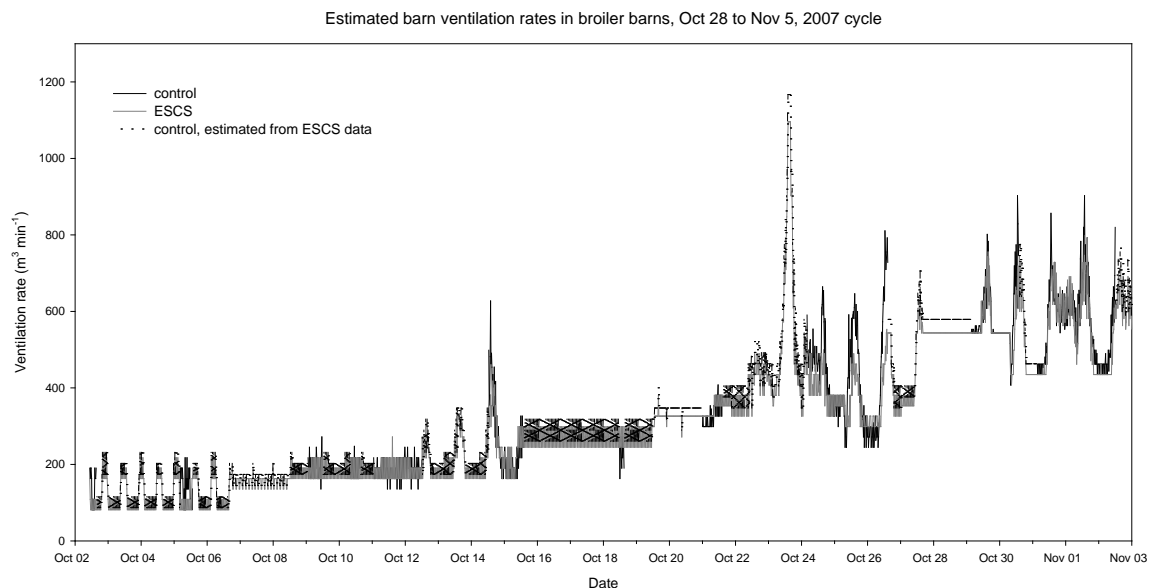


Fig. 7. Volume of air exhausted from control and ionizer-fitted broiler barn over a portion of the broiler lifecycle.

The ventilation is controlled mainly barn temperature which strives to track ideal temperature of growing birds through at least 5 stages. Measurements are based on fan calibrations using balometers and monitoring fan activity with a data logger. Fans are fixed speed.

Testing Grimm spectrometer measurements with two types of impactors.

Table 3. Dust mass concentrations (mg m^{-3}) in the control barn, measured 1.9-m high at location B (Figure 1). Note differences in size fractions.

Sample dates	PM ₁₀ Grimm1	PM ₁₀ Grimm2	PM ₁₀ Harvard impactor	PM ₉ Cascade impactor	PM ₂ Grimm1	PM ₂ Grimm2	PM _{2.5} Harvard impactor	PM _{2.1} Cascade impactor
Oct18 to 19, 2007 ^a	1.817	1.726	0.263	1.606	0.048	0.045	0.019	0.022
Nov 1 to 2, 2007 ^b	1.488	1.473	0.488	n/a	0.101	0.090	0.031	n/a

a. sampling time was 27.5 hours, from 11:45 (Oct 18) to 14:16 (Oct 19).

b. sampling time was 18 hours, from 13:12 (Nov 1) to 09:11 (Nov 2).

Differences in $<10 \mu\text{m}$ results between Harvard impactors and other instruments may be an artefact of differences in the sampling mechanisms of the samplers. A shorter sampling time may resolve differences between the Harvard impactors and Grimm or Cascade samplers. Although Grimm1 had greater average PM₁₀ and PM₂ concentrations than Grimm2 during both sampling periods, Grimm2 sometimes measured greater concentrations than Grimm1 (data not shown). Differences in dust concentrations are partly due to different air sampling inlets. It should be noted that Grimm samplers are calibrated against silica which may have a higher density than poultry PM. Some adjustment is made by

setting a linear correction factor based on weights of PM collected on a filter in the instrument. These weights reflect the large heavier particles much more than the smaller ones. The actual values of mass may lie somewhere between the Grimm values and the impactor values. It is important to build in safeguards into the measurement system to ensure reliable data.

