Report on

Studies of Particulate Matter in and Around Poultry Barns in the Lower Fraser Valley

Presented to the Sustainable Poultry Farming Group
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1.0 Effect of Electrostatic Charge Precipitator (ESCS) on Particulate Matter Concentrations in a Broiler Barn and Rates of Expulsion to the Atmosphere

Methodology:

Measurements were mad on a semi-continuous basis on two barns fitted with the ESCS. Only one barn operated the ESCS and the other was monitored as a control. Measurements reported here were carried out between May 2008 and March 2009 over approximately 5 production cycles. Data collected before May 2008 are not reported here.

Measurements were made with a continuous optical analyzer (Grimm Instruments) set to determine mass concentrations (ug/m^3) for three size categories based on their Aerodynamic diameters: <10u, <02.5u and <1.0u). The analyzer was situated near the middle of each barn at about 1 m above the ground. Analyzer data was periodically down loaded and a dust collecting filter weighed to test and adjust the size/ weight relationship. In addition, Harvard type impactors (10 and 2.5u) were used to obtain independent measurements of mass over some corresponding periods of time. These data are not complete and are not included in this report.

Two types of comparison were made. In one, all data were obtained from the same Grimm unit (#2) which was alternated between the barns at intervals usually ranging from 2 -4 days. Comparisons were made between ESCS and control barns on successive days in group of up to 3 days (1,2 or 3 days of ESCS followed by the same number of days of Control, or the reverse). Measurements over 24 hrs were typically used as base measurements. The goal was to achieve the same average bird age, ventilation rates and ambient conditions over many measurement periods to allow a fair comparison of the Control and ESCS techniques. This was tested by averaging bird age and ventilation rates over the measurement periods and the differences were comparatively small. Some ventilation values are missing at the time of this writing.

A second method was made possible when one Grimm Analyzer was placed in each barn. Analyzers were switched between barns to reduce any bias between analyzers. This comparison over most of two cycles was made on exactly the same dates.

It should be noted that for the entire measurement period in this report, the control and ESCS treatments were allocated to the same barn. Previous measurements were made with opposite barns and these data will need to be combined with the current data to ensure that there was no bias due to the barn itself. We can assume for the purpose of this report that there were no large differences between barns that would significantly bias the results. Further measurements and calculations will be performed to confirm this assumption.

Ventilation measurements were made by calibrating fan stages to ventilation rates using a group of balometers. Measurements were lower than fan ratings and this could be caused by a number of factors. We are in the process of improving our ventilation measurements using a new procedure and new instrumentation. The current estimates are considered reasonable. Fan stages were monitored continuously using a datalogger and the stages were converted to ventilation rates of the whole barn based on the calibrations. No adjustments were made for effect of conditions such as wind on the ventilation rates. It would be expected that the barn which is more often blowing into the wind will have lower actual ventilation rates. To some extent this is overcome by fans operating longer to maintain a temperature although there is likely always to be a difference between barns. Therefore there is a need to alternate barns. PM emissions were estimated by multiplying the fan ventilation rates by the PM concentration, which assumes that the PM concentration in the centre of the barn is equivalent to the concentration near the fans. The latter is likely to be slightly lower so a slight overestimation of emission is expected here. Future measurements should compare concentrations near the main fans with those near the middle of barn in order to determine an adjustment factor.

Results

These graphs show relative concentrations in ESCS barn and Control barn through large parts of 5 cycles from May 2008 to March 2009. These graphs are based on comparisons of measurements taken in the Control and ESCS barns on 'adjacent' days, with Grimm 2 analyzer. The data from the 5 cycles are plotted by day of cycle. The data are fitted with second order polynomial regressions with generally very high (significant) regression coefficients.

- Concentrations by weight are about 100x greater for PM10 than for PM1, while PM 2.5 is about 10x higher than PM1 (Fig. 1)
- Concentrations of PM in barns can be quite high from a human health (and bird health?) perspective.
- All PM sizes increases in concentration with the bird age as expected and these increases were consistent with a 2^{nd} order polynomials (Fig.1).
- ESCS significantly ($P<0.001$) reduced concentration of all sizes of PM throughout the growth cycles. Difference for all particle sizes were almost two fold with no evidence of more or less efficacy for the ESCS at high concentrations vs. low PM concentrations (latter data is not shown here)
- Similar results were obtained when barns were compared on same days using different Grimms (Fig. 3).
- There was a seasonal pattern of PM concentrations for both barn types with higher PM concentrations evident in late cycles in winter (Fig. 4). The ESCS seems effective in reducing the peak concentrations.

These results provide strong evidence for the efficacy of the ESCS system. The reduction of PM may explain the improved performance of the poultry – reported eldewhere in this report.

The reduction of emissions due to ESCS will lower the poultry PM emission factor. Further calculations are needed to determine the effect on emission factor but based on these data the reduction should be around 50%.

