Dust

The main environmental issue associated with dust concerns the air quality in the livestock building. Although the ventilation system of a building discharges dust particles into the environment, considering the high dilution rate with the outside air, the following discussion focuses on the dust level and control inside the livestock building.

Health effects of dust on the worker are presented in the health chapter. The reader is referred to this section for more detailed information on that topic.

Glossary

Inhalable dust: all dust particles in the air that are inspired by a human.

Modified inhalable dust: all the dust particles that are inspired by a human having an aerodynamic diameter larger than 0.5 micron (µm).

Modified respirable dust: all the dust particles suspended in the air having an aerodynamic diameter larger than 0.5 µm and lower than 5 µm.

Respirable dust: all the dust particles that are suspended in the air having an aerodynamic diameter lower than 5 µm.

Total dust: All dust particles that are suspended in the air.

■ Dust in Livestock Buildings: Sources, Composition and Type

Dust is normally considered to be one of the contaminants in livestock buildings. Dust is generated from feed, bedding, dried manure, skin debris and building materials (Maghirang et al., 1995). According to Zhang et al. (1994), other forms of airborne particulates referred to as bioaerosols include bacteria, endotoxins, and molds. In fact, Butera et al. (1991), found that moulds amounted to less than 1% of total microorganisms in dust from a growing-finishing pig building. Gram positive bacteria made up to 72% of the bacterial isolates. Martin et al. (1996) demonstrated that dust can include many components in finding 6 species of bacteria or fungi in dust from a room with no pigs, whereas 22 different microorganisms were detected in dust from the room with pigs.

Respirable dust is normally defined as particles having a mean aerodynamic diameter lower than 5 µm (Pearson and Sharples, 1995). They can be inhaled deep into the human or animal lung where they can lodge in the alveoli. Particles smaller than 0.5 µm normally remain suspended and are expelled when exhaling. Total dust particles are very often defined as inhalable dust.

Total dust mass concentrations in a mechanically ventilated swine nursery were measured for 13 sampling days over a six week period during warm weather conditions (Maghirang et al., 1997). The respirable dust fraction ranged from 2 to 30% of the total dust, with an overall mean of 11%. Considering the amount of energy required to create dust from the feed ration, Jansen and Feddes (1995) concluded that fecal material is likely the major source of respirable dust in animal confinement housing. Pickrell et al. (1993) also observed that smaller particles in swine confinement buildings had four fold higher concentrations of endotoxin than did larger particles, suggesting they had higher fecal material concentrations. Therefore, especially in swine buildings, respirable dust originates mainly from dry manure. Because they are biologically active and they penetrate the lungs, respirable dust can have an adverse affect on the animal and the worker.

■ Effects of Dust on Animal Health and Productivity

In general, dust can have adverse effects on the health of the animal in poultry buildings but will have a limited impact in pig buildings. For example, Feddes et al. (1995) concluded that the addition of canola oil and increasing the ventilation rate did not affect body mass gain but reduced the incidence of lung lesions for turkeys. Although Crowe et al. (1996) found an association between low facility dust, low endotoxin concentrations and improved growth rates in pigs reared by Isowean, in other experiments, dust concentrations did not affect pig performance and health status.

Reduced dust concentration did not result in improvement of an already high pig performance (Takai et al., 1995). It was concluded that expenses for dust control must be covered by other means than improved pig performance. Similar results were obtained by Jansen and Feddes (1995), when they determined the effect of high concentration of airborne dust on the health and performance of growing pigs. According to this experiment, there was no apparent relationship between growth rate, lung score and dust concentration. There was also no apparent differences in the effect of feed and fecal dust on pig performance and health.

■ Dust Control Techniques

Feed Additives

Additives such as oils or fats can be added to the animal feed in an effort to reduce the dust concentration in the building. Many studies have been completed on feed additives and in summarizing this research, Maghirang et al. (1995) indicated that dust levels can potentially be reduced by adding oils or fats to the feed. Use of feed additives may be an effective dust control strategy if the main source of dust is the feed.