Concentrations and emission of PM in standard barn and barn with ionizer installed

The data in Figs. 12—16 below show the increase in PM fractions in the barns and exhausted from the barns through a production cycle. The spikes represent daily variation which may be related to increase bird activity due to feeding, day-night cycle and farmer entry in barn.

In terms of mass, the large PM10 far exceeded the smaller PM 2.5 particles. The opposite is true when examining particle numbers. During the last 7 days, PM10 always exceeded $1000 \mu\text{g m}^{-3}$ and occasionally exceeded $5,000 \mu\text{g m}^{-3}$. The periods of maximum concentrations generally corresponded with maximum emissions showing that the high concentrations are due primarily to production of particles rather than reduced ventilation. Concentrations of particles under 2μ were about 10-fold less than the larger PM 10 particles. The concentrations of PM2 may be of concern to workers spending time in the poultry buildings or working near the buildings. It is not know whether the PM concentration is deleterious to the birds. The values measured in our study are similar in magnitude to those reported in Ontario by Roumeliotis and van Heyst (2007).

The overall PM reduction s by the ionizer can be seen in Tables 3 and 4. Reduction of 57-75 % for PM2.5 an PM 10 were observed for day 1-day 26. Reductions during the last 3 days were only half as great. This may be due to the heavy loadings of dust in the air at this time, or it may be due to need for more frequent cleaning of the ionizer or of surfaces that have become covered in PM.

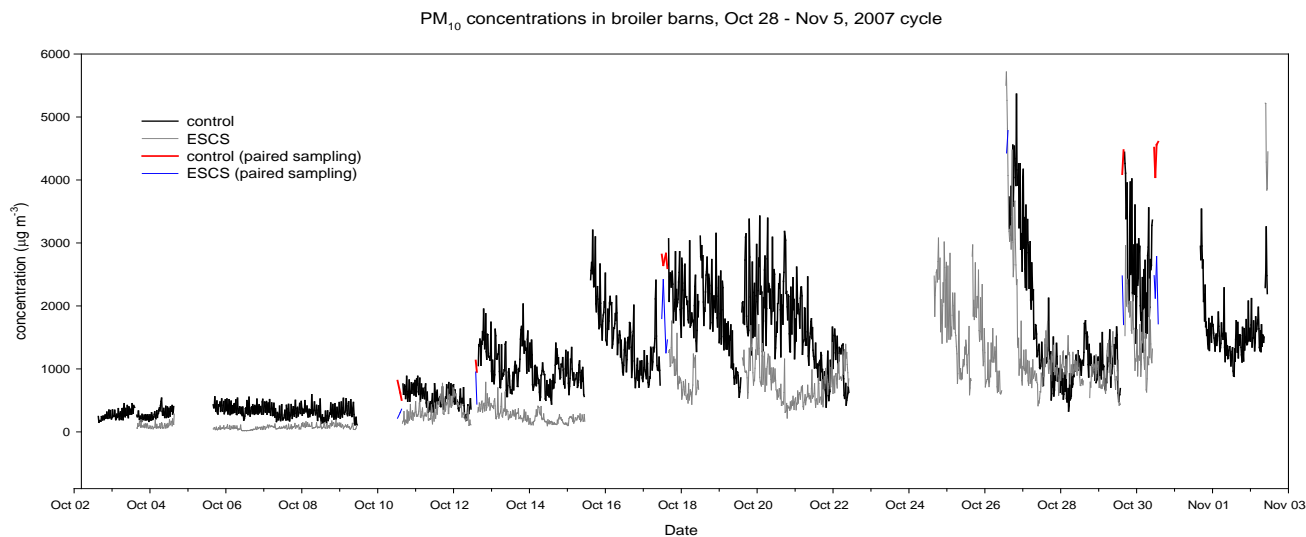


Fig. 8 PM10 concentration during peak emission period over the last 7 days of production cycle.