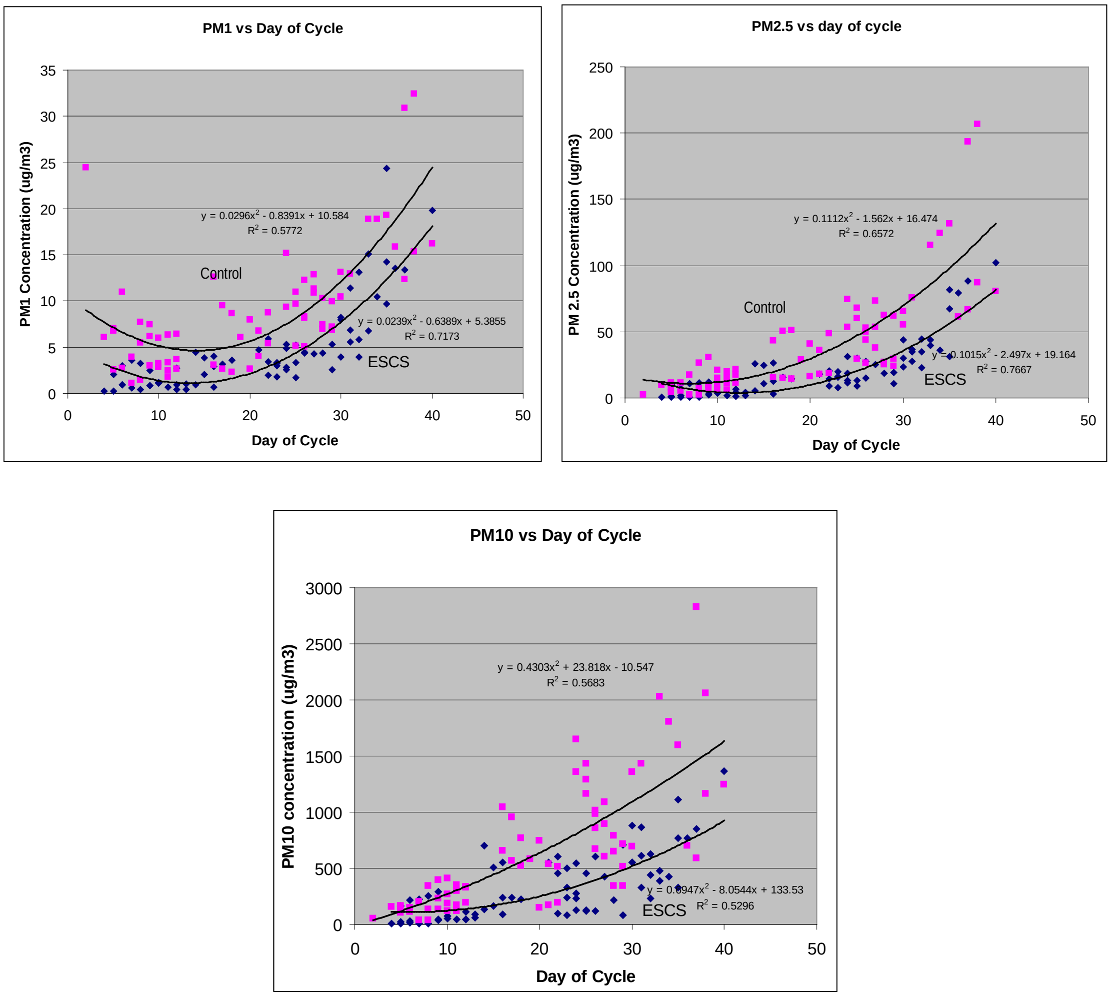


Figure 1. Three graphs showing the effect of cycle date on concentration of three particle sizes in Control (squares) and ESCS (diamonds) broiler barns. Measurements were taken over 5 broiler production cycles. Curves are fitted 2nd order polynomials.

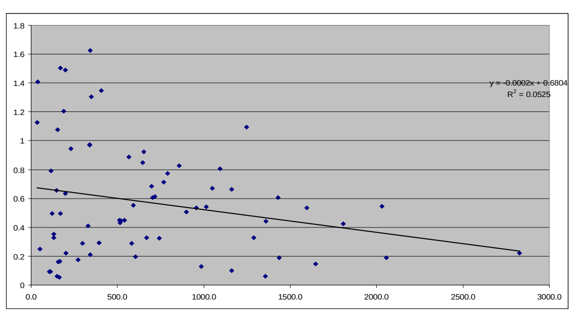


Figure 2. Relationship between ESCS:Control ratio and particle (PM10) concentration; a ratio of <1.0 indicated reduction due to ESCS. Graph shows that there is a slight improvement in ESCS effect with PM concentration i.e. that effectiveness does not decline with bird age.

Table 1. Average values for Cycle day Julian day and air quality and emission values for ESCS and control barns measured intermittently over 5 bird production cycles between May 2008 and March 2009. Note that the data, especially the emission data, was not normally distributed so analysis was done by less powerful Mann-Whitney Rank Sum Test. With this test only PM1 was significantly reduced. Further analysis will be done. (** $P<0.001$, *$P<0.05$).