Since the respirable dust in pig buildings comes mainly from the fecal material, feed additives have a limited effect on dust concentration. For example, Welford et al. (1992) observed that 2% of canola oil added to the feed reduced inhalable mass concentration by 31% but increased the respirable dust particles by 45%. More recently, Takai et al. (1996) showed that dust concentrations were reduced by 35 to 60% in pig buildings, while human dust exposure was lowered by 50 to 70% by adding 4% animal fat to the feed. However, it was indicated that a large quantity of airborne dust remained in these buildings and workers should reduce their exposure risk to the high concentrations by wearing a dust mask.

Water or Oil Sprinkling

In a review of dust control strategy, Maghirang et al. (1995) concluded that oil/water spraying is a promising technique for dust control in livestock buildings. Airborne dust concentrations in pig houses were reduced by spraying with a mixture of water and rapeseed oil (Takai et al., 1995). The respirable dust was reduced by 76, 54 and 52% in long-term observations in houses for piglet, growing and finishing pigs, respectively. Sprinkling a small quantity of canola oil on the floor of animal buildings reduced respirable and inhalable dust by 71 and 76%, respectively (Zhang et al., 1996). Perkins and Feddes (1996) applied mineral oil in a farrowing building to control total dust concentration and applying oil 24 h before measurement resulted in an average dust reduction of 73%. In a complementary study, Zhang et al. (1997) observed a reduction of 81 and 85% of respirable and inhalable dust with crude canola oil sprinkling.

Ventilation Rate and Air Distribution

Purge ventilation (short period of high ventilation) may be effective in producing a short term decrease in particle concentration and by timing the purge, workers would be exposed to lower dust concentrations during specific tasks (Maghirang et al., 1995). A purge was used in pig buildings to reduce dust concentrations (Robertson, 1989). In this experiment, in a building with automatically controlled natural ventilation, the purge produced a 60% reduction in estimated total dust concentration. Most of the reduction occurred in the first two minutes. Dust concentrations increased rapidly after the purge and it created a significant reduction in air temperature for a short period.

The air distribution can also have an impact on the concentration of contaminants in the livestock building. Breum et al. (1990) evaluated the performance of two types of exhaust ventilation systems for swine production: upward and downward airflow systems. In the zone of occupancy, the air exchange efficiency of upward air flow was superior to downward air flow. For some contaminants (CO_2, excessive heat, dust), the ventilation effectiveness of upward air flow was also superior to downward air flow, but this result does not apply to contaminants in general.

A standard ventilation system was modified to reduce dust levels in a room with weaned piglets (Van't Klooster et al., 1993). It was based on the assumptions that it is important to minimize exposure of stockmen to dust in livestock confinement buildings and that airborne particles were largely re-entrained sedimented particles agitated by animal activity. The modified system had the inlet located near the nose height of workers and the air outlet near the re-entrainment area, underneath the slats. Results showed that without additional costs the exposure of stockmen was reduced by 40%. According to Aarnink and Wagemans (1997), a ventilation system with the inlet in the feeding passage and the outlet just above the slatted floor reduced the total dust concentration by 78% compared with a typical ventilation system. Therefore, the configuration of the ventilation system in a livestock building can have a significant impact on the dust concentration.

Electrostatic Precipitation and Negative Ionization

Electric forces can be used to remove dust particles from the airspace of a livestock building. An electrostatic precipitation system would have to be installed to treat the air of a room such as a filtration unit. Electrostatic precipitators use an electric field between opposite charged electrodes to electrically charge particulate matter that is suspended in a gas stream, and then to separate the charged particulate matter from the gas (ASHRAE, 1992). St-George and Feddes (1995) evaluated the collection efficiency of an electrostatic precipitator by varying applied voltage and airspeed levels for airborne swine dust. The applied voltage and current levels had a significant effect upon collection efficiency of the prototype electrostatic precipitator but the three levels of airspeed did not affect the collection efficiency. The overall collection efficiency increased from 18.6% at an applied voltage of -10.3 kVDC to 96.4% at an applied voltage of -12.1 kVDC. When applying a voltage and current of -12.1 kVDC (3 mA), the ventilation rate should be sufficient to reduce ozone concentration to 0.1 ppm.