PM₁₀ emissions from broiler barns, Sep 28 - Nov 5, 2007 cycle

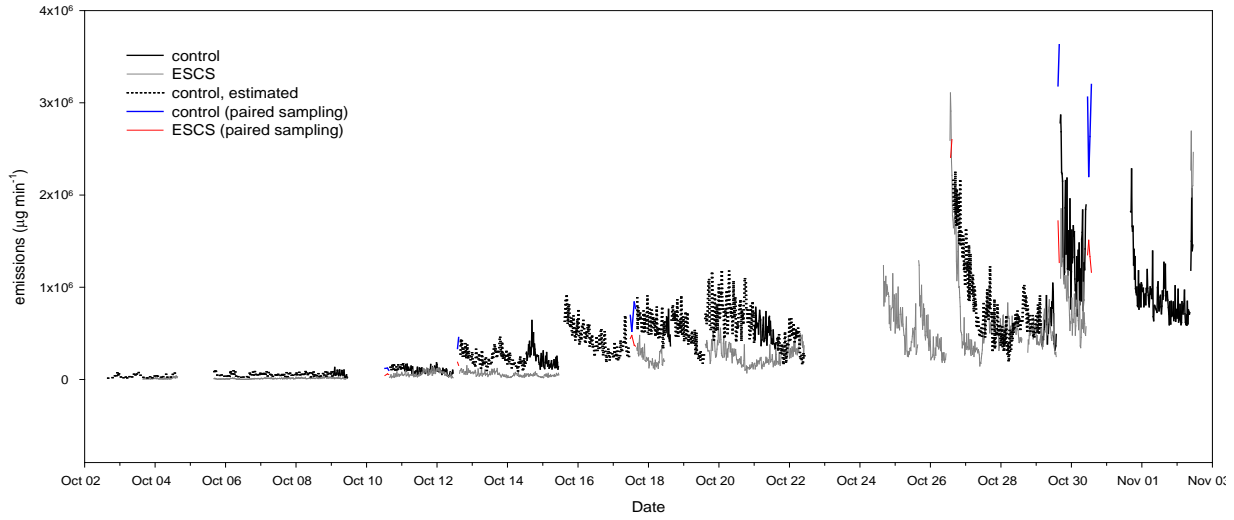


Fig. 9 PM₁₀ emissions during peak emission period over entire production cycle.

PM₂ concentrations in broiler barns, Oct 28 - Nov 5, 2007 cycle

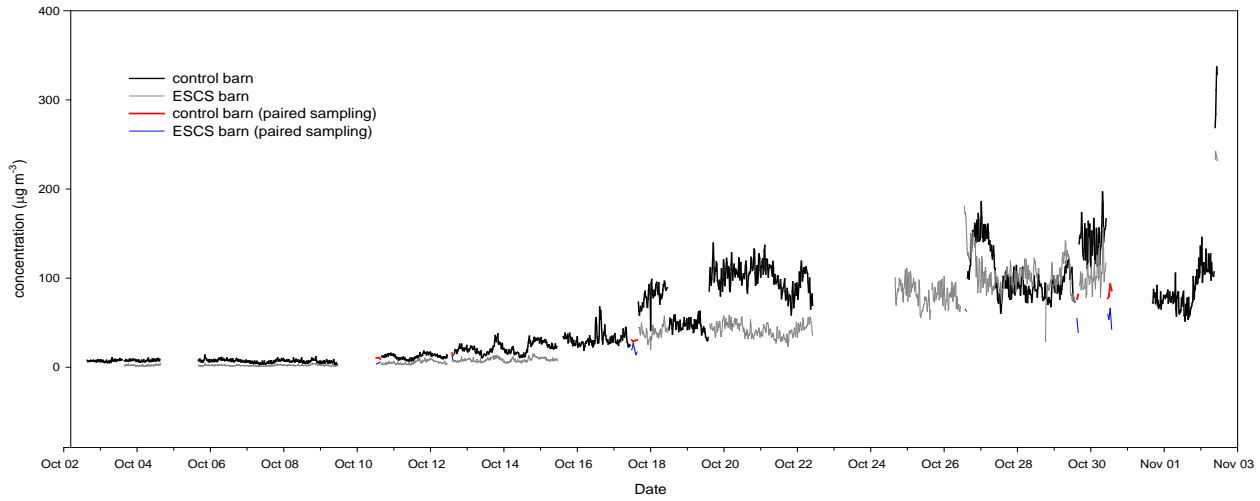


Fig. 10 PM₂ concentration during peak emission period over the last 7 days of production cycle.

