PENNSYLVANIA

ODOR MANAGEMENT PROGRAM

PA Odor BMP Reference List

Effective: August 26, 2013
(Required: January 1, 2014)

Provided by:

The Pennsylvania State Conservation Commission with the assistance of the Penn State University

Preface

This Reference List has been developed in order to provide consistent program guidance to be utilized in the development, review, and implementation of Pennsylvania Act 38 (of 2005) odor management plans.

Information in this Reference List is to be used as a guide for those individuals working within the program. For the final direction on how to implement and interpret program requirements or policies, please contact Nutrient and Odor Management Act (NOMA) program staff from the Pa. State Conservation Commission for assistance. Additional program refinements will be incorporated into later revisions of this manual as time and resources permit.

The main audience for this Reference List consists of those Pennsylvania-certified odor management specialists who will be developing, reviewing, or assisting with implementing plans to meet the requirements and intent of Pennsylvania's Act 38 Odor Management program.

Odor BMPs for Facility Odor Management

Identification of Odor BMPs

The Pennsylvania State Conservation Commission has approved the use of Odor BMPs described in the following three reference sources for identification, design, construction and operation of the Odor BMPs that are appropriate for the site specific situation. Please note that in addition to the Odor BMPs described in these reference sources, other Odor BMPs as proposed by the operator may be used if approved by the Commission.

1. PA Odor BMP Reference List. This list was compiled with the assistance of odor management experts at Penn State University to assist odor management specialists and farmers in developing odor management plans consistent with the State Conservation Commission's Odor Management Guidance. This list is intended to provide links to a number of possible references describing various Odor BMPs a farmer may consider for their operation.
2. "PA Tech Guide", Section IV of the NRCS electronic Field Office Technical Guide, at http://efotg.nrcs.usda.gov/efotg_locator.aspx?map=PA.
3. ASABE Standards: Management of Manure Odors. (ASAE EP379.4 Jan2007), at http://elibrary.asabe.org/ (Search – Title: Management of Manure Odors)

Odor BMP Principles

These are the core Odor BMP principles for reducing odor generation and/or transport from any animal operation.

1. Steps are taken to reduce dust and feed accumulation in pens, aisles, and on animals.
2. Ventilation is managed to provide sufficient fresh airflow throughout the facility to keep animals and facility surfaces clean and dry.
3. Manure is managed to minimize damp, exposed manure that contributes to odor generation.
4. Mortalities are removed daily and managed appropriately.
5. Feed nutrients are matched to animal nutrient requirements to avoid excess nutrient excretion.
6. Manure storage facility is managed to reduce exposed surface area and off-site odor transfer.

Level I Odor BMPs

Level I Odor BMPs are basic Odor BMPs that are applicable to the operation according to the species of animals and/or to the manure handling system. These Odor BMPs manage odors by using generally accepted operation and maintenance activities used in Pennsylvania animal industries. **The OMP will specifically describe how each of the Odor BMP principles will be accomplished for the site-specific situation.** The plan writer and operator together will determine how to implement the applicable Odor BMPs for the site specific scenario, detailing how they will meet the goals of reducing odor generation and/or transport.

For OSI scores of fewer than 50 points AND in which the Operational Map identifies one or more neighboring or public facilities in the evaluation distance area, the operation must implement Level I Odor BMPs that are applicable to their operation, and are required to attest implementation of the Odor BMPs.

For OSI scores of 50 or above, the operation must implement Level I Odor BMPs that are applicable to their operation, and are required to attest implementation of the Odor BMPs and implement maintenance documentation.

Examples of Level 1 BMPs are given, but are not meant to merely be cut and pasted into the OMP without verifying with the operator.

Animal Housing Facilities Related Odor BMPs

1. Steps taken to reduce dust and feed accumulation in pens, aisles, and on animals. **(Planner specifically describes how these will be accomplished).**

Examples for All Species:
- Feed Cleanup – Spilled feed will be removed promptly.

- Dust Control of Ventilation Components – Fan motors, blades, and shrouds will be cleaned on a standard schedule (Planner details frequency).

Examples for Swine:
- Feed Wastage –
  - Keeping aisles and pens (if applicable) free of accumulated feed in all phases of production via (Planner details frequency) scraping or sweeping.

- Cleaning and Sanitation –The entire inside of the facility will be power washed and disinfected (Planner describes when it will occur within the production schedule).

- Dust Control – (Nursery and Grow Finish)
  - Drop tubes will be extended from the feed delivery auger into each feeder.
  - Feeder Adjustment – Dry feeders will be checked (Planner