In an ionization process, an electrical charge is introduced into an electrical field, and a force is exerted on this charge in the direction of potential gradient (Tanaka and Zhang, 1995). For ionization in a room airspace, the collecting electrode is the room surfaces and the negative charged particles are collected on the surface of the room. The collection efficiency is affected by the dust spatial distribution, air flow rate, scattering of collected particles and thickness of the particle layers accumulated on the surface.

Tanaka and Zhang (1995, 1997) completed two studies on the impact of an ionization system to reduce the dust concentration in a pig building. After the first project, it was confirmed that ionization reduced the dust concentration by as much as 46% at low ventilation rate. Dust reduction efficiency decreased with the time due to the accumulation of dust on surfaces. In the second study, the ionization system consisted of ion emitters having an average output voltage from the emitting head of -14.7 kV. The dust reduction ranged from 12.7 to 31.0% (average 19.8%) in the alley, and the weekly dust reduction efficiency did not decrease over the time of experiment. The dust concentration was reduced by the ventilation, but the effect of ventilation on the performance of the ionization system was small.

Filtration and Wet Scrubbing

The filtration process occurs in different ways: direct interception, inertial deposition, diffusion and electrostatic effects (ASHRAE, 1992). Carpenter and Fryer (1990) concluded that air filtration using dry filters was a feasible method for reducing dust mass concentration and the number of bacteria colony-forming particles by 50 to 60% in small rooms for early weaning piglets. A three stage filtration system was evaluated by Lau et al. (1996) in pig barns. The reduction in inhalable dust using the fabric filters ranged from 18 to 64%. The fabric filter system required intensive labor for cleaning and induced high recurring operating cost upon frequent filter replacement.

Wet scrubbers use water to capture particulates or increase the size of the dust. Wet scrubbers have the following advantages: 1) fine particles, ranging from 0.1 to 20.0 μm in diameter, can be effectively removed; 2) water-soluble gases such ammonia and carbon dioxide can also be removed; and 3) wet scrubbers do not have to be cleaned frequently (Maghirang et al., 1995). Disadvantages include: 1) a large quantity of water is needed; 2) dirty water has to be disposed of; and 3) it may result in increased humidification of the air in the building.

Pearson (1989) used a wet scrubber that removed 83% of the dust mass from air passing through but only reduced the concentration in the room by 8%. The limited effect was due to the small size of the scrubber and in a later paper (Pearson, 1991), the same author demonstrated that the size of dry filter or wet scrubber required was likely to be uneconomic. A counter flow bioscrubber was tested at air flow rates of 43 and 63 L/s (Dong et al., 1997). Ammonia removal efficiency was 32% for wet scrubbing only, and 54% for wet scrubbing with the packed bed of the scrubber seeded with microbes (bioscrubbing). Siemers and Van Den Weghe (1997) obtained clear reductions of dust emissions (>80%) making use of modified wetscrubber/biofilter combinations.

Fabric filters or wet scrubbers are not widely used to reduce dust concentration in livestock buildings. As it has been mentioned previously, they are labor intensive and expensive to operate. Because they remove particles from the air flow that is passed through it only (filter or scrubber), large equipment are required to really reduce dust concentration in the whole airspace.

■ What Else Needs to Be Done

Dust concentration must be controlled in livestock buildings to provide adequate air quality for the worker and the animal. On a long term basis, high dust concentrations can represent a risk for the lung functions of the barn operator. As mentioned by Maghirang et al. (1995), promising dust control techniques involve feed additives, oil/water sprinkling, purge ventilation and effective room air distribution.

Because the animal productivity is mostly independent of the dust concentration, dust control techniques should be developed in keeping implementation and operating costs down. Also, in order to develop those techniques, more information is needed on dust generation rates and distribution. For example, more work is required to describe how the ventilation system design will affect dust concentration in some parts of the room. The optimal design will be identified only when we will know more about how the dust is generated.

Other techniques like feed additives and oil sprinkling still need optimization. The fat or oil content in the feed and the oil application rate and its concentration (oil and water) need to be optimized.

References

Aarnink, A.J.A. and M.J.M. Wagemans. 1997. Ammonia volatilization and dust concentration as affected by ventilation systems in houses for fattening pigs. Transactions of the ASAE 40(4): 1161-1170.

ASHRAE. 1992. Systems and Equipment Handbook. ASHRAE, Atlanta.