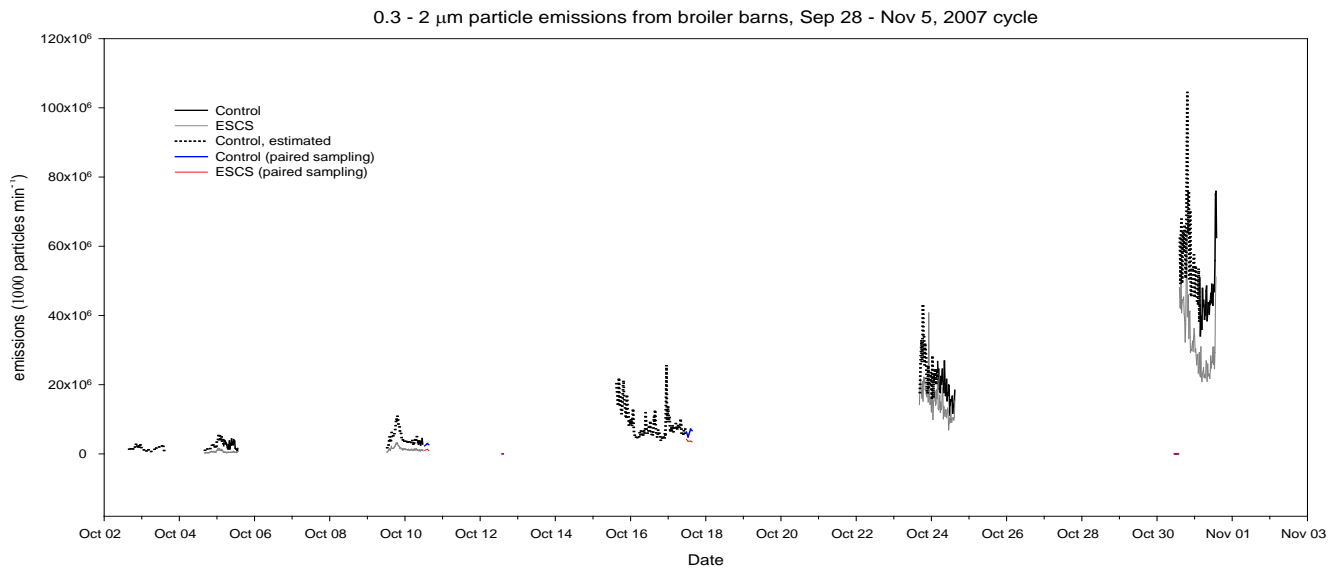


Fig. 11 Emissions of PM₂ based on particle counts during production cycle.

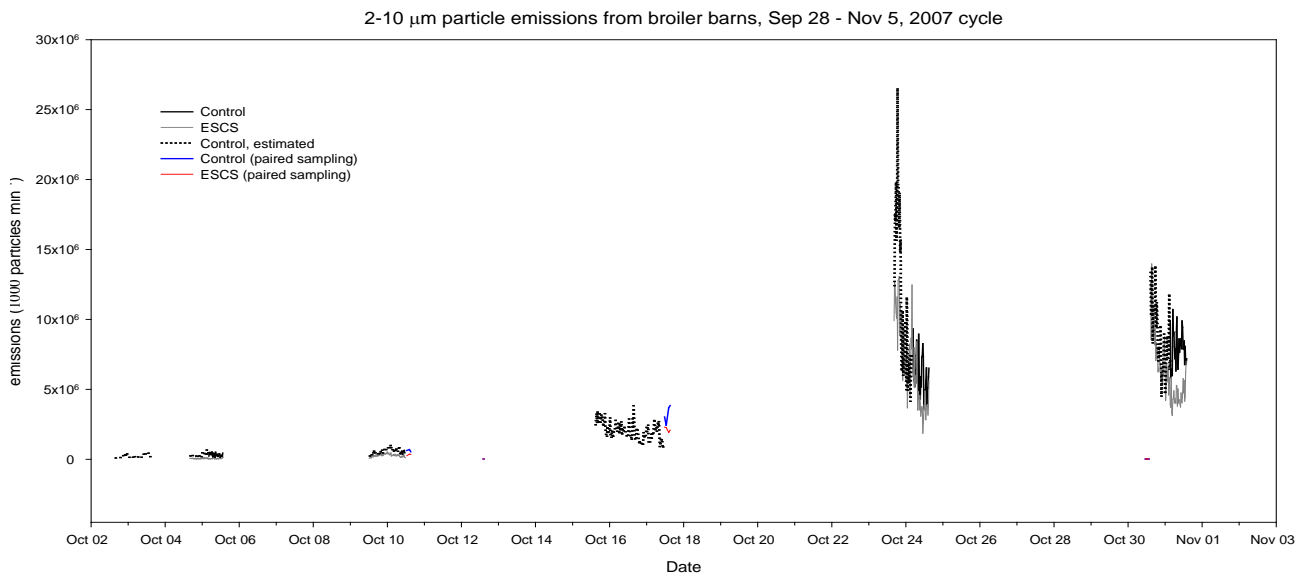


Fig. 12 Emissions of PM₁₀ to PM₂ over a poultry production cycle.