	ESCS	**Control**
Cycle day	**19.6**	**18.1**
Julian day	**158.1**	**156.6**
Barn Ventilation (m3/day)	453,869	424,381
Concentration PM10 (ug/m^3)	290**	525**
Concentration PM2.5 (ug/m^3)	17.2**	30.8**
Concentration PM1.0 (ug/m^3)	4.01**	7.61**
Emission PM10 (g/day)	158	284
Emission PM2.5 (g/day)	10.1	17.0
Emission PM1.0 (g/day)	2.41*	3.53*

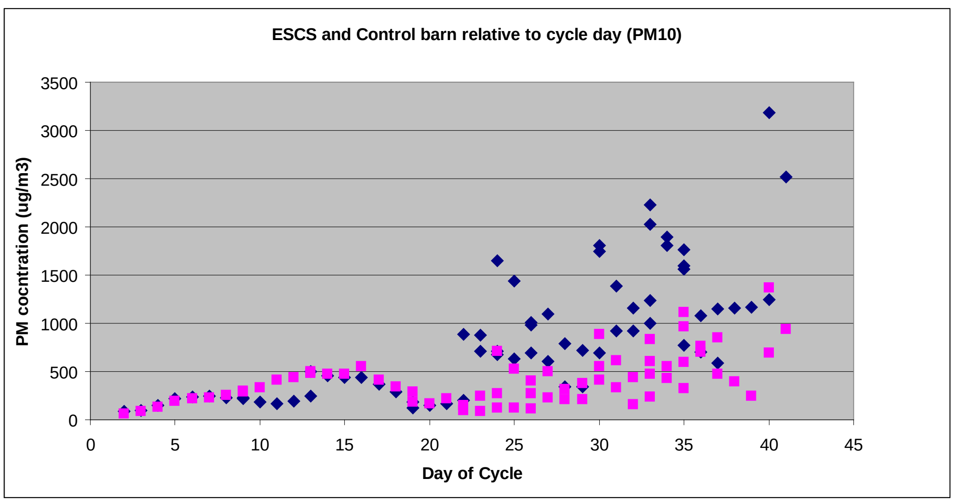


Figure 3. This graph shows a comparison of the two barns on the same days but with different Grimms (alternating). Only about 1.5 cycles available for this comparison. ESCS=squares; Control =Diamonds)

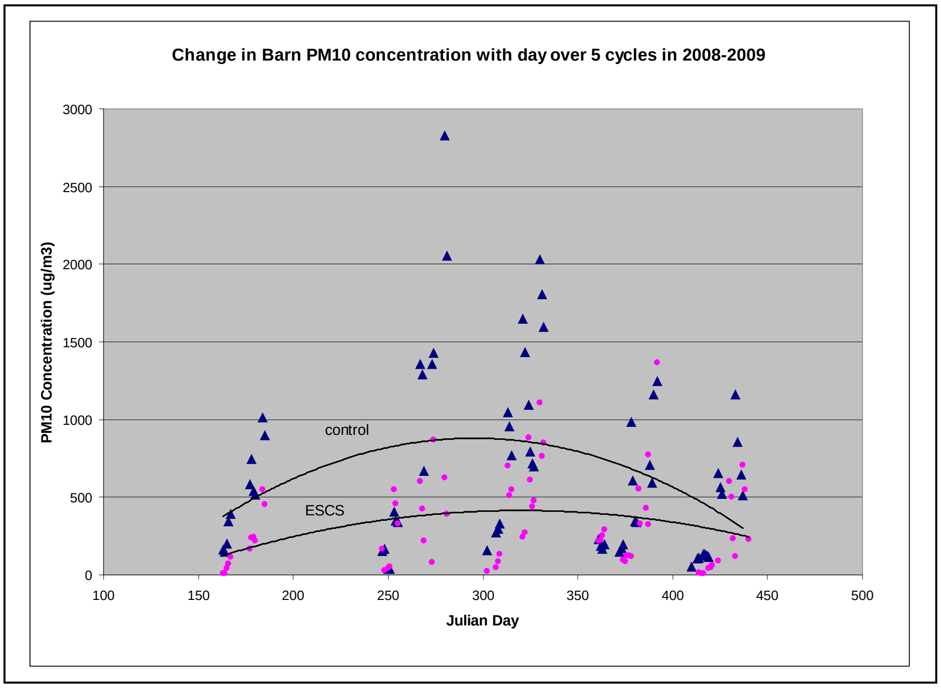


Figure 4. The graph above shows the PM patterns on a calendar date basis for the 5 cycles shown above. Here we can see that barn concentrations are potentially higher in winter than in spring or in summer. The ESCS (circles) seems effective in reducing the peak concentrations compared to control (triangles).