Breum, N.O., H. Takai and H.B. Rom. 1990. Upward vs. downward ventilation air flow in a swine house. Transactions of the ASAE 33(5): 1693-1699.

Butera, M., J.H. Smith, W.D Morrison, R.R. Hacker, F.A. Kains and J.R. Ogilvie. 1991. Concentration of respirable dust and bioaerosols and identification of certain microbial types in a hog-growing facility. Canadian Journal of Animal Science 71: 271-277.

Carpenter, G.A. and J.T. Fryer. 1990. Air filtration in a piggery: Filter design and dust mass balance. Journal of Agricultural Engineering Research 46(3): 171-186.

Crowe, C.K., D.L.H. Harris, L.P. Elliott, E.R. Wilson and B.S. Wiseman. 1996. A possible relationship between low facility dust and endotoxin levels and improved growth rates in pigs reared by IsoweanSM. Swine Health and Production 4(5): 231-236.

Dong, L., A.J. Heber, J.A. Patterson, B.R. Strobel, D.D. Jones and A.L. Sutton. 1997. Bioscrubber for removing ammonia from swine house exhaust air. In Proceedings of the International Symposium on Ammonia and Odour Control from Animal Production Facilities, 2, 529-532. CIGR and Eur Ag Eng publication, Rosmalen, The Netherlands.

Feddes, J.J.R., K. Taschuk, F.E. Robinson and C. Riddell. 1995. Effect of litter oiling and ventilation rate on air quality, health, and performance of turkeys. Canadian Agricultural Engineering 37(1): 57-62.

Jansen, A. and J.J.R. Feddes. 1995. Effect of airborne dust on health and performance of growing pigs. Canadian Agricultural Engineering 37(3): 211-216.

Maghirang, R.G., G.L. Riskowski, L.L. Christianson and H.B. Manbeck. 1995. Dust control strategies for livestock buildings - a review. ASHRAE Transactions SD-95-15-1: 1161-1168.

Maghirang, R.G., M.C. Puma, Y Liu and P. Clark. 1997. Dust concentrations and particle size distribution in an enclosed swine nursery. Transactions of the ASAE 40(3): 749-754.

Martin, W.T., Y. Zhang, P. Willson, T. P. Archer, C. Kinahan and E.M. Barber. 1996. Bacterial and fungal flora of dust deposits in a pig building. Occupational and Environmental Medicine 53(7): 484-487.

Lau, A.K., A.T. Vizcarra, K.V. Lo and J. Luymes. 1996. Recirculation of filtered air in pig barns. Canadian Agricultural Engineering 38: 297-304.

Pearson, C.C. 1989. Air cleaning with wet scrubbers. Farm Buildings and Engineering 6(2): 36-39.

Pearson, C.C. 1991. Air cleaning cost and effectiveness. Farm Buildings and Engineering 8(2): 29-31.

Pearson, C.C. and T.J. Sharples. 1995. Airborne dust concentrations in livestock buildings and the effect of feed. Journal of Agricultural Engineering Research 60(3): 145-154.

Perkins, S.L. and J.J.R. Feddes. 1996. The effect of timing of floor-application of mineral oil on dust concentrations in a swine farrowing unit. Canadian Agricultural Engineering 38(2): 123-127.

Pickrell, J.A., A.J. Heber, J.P. Murphy, S.C. Henry, M.M. May, D. Nolan, F.W. Oehme, J.R. Gillespie and D. Schoneweis. 1993. Characterization of particles, ammonia and endotoxin in swine confinement operations. Veterinary and Human Toxicology 35(5): 421-428.

Robertson, J.F. 1989. Effect of purge ventilation on the concentration of airborne dust in pig buildings. Agricultural engineering. Proceedings of the 11th International Congress on Agricultural Engineering, 1495-1499. Dodd & Grace, Rotterdam, The Netherlands.

Siemers, V. and H. Van Den Weghe. 1997. Biofilter/wetscrubber combinations for the reduction of ammonia, odour and dust emissions of pig fattening houses. In Proceedings of the International Symposium on Ammonia and Odour Control from Animal Production Facilities, 2, 537-544. CIGR and Eur Ag Eng publication, Rosmalen, The Netherlands.