Table 4. Dust mass concentration reductions due to the ESCS, i.e. the difference in average particulate mass concentrations between the two barns, expressed as a percent of average control barn mass concentrations.

ycle	PM ₂	PM ₁₀	PM	Hours ^a
	68.1%	74.3%	72.1%	123
	57.1%	58.4%	46.7%	190
ESCS off)	0.6%	26.9%	32.6%	64
ESCS back on)	26.6%	31.9%	46.2%	62

^a The number of hours of measurements averaged.

Table 5. Dust emissions reductions due to the ESCS, i.e. the difference in average particulate mass emissions between the two barns, expressed as a percent of average control barn mass emissions.

ycle	PM ₂	PM ₁₀	PM	Hours ^a
	69.2%	74.9%	72.6%	123
	58.9%	59.2%	45.9%	190
ESCS off)	2.9%	25.9%	33.6%	64
ESCS back on)	29.6%	34.7%	48.5%	62

^a The number of hours of measurements averaged

3. AERIAL TRANSPORT OF MICROBES ASSOCIATED WITH PM OF VARYING SIZES

Results and Discussion

Tables 5-9 show the number of cell forming units attached to particles of various sizes sampled at 5, 20 and 34 days (top) and microbes on two selective and the non-selective media on day 34. It is interesting the background levels at the source seem to increase during the cycle suggesting a backflow. The size gradient was low on day 20 probably due to the rainy weather. Intake air on day 34 was similar in density and size distribution to exhaust air on Day 5. This information is important since it suggests that the microbes will survive through a fairly long transport through the air.

Microbial concentrations exceeded range in barn by day 20 at all but the smallest particle sizes on the TSA medium due to preponderance of gram positive bacteria; the MAC gram negative selective medium showed few microbes on any of the sampling days. In general the Staph-selective BP medium produced more microbes than the gram negative plates and even the Staph aureus bacteria outnumbered the gram negatives.

The microbial density in the air leaving the barns was slightly lower than the air tested inside the barn. Quantities declined further through the tunnel although dilution was kept to a low level since the tunnel prevented most (not all) mixing with outside air.

There is indication, although data is limited, that there is a greater decline in microbes on larger than on small particles when comparing the air near the exhaust and air past the shelterbelt. This suggests that some of the larger particles were dry-deposited or entrapped by the trees. The possibility of entrapment of the small particles is much lower than for the larger particles and would require high airflow rates. This would require that the tunnels were made much smaller (ducts) or that the trees were moved very close to the buildings. The latter might not be very practical since unrestricted access is needed on all sides of the barns.

These results need to be validated additional sampling and additional cycles. Also, other types of poultry operation need to be examined, especially turkey and layer. To avoid exceeding sampling limit, future work at high microbial densities will require much shorter sampling times or use of impinger type system for collecting the microbes. It is also important to determine the fate of the microbes in terms of survival over time, and distance of travel. The increase in microbes at the inlet, which appears to come from exhaust air returning over the barn roof to the inlet side, is first evidence for survival of microbe on fine particles. Even the larger particles appear to be transported.

Table 6 Microbial densities associated with different particle sizes in air samples collected near intake of broiler barns (collected with 6-stage Anderson Sampler),. Top: Sampling at 5, 20 and 34 days of 38

day growth cycle using TSA medium. Bottom: Sampling at day 34 using 3 different media as described below.

Ambient Intake Air (TSA Medium)

		Day 5		Day 20	Day 34
				CFU/m3	
1	ge	18	14	339	> QDL*
2	um	11	18	NA	3975
3	um	53	42	360	5364
4	um	11	14	134	2830
5	um	18	18	184	746
6	l um	4	0	99	78

Ambient Intake Air Day 34

		TSA	MAC	Baird-Parker	S. aureus
				CFU/m3	
1	ge	> QDL*	0	60	4
2	um	3975	0	25	4
3	um	5364	0	28	0
4	um	2830	0	11	0
5	um	746	0	14	0
6	l um	78	0	18	0

rypticase soy agar; allows growth of gram positive and negative bacteria

lcConkey agar; only allows gram negative bacteria to grow.

arker = selective media for Gram positive cocci, particularly Staphylococci

s = growth on Baird-Parker with halo indicates coagulase positive *Staphylococcus aureus*.