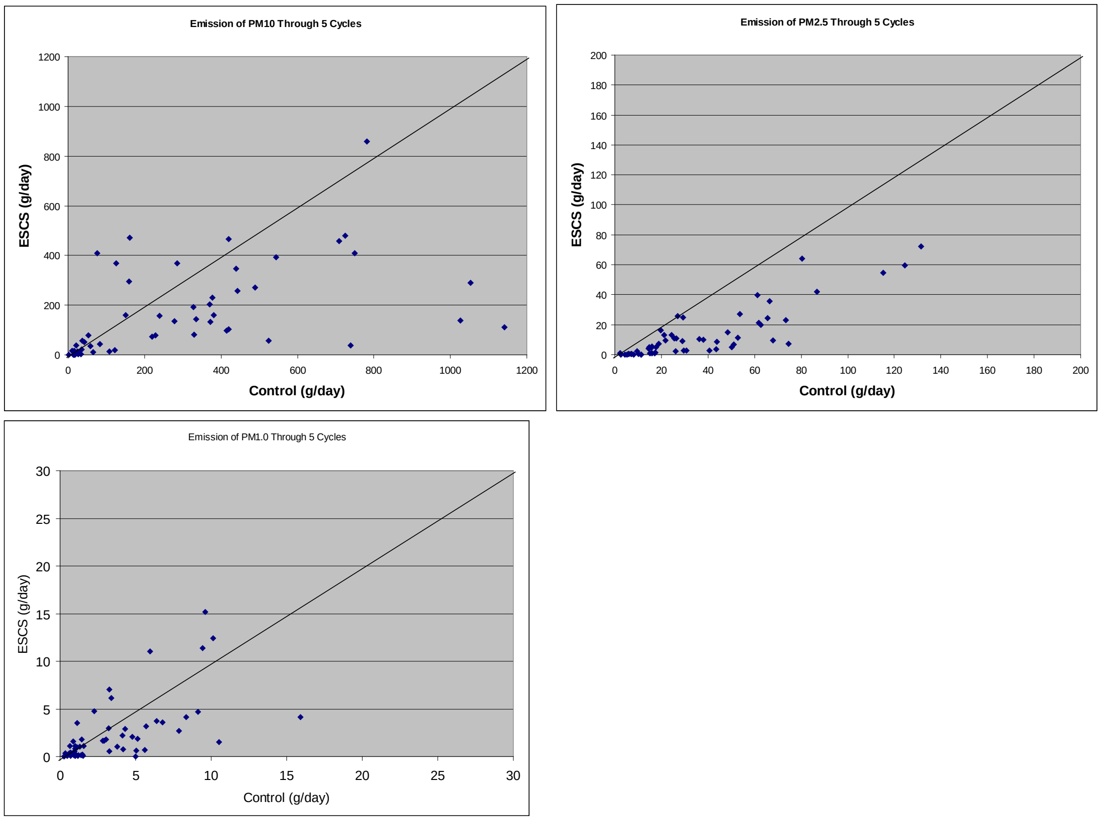


Figure 5. The graphs above shows direct comparison of PM10 emissions from control and ESCS barns measured simultaneously. The emission values are calculated by multiplying the concentration x ventilation values. Although there maybe some error involved with this method, the relative comparison should be relatively close. Note that over 3kg of PM 10 can be emitted from the barn in a single day, but most days emissions are well under 1kg/day.

1.1 ESCS - Poultry Production Analysis

Given the potential dust reduction benefits of the ESCS technology and resultant air quality improvements in the barn, it was decided to collect poultry flock productivity data to assess the financial impact of the technology. To do this, an evaluation comprised of two farms each with an ESCS and control treatment was conducted.

One farm had three single storey barns; the ESCS system was installed in two of them. For this farm (farm #1), at any time, there was one barn with the ESCS operating and two barns acting as a control. The barn where the ESCS operated was alternated at different times so that the effect of the barn rather than the treatment could be minimized.

The trial on farm #2 was conducted at the end section of a 500 ft. two storey barn. The study area of the larger barn was comprised of two floors one over the top of the other in which the ESCS was installed on both floors. The operation of the ESCS was alternated between floors.

On both farms, each ESCS operating cycle conformed with the timing of the poultry production cycle.

1.1.1 Typical Farm Production Information and ESCS Design and Layout

Chicken Broiler Farm #1
Farm Production Design Information

- Three barns in test with each barn 400 ft x 40 ft = 16,000 ft^2/barn
- Barns laid out side by side lengthwise with a separation distance of about 40 ft
- Production per cycle = 21,000 birds per barn
- Bird density = 0.76 ft^2/bird
- Cycle production period = 34 - 42 days

ESCS system design

- 1 x 2 mAmp 30KV power supply delivering an charge to 1200 ft of electrified wire and corona points for each barn
- 1200 ft of line made up of 3 x 400 ft lines attached about 14 inches below ceiling with center line running the down the middle of the length of the barn and the other two adjacent lines positioned about 10 feet from the middle on each side

Chicken Broiler Farm #2
Farm Production Design Information

- One two-storey barns in test with each floor 150 ft x 40 ft = 6,000 ft^2/floor
- Production per cycle = 4,000 birds per floor
- Bird density = 1.5 ft^2/bird
- Cycle production period = 34 - 42 days

ESCS system design

- 1 x 1.5 mAmp 30KV power supply delivering an charge to 450 ft of electrified wire and corona points for each floor
- 450 ft of line made up of 3 x 150 ft lines attached about 14 inches below ceiling with center line running the down the middle of the length of the barn and the other two adjacent lines positioned about 10 feet from the middle on each side

1.1.2 Production Analysis

Broiler Farm #1 - General Information
A total of eight production cycles were analyzed over the period October 2007 - March 2009. Production information for several cycles was not used due to incomplete, or incongruent information. All feed information was collected and reported by the farmer. Bird weights were those reported by the processing companies and assembled into usable form by the farmer. Bird numbers at placement were the same for each barn.

Figure 6 shows the feed conversion values for eight cycles of analysis. Of the cycles shown, seven indicated lower feed conversion values for the ESCS treatment while feed conversion was higher for the ESCS for one cycle. Table 2 identifies the production information and financial information indicting financial benefit or value from the ESCS treatment.