St-George, S.D. and J.J.R Feddes. 1995. Removal of airborne swine dust by electrostatic precipitation. Canadian Agricultural Engineering 37(2): 103-107.

Takai, H., F. Moller, M. Iversen, S.E. Jorsal and V. Bille-Hansen. 1995. Dust control in pig houses by spraying rapeseed oil. Transactions of the ASAE 38(5): 1513-1518.

Takai, H., L.D. Jacobson and S. Pedersen. 1996. Reduction of dust concentration and exposure in pig buildings by adding animal fat in feed. Journal of Agricultural Engineering Research 63(2): 113-120.

Tanaka, A. and Y. Zhang. 1995. Efficiency of a negative ionization system on dust settling and the electrostatic effect in a confinement swine building. ASAE Paper No. 954481. St. Joseph, MI: ASAE.

Tanaka, A. and Y. Zhang. 1997. Dust settling using a negative ionization system in a confinement swine building. In Livestock Environment V, Proceedings of the Fifth International Symposium, 1, 528-535. Bloomington, Minnesota, May 29-31.

Van't Klooster, C.E., P.F.M.M. Roelofs and P.A.M. Gijsen. 1993. Positioning air inlet and air outlet to reduce dust exposure in pig buildings. In Livestock Environment IV, Proceedings of the 4th International Livestock Environment Symposium, 754-760. ASAE Publication 3-93. St-Joseph, MI: ASAE.

Welford, R.A., J.J.R. Feddes and E.M. Barber. 1992. Pig building dustiness as affected by canola oil in the feed. Canadian Agricultural Engineering 34(4): 365-373.

Zhang, Y., L. Nijssen, E.M. Barber, J.J.R Feddes and M. Sheridan. 1994. Sprinkling mineral oil to reduce dust concentration in swine buildings. ASHRAE Transactions 100 (2): 1043-1050.

Zhang, Y., A. Tanaka, E.M. Barber and J.J.R. Feddes. 1996. Effects of frequency and quantity of sprinkling canola oil on dust reduction in swine buildings. Transactions of the ASAE 39(3): 1077-1081.

Zhang, Y., A. Tanaka, J.A. Dosman, A. Senthilselvan, E.M. Barber, S. P. Kirychuk, L.E. Holfeld and T. Hurst. 1997. Respiratory responses of human subjects to air quality in a swine building. In Livestock Environment V, Proceedings of the Fifth International Symposium, 2, 655-663. Bloomington, Minnesota, May 29-31.

Abstract or Summary of Interesting Publications

Carpenter, G.A. and J.T. Fryer. 1990. Air filtration in a piggery: Filter design and dust mass balance. Journal of Agricultural Engineering Research 46(3): 171-186.

The design principles of internal recirculating dry air filters for use in livestock buildings are discussed and several designs described. In one design for a flat-deck early-weaner room a centrifugal rotor draws air through a floor-standing pre-filter and discharges it through a fine filter at a velocity of about 0.4 m/s. The fine filter constitutes the under-surface of a duct located above the pigs. The air throughput of the filter is equal to the maximum ventilation rate of the room in order to achieve adequate dust reduction. When used in flat-deck rooms with early-weaner pigs, the filter unit reduced dust mass and bacterial colony-forming particle concentration by 50-60% and collected dust at daily rates of 100 to 500 g per 100 piglets, depending on the design of the room and the age of the pigs. The pre-filter was periodically vacuum cleaned and the changes in pressure losses across the filters recorded for several weeks. The airborne dust concentration in a flat-deck room with a wire-mesh pen floor was only one-quarter of that in a room with similar stocking and ventilation rate with a solid floor. Measurements of dust deposition rate suggest that it is approximately proportional to the airborne dust concentration. A theory is proposed which relates dust concentration to ventilation, filtration and deposition rates and accounts for the reductions in dust concentration achieved by the filtration described above. Calculations suggest that, under certain conditions, sedimentation can clear as much as 74% of the dust mass and of the number of particles generated and that this value is normally likely to exceed the percentage cleared by ventilation. It is probable that a floor of high voidage reduces dust because of the combined effects of a reduction in floor-generated dust and the voids providing a clearance path.