Table 7 Microbial densities associated with different particle sizes in air samples collected inside control broiler barn (collected with 6-stage Anderson Sampler). Top: Sampling at 5, 20 and 34 days of 38 day growth cycle using TSA medium. Bottom: Sampling at day 34 using 3 different media as described on Table 5.

Barns (TSA)					
Stage	size range	CFU/m3			
		Day 5	Day 20	Day 34	
1	> 7 um	9286	3219	> QDL*	> QDL*
2	4.7 - 7.0 um	3442	3219	> QDL*	> QDL*
3	3.3 - 4.7 um	3615	1823	> QDL*	> QDL*
4	2.1 - 3.3 um	1262	470	> QDL*	> QDL*
5	1.1 - 2.1 um	608	300	7618	25053
6	0.65 - 1.1 um	14	7	170	1578

*QDL = quantitative limit of detection exceeded. For 3 minute sample nominally given value of > 30954 or 5 minute sample is nominally given value of > 18572

Barn 1	TSA	MAC	Baird-Parker	S. aureus	
Stage	size range	CFU/m3			
1	> 7 um	> QDL*	28	23.3	could not be determined
2	4.7 - 7.0 um	> QDL*	4	3.3	could not be determined
3	3.3 - 4.7 um	> QDL*	85	70.8	could not be determined
4	2.1 - 3.3 um	> QDL*	4	3.3	389
5	1.1 - 2.1 um	25053	0	0	0
6	0.65 - 1.1 um	1578	0	0	0

*QDL = quantitative limit of detection exceeded. For 3 minute sample nominally given value of > 30954

** QDL for 5 minute sample is nominally given value of > 18572

Table 8 Microbial densities associated with different particle sizes in air samples collected near exhaust of control broiler barn (collected with 6-stage Anderson Sampler). Top: Sampling at 5, 20 and 34 days of 38 day growth cycle using TSA medium. Bottom: Sampling at day 34 using 3 different media as described on Table 5.

Near exhaust

Stage	size range	Day 5		Day 20	Day 34
		CFU/m ³	CFU/m ³	CFU/m ³	CFU/m ³
1	> 7 um	9286*	9286*	> QDL*	> QDL*
2	4.7 - 7.0 um	5364	3219	> QDL*	> QDL*
3	3.3 - 4.7 um	1385	4035	1371	> QDL*
4	2.1 - 3.3 um	746	1201	1604	> QDL*
5	1.1 - 2.1 um	304	562	686	28704
6	0.65 - 1.1 um	60	46	57	1849

quantitative limit of detection exceeded. For 3 min. sample nominally given value of > 30954
 or 5 minute sample is nominally given value of > 18572

Stage	size range	TSA	MAC	Baird-Parker	S. aureus
		CFU/m ³			
1	> 7 um	> QDL*	99	> QDL**	could not be determined
2	4.7 - 7.0 um	> QDL*	28	> QDL**	could not be determined
3	3.3 - 4.7 um	> QDL*	138	> QDL**	912
4	2.1 - 3.3 um	> QDL*	180	> QDL**	608
5	1.1 - 2.1 um	19835	0	> QDL**	452
6	0.65 - 1.1 um	1873	0	8071	0

quantitative limit of detection exceeded. For 3 min. sample nominally given value of > 30954
 or 5 minute sample is nominally given value of > 18572

Table 9 Microbial densities associated with different particle sizes in air samples collected at mouth of tunnel, 10 m from exhaust fan of control broiler barn (collected with 6-stage Anderson Sampler). Top: Sampling at 5, 20 and 34 days of 38 day growth cycle using TSA medium. Bottom: Sampling at day 34 using 3 different media as described on Table 5.

10m from barn (Mouth of tunnel)

Stage	size range	Day 5		Day 20		Day 34	
		CFU/m3		CFU/m3		CFU/m3	
1	> 7 um	1138	4643	> QDL*	> QDL*	> QDL*	> QDL*
2	4.7 - 7.0 um	488	1081	> QDL*	> QDL*	> QDL*	> QDL*
3	3.3 - 4.7 um	587	1021	2212	1477	> QDL*	> QDL*
4	2.1 - 3.3 um	156	410	1477	1081	> QDL*	> QDL*
5	1.1 - 2.1 um	74	170	1081	155	16148	16148
6	0.65 - 1.1 um	21	21	155		1472	1472

quantitative limit of detection exceeded. For 3 minute sample nominally given value of > 30954
 or 5 minute sample is nominally given value of > 18572

Stage	size range	TSA	MAC	Baird-Parker	S. aureus
		CFU/m3			
1	> 7 um	> QDL*	21	> QDL**	could not be determined
2	4.7 - 7.0 um	> QDL*	18	> QDL**	could not be determined
3	3.3 - 4.7 um	> QDL*	21	> QDL**	could not be determined
4	2.1 - 3.3 um	> QDL*	25	> QDL**	88
5	1.1 - 2.1 um	16514	0	2996	7
6	0.65 - 1.1 um	2792	0	223	7

quantitative limit of detection exceeded. For 3 minute sample nominally given value of > 30954
 or 5 minute sample is nominally given value of > 18572

Table 10 Microbial densities associated with different particle sizes in air samples collected past the shelterbelt, approximately 18m from exhaust fan, and 8 m from mouth of tunnel, at control broiler barn (collected with 6-stage Anderson Sampler). Top: Sampling at 5, 20 and 34 days of 38 day growth cycle using TSA medium. Bottom: Sampling at day 34 using 3 different media as described on Table 5.

Past Shelterbelt

Stage	size range	Day 5		Day 20	Day 34
				CFU/m3	
1	> 7 um	170	170	148	1072
2	4.7 - 7.0 um	32	32	177	459
3	3.3 - 4.7 um	92	92	339	683
4	2.1 - 3.3 um	99	99	134	424
5	1.1 - 2.1 um	88	88	622	165
6	0.65 - 1.1 um	39	39	14	12

quantitative limit of detection exceeded. For 3 minute sample nominally given value of > 30954
 or 5 minute sample is nominally given value of > 18572

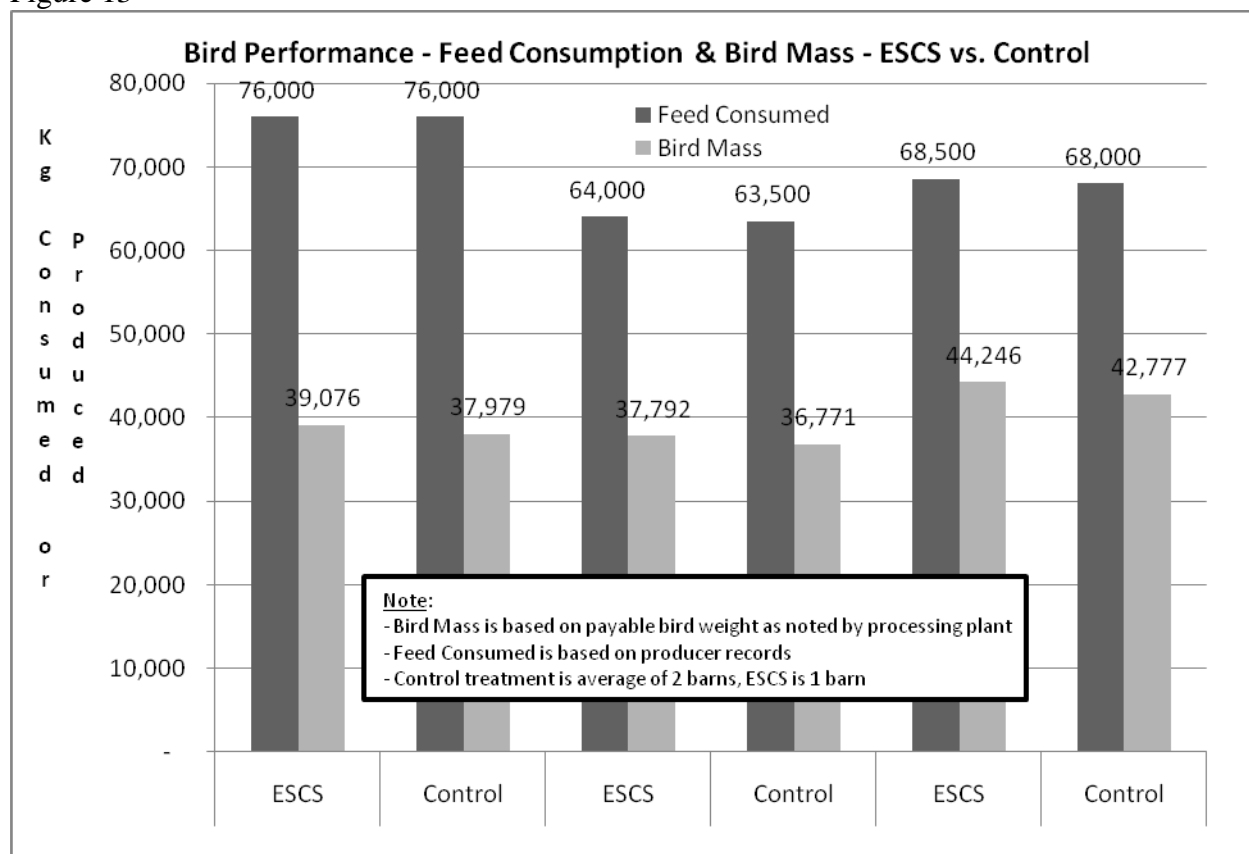
Stage	size range	TSA	MAC	Baird-Parker	S. aureus
		CFU/m3			
1	> 7 um	1072	7	353	14
2	4.7 - 7.0 um	459	0	233	7
3	3.3 - 4.7 um	683	4	233	7
4	2.1 - 3.3 um	424	0	205	7
5	1.1 - 2.1 um	165	0	78	0
6	0.65 - 1.1 um	12	0	7	0

quantitative limit of detection exceeded. For 3 minute sample nominally given value of > 30954
 or 5 minute sample is nominally given value of > 18572

4. EFFECT OF ELECTROSTATIC SPACE CHARGER SYSTEM (ESCS) ON BIRD WEIGHTS AND FEED CONVERSION

This section reports on the effect of operating the ESCS system in a broiler barn on bird weights and feed consumption. We tested the hypothesis that bird performance improved due to better air quality in a barn equipped with the ESCS system. The barn installed with the systems was compared with its mate over 3 production cycles in 2007 and 2008. The 'Bird Mass' is based on payable bird weight. The value was calculated as the difference between the bird mass and actual feed costs. Note that in both cycles there was a reduction in feed consumption and in one cycle there was an improvement in bird mass. The net value to the producer of the ESCS system is about 6 to 9 cents per bird. Note that these data must be seen as preliminary as there was no barn randomization; future work will alternate the treated and control barns.

Figure 13



General Discussion

Increase in knowledge:

1. Modelling results:

- Shelterbelts affect airflow-
- part passes through at reduced speed (varies with optical porosity)
- so rest is forced over top
- Particles are removed by entrapment within the vegetation and dry deposition on top
- Particles exceeding 10u are removed mostly by settling

- PM₆ and less are most detrimental and remain aloft; the smaller particles are difficult to entrap and require small vegetative elements
- Optical density needs to be optimized

2. PM measurements

- Turbulence of air flow within tunnels near fan. Therefore the optimum location for measurements is near mouth
- Significant emissions of particles of all sizes; we found substantial variation, diurnally, daily (growth cycle) and seasonally.
- Differences in concentration may reflect rate of exhausting air/
- Trees provide a practical opportunity with medium to large particles but effectiveness for removing small particles has to be determined.
- Relationship between particle size and pathogens (bacteria, fungi and viruses needs to be determined

3. Microbials

- Microbes increased throughout the bird cycle
- Proportionately more microbes on larger particles; most gram positive. While these disperse less than small particles, they may represent a greater local concern. Trees might be most effective in reducing these particles protecting nearby residents, crops and field workers.
- Microbes attached to small particles and numbers maximum near detection limit at end of cycle
- Small particles carrying microbes have potentially long dispersion
- Microbial densities decrease with distance from the fan exhaust.
- Primarily Gram +ve bacteria esp. Staphylococcus (*S. xylosus*)
- Gram -ve less than 1%. (esp. *E. coli* and *Klebsiella pneumoniae*)
- Fungal organisms comprised ~ 10% of total aerobic microbes
- Correlation between inside barn and outside (directly under fan) levels of microorganisms.
- Evidence of antibiotic resistance in Gram +ve and -ve bacteria isolates. Some were isolates were multi-resistant.

BMPs and additional research

The project has not yet yielded a full BMP on use of trees to reduce dispersion of PM from poultry operations. More work needs to be done on delivery of air to trees, and understanding of the factors affecting deposition of the PM ranging in sizes. Information is also needed on tending of trees to ensure their survival and continued effectiveness. Finally additional information is needed on the fate PM and associated chemicals that are accumulated by the trees and eventually deposited on the ground.

Results to date are encouraging because the red cedars tested have been shown to be persistent and to have PM trapping capability. Tree belts have other benefits such as beautification and biodiversity. However, trees may pose a biosecurity risk if AI infect birds are attracted to the trees. The opposite would be true for birds that prefer open fields, and those that are threatened by raptors. Attracting raptors may reduce rodent populations. Soil testing is being conducted.