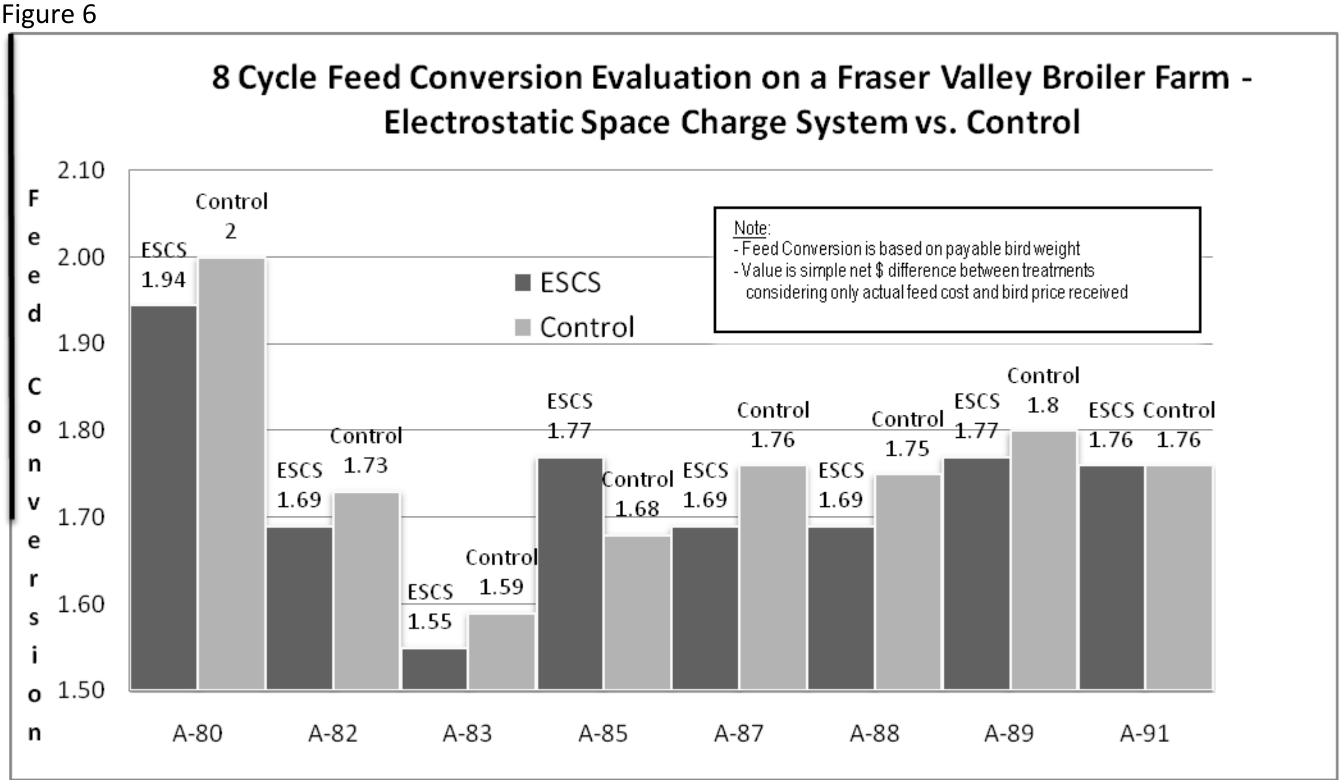
Specific Cycle Information

Table 2 Farm #1 Production and Financial Information

Cycle #	Production Period (days)		Bird Density - Cycle End (ft2/bird)		Feed Conversion		ESCS Treatment Value*	
	Control	ESCS	Control	ESCS	Control	ESCS	$/barn	$/bird
A-80	35	35	0.88	0.78	2.00	1.94	1,460	0.07
A-82	35	35	0.82	0.80	1.73	1.69	1,200	0.06
A-83	42	42	0.93	0.91	1.59	1.55	1,813	0.09
A-85	34	34	0.77	0.78	1.68	1.77	(858)	(0.04)
A-87	40	40	0.99	0.92	1.76	1.69	760	0.04
A-88	38	38	0.92	0.92	1.75	1.69	2,258	0.11
A-89	41	41	1.04	1.02	1.80	1.77	1,427	0.07
A-91	41	40	1.04	1.02	1.76	1.76	144	>0.01
					Total Value		**8,204**	**-**
					Mean Treatment Value		**1,025**	**0.05**

**Treatment Value is simple net difference between treatments considering only assumed feed cost ($371/MT) and given a bird farm gate value of $1.328/kg. Calculations based on payable bird weight and 21,000 bird flock.*

Figure 6



Broiler Farm #2 - General Information

A total of four production cycles were analyzed over the period July 2008 - March 2009. Production information for several cycles was not used due to incomplete information. All feed information was collected and reported to the author by the farmer. Bird weights were those reported by the processing companies and assembled into usable form by the farmer. Bird numbers at placement were the same for each barn floor.

Specific Cycle Information

For all four cycles, the ESCS treatment location was alternated between upper and lower floor so that each floor was used twice for each treatment. Reported cycle length varied from 37 to 40 days. Full production details can be seen in Table 2.

Table 3 Farm #2 Production Information

Cycle #	Production Period (days)		Bird Density - Cycle End (ft2/bird)		Feed Conversion**		ESCS Treatment Value*	
	Control	ESCS	Control	ESCS	Control	ESCS	$/barn	$/bird
A-86	40	40	1.91	1.91	1.69	1.75	(3)	Neg.
A-87	37	37	1.96	1.97	1.62	1.64	(833)	0.13
A-89	39	39	nd	nd	1.64	1.65	nd	Nd
A-90	nd	nd	nd	nd	1.59	1.65	nd	nd

**Treatment Value is simple net difference between treatments considering only assumed feed cost ($371/MT) and given a bird farm gate value of $1.328/kg. Calculations based on payable bird weight and 6,500 bird flock.*
*** Data calculated by farmer*
nd = no data available

1.1.3 Discussion

Value of Treatment

From Table 2, Farm #1 results showed a positive treatment value (>$0.01 to $0.11 per bird) for seven out of the eight cycles, however one cycle showed a negative value of -$0.04 per bird. Assessment of all cycles shows an average treatment value of $1,025 per barn per cycle, or $0.05 per bird per cycle. In comparison, complete data was only available for two cycles for Farm #2 (Table 3) which shows a negative value ($3 - 833 per barn, or 0 - $0.13 per bird).

Variation in Results

Between the two farms, there is an apparent difference in treatment value. Farm #1 indicates a fairly consistent positive value from the ESCS treatment, whereas the ESCS treatment in Farm #2, limited results suggest no value to a highly negative value. Since the ESCS is a relatively new technology, application and benefits from this technology are in the early stages of development and understanding. However, there are important differences in the production environment between Farm #1 and #2.

These differences include:

- Bird production density - Farm #1 varied from 0.78 - 1.04 ft2/bird, whereas Farm #2 was much higher and varied much less from 1.91 - 1.97
- Production conditions - the brooder heater in Farm #2 was used for a much greater duration of the production cycle than for Farm #1
- ESCS treatment - the ESCS system was a lower amperage unit (1.5 mAmps) versus the 2.0 mAmp unit used for Farm #2. Voltage remained the same for both farms.

Given these difference in barn production environment, it would seem likely that these factors may be responsible for the discrepancy in treatment value found between Farm #1 and #2. Farm #1 is considered to be more typical of industry standard production conditions. As such, Farm #1 results are considered to carry more weight for the potential application of this technology to Fraser Valley poultry farms. However, the variation in results emphasizes a need for more evaluation of the technology under typical production conditions on Fraser Valley poultry farms.

2.0 Effect of Vegetative (Tree) Filters on Particle Dispersion

Measurements

Cedar trees were planted at about 12-15 m in from of two sets of major fans on same barn. The PM concentrations in air in from of the fans were monitored in a grid pattern as shown in Figure 6.
Three transects outward from the barn with sampling positions at 3, 6, 9 12 and 15m from the barn at heights of 0.3, 1.45 2.50, 3.55 and 4.6m. Note that 4m high sidewalls were set up to minimize cross winds, but not to constrict the air flow.

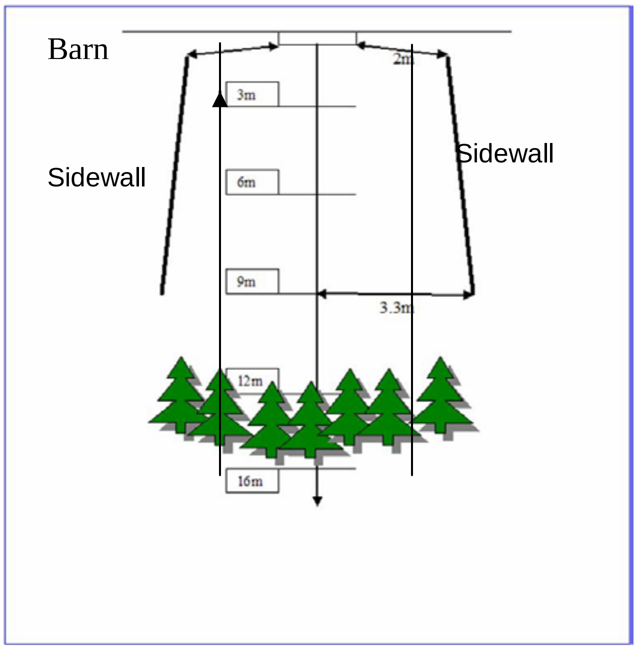


Figure 6. This figure shows the relative arrangement of the barn, sidewall and trees and indicates the sampling locations. At each sampling point samples were taken at 5 heights form 0.3 to 4.2m.

2.1 Results

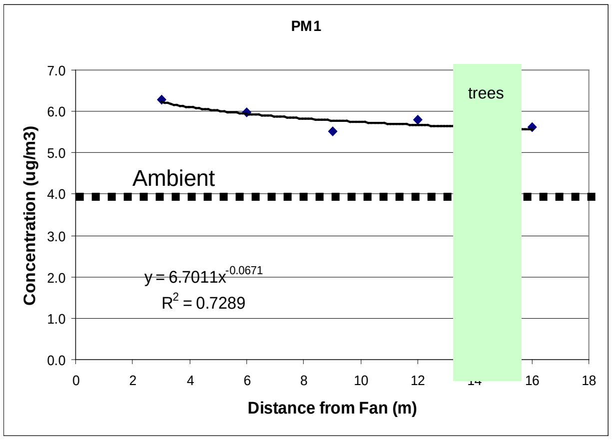
The results of only a single campaign will be discussed. Interpretation of the vegetative filters requires adequate data for background (ambient) PM and this measurement was only recently added.

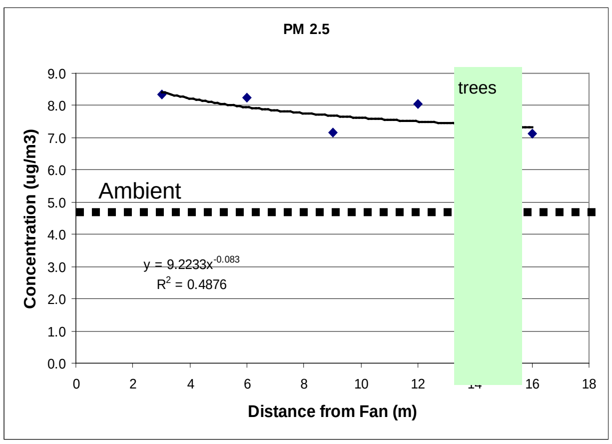
The challenge of this study is to distinguish between dilution and settling of particles with due to distance (air slowing down) and the trees. The data presented (Figure7) here was with the sidewalls in place and represent means of all five heights and the three transects as shown in Figure 6.

Results show a much greater decline in PM concentration with distance from the barns for the larger particles than for the smaller particles. This is due both to settling and to dilution. The large particles have a much higher settling velocity while the smaller particles are more buoyant. Also, the background air has lower concentrations of larger particles so that the same amount of mixing of barn and ambient air will reduce the concentration of the larger particles by a greater amount than the smaller ones. We are attempting to develop a method to estimate the rate of settling of the different sized particles. It may be argued that particles that settle in close proximity to the barn should be deducted from the barn emission factor. By eliminating the dilution factor we will be able to calculate this, which will be most significant obviously for PM10.

It is evident that the smaller particles do not settle very quickly even with cross winds restricted by the sidewalls. Cross winds are likely to reduce the settling velocity further, especially settling of the smaller particles. The results shown here do not provide much evidence for the trees intercepting a large amount of PM, since there is no clear break in the decline at the trees. Still the trees are clearly covered in dust so some attenuation must be occurring. Additional tests will be tried to examine the effect and perhaps improve the effect of the trees.

Note that for all three particle sizes the concentrations as far as 16m from the barn, beyond the trees, are still well above ambient so there is certainly room for reducing dispersal of the PM.





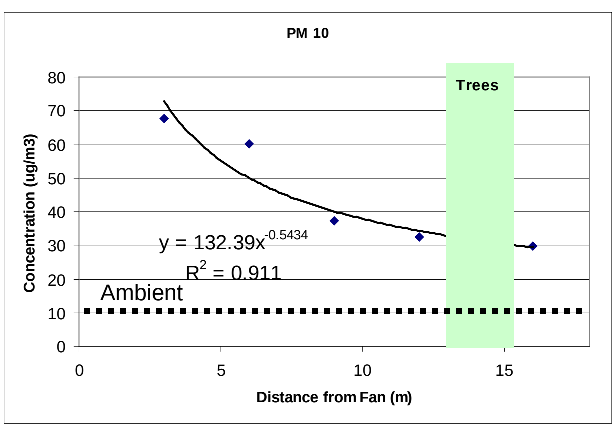


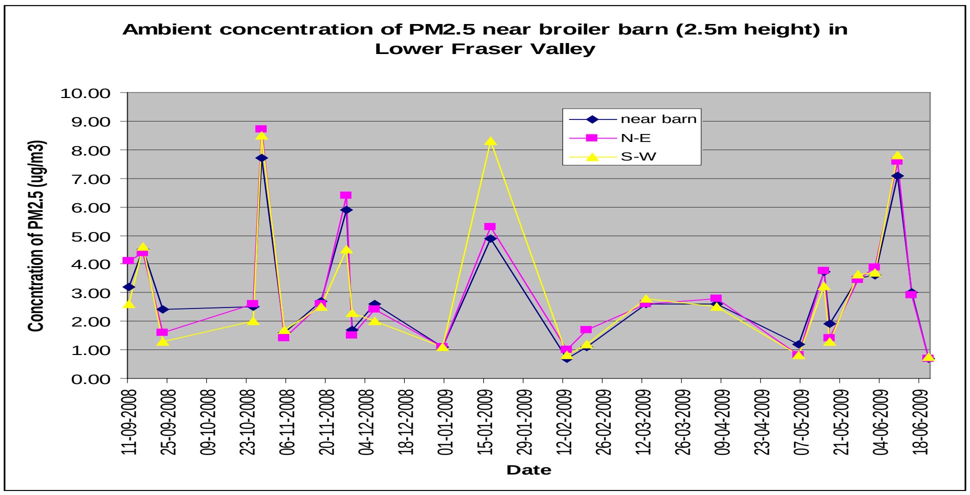
Figure 7. Depicts decline of PM with distance for the barn on both sides of the tree barrier. The ambient concentrations are indicated by the dotted lines

3.0 Ambient concentrations near a Broiler Operation in the Lower Fraser Valley

Methodology

Samples were collected intermittently at various locations around a broiler farm. At each location measurements were taken at 3 heights.

Results



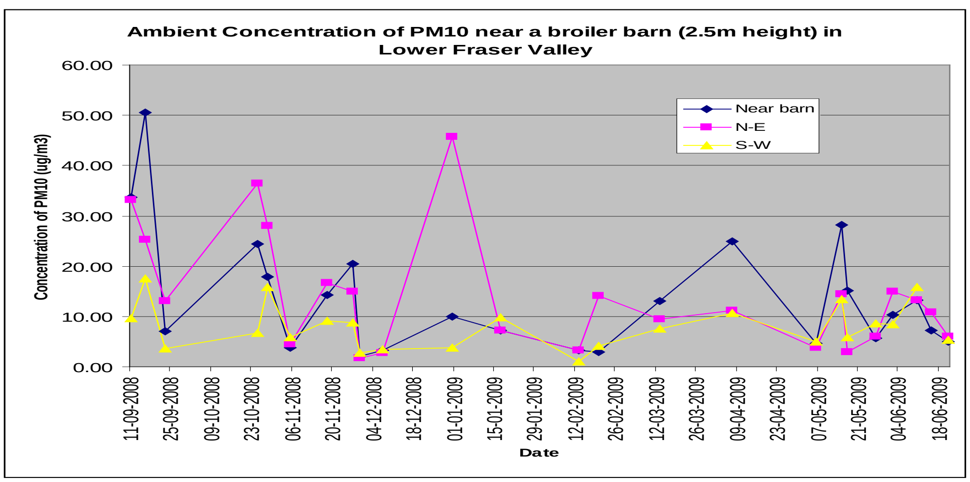


Figure 8. These figures show the change of ambient concentration of PM2.5 (top) and PM10 (bottom) at three locations (away from main fans) around a poultry operation over several months. The elevated concentrations are not correlated with the size of birds or environmental factors such as wind speed and humidity. Additional data may be needed to determine if there is a correlation. Concentrations of PM2.5 are fairly low on most sampling dates.

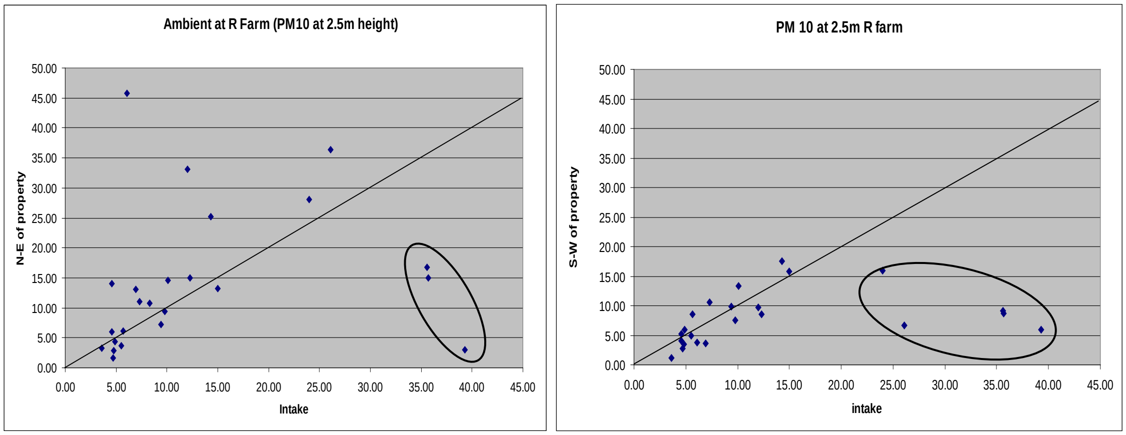


Figure 9. This figures shows PM 10 values near barn intake and at two positions away from the barns on different sampling days over several months. The ovals indicate that Concentrations near the intake are higher than ambient suggesting that some of the emissions are circulating back into the intake.

Figure 10. This is a map of the farm where ambient measurements are being made. The ovals represent locations with PM10 values that are significantly correlated at 2.5 meter height. The transverse angel of the two large ovals may indicate the direction of the prevailing winds in the area.

Conclusions

1. Concentration of PM in the barns follows the bird cycle, as expected. Higher concentrations are associated with winter measurements. All size particle concentrations are considered very high about 2 weeks after start of cycle

2. The ESCS results are very promising for reducing concentration of PM in the barn. Additional statistical analysis is likely to show that emissions are also reduced.

3. The ESCS works equally well for all particle sizes. The ESCS works very well in latter part of cycle.

4. The Electrostatic Space Charge System technology shows promise as a means to increase production performance under typical production conditions on a Fraser Valley broiler farm. Further testing of the system on broiler (and other poultry) production performance would make sense. The use of another industry-typical farm to verify production performance results obtained in this study should be pursued.

5. The value of the Vegetative filter has not yet been scientifically demonstrated. I have been in consultation with renown atmospheric modeller, Dr. Willem Asman of Denmark. He confirms that this is quite complex. I believe we our techniques are improving. However, it seems unlikely that the trees will stop PM1 although they may act to help disperse the particles. Perhaps moistening the trees will improve their dust capture in dry weather.

6. There is evidence that some emitted dust will enter back into the barn under certain conditions. There seems to be a relationship between PM in a SW-NE pattern on the farm perhaps reflecting the prevailing wind direction. There is insufficient data on the broiler farm to show a relationship between PM and causal factors. This may prove easier to discern on the layer farm where emissions should be more consistent. These data are being compiled.