Maghirang, R.G., G.L. Riskowski, L.L. Christianson and H.B. Manbeck. 1995. Dust control strategies for livestock buildings - a review. ASHRAE Transactions SD-95-15-1: 1161-1168.

Dust in animal buildings should be controlled to levels that affect health only minimally. Dust control strategies include reducing the rate of emission (source control), effective ventilation (ventilation control) and air cleaning (removal control). Source control strategies include use of feed additives, cleaning dusty surfaces and spraying water or oil over dusty surfaces. Ventilation control includes purge ventilation and effective room air distribution. Air cleaning strategies involve filtration, electrostatic precipitation, or wet scrubbing. Promising techniques for livestock buildings include the use of feed additives, oil or water spraying, purge ventilation, and effective room air distribution. Technical and economic constraints have prevented these methods from being widely practiced. Effective and economically feasible dust control methods should be developed and systematically tested under both controlled laboratory and field conditions. Other research and development needs include: 1) characterization of dust particles, dust sources and sinks; and 2) development of sensors and control devices that incorporate the dust control technology into the environmental control system.

St-George, S.D. and J.J.R Feddes. 1995. Removal of airborne swine dust by electrostatic precipitation. Canadian Agricultural Engineering 37(2): 103-107.

An electrostatic precipitator used in conjunction with a recirculation duct was developed to remove airborne pig dust from an environmental chamber. The collection efficiency of the precipitator was evaluated by using 3 applied voltage levels (-10.3, -11.0 and -12.1 kVDC) and 3 airspeeds (0.55, 0.76 and 0.95 m/s). The overall collection efficiency of the precipitator ranged from 18.5 to 96.4% at applied voltages of -10.3 and -12.1 kV, respectively. Removal efficiency was highest at 0.76 m/s for all applied voltages. An applied voltage of -12.1 kV produced ozone levels of 0.21 ppm, which exceeded the recommended level of 0.1 ppm.

Takai, H., F. Moller, M. Iversen, S.E. JOrsal and V. Bille-Hansen. 1995. Dust control in pig houses by spraying rapeseed oil. Transactions of the ASAE 38(5): 1513-1518.

Airborne dust concentrations in pig houses were reduced by spraying with a mixture of water and rapeseed oil (1 to 4 treatments/d). The daily doses of oil (5 to 64 mL/pig-d) were varied as the oil concentrations (5 to 20%) and the duration of the spraying time (5 to 90 s/d) were changed. The treatment did not cause an increase of the average concentration of vegetable oil in the air. No pathological lung change in the pigs related to the treatment with rapeseed oil was found and no indication of oil resorption to lung tissues, lymph nodes, or upper respiratory systems in the pigs was seen. Long-term observations in houses for piglets, young pigs and fattening pigs at a commercial farm showed that the respirable dust was reduced by 76, 54 and 52%, respectively. No significant difference in pig performance between treated and reference groups was found. A farmer, whose lung function usually decreased when weighing fattening pigs, was not affected when the house was treated. This suggests that a substantial improvement in the working environment can be achieved by spraying a vegetable oil in pig houses.

Zhang, Y., A. Tanaka, E.M. Barber and J.J.R. Feddes. 1996. Effects of frequency and quantity of sprinkling canola oil on dust reduction in swine buildings. Transactions of the ASAE 39(3): 1077-1081.

Dust concentrations in animal buildings can be reduced by sprinkling a small quantity of canola oil on the floor. The efficiency of dust reduction was expected to be dependent on the frequency and quantity of oil application. Canola oil was sprinkled at six application rates (QF1 to QF6) in three identical swine grower/finisher rooms to examine the effect of oil application/frequency and quantity on dust concentration in the room air. For the six oil application rates, dust concentration was reduced between 37 to 89% with an overall mean reduction of 71 and 76% for modified respirable (0.5 to 5 μm) and inhalable (> 0.5 μm) dust respectively. At the same total volume of oil sprinkled, a higher oil application frequency was more effective than a lower application frequency in terms of dust reduction. However, sprinkling more often than once a day was difficult when the oil application is less than 10 mL/m^2 per day. The more oil sprinkled, the more dust could be reduced. Variable daily dosages (from 30 to 10 mL/m^2) for oil sprinkling had a higher efficiency of dust reduction than a constant daily dosage (20 mL/m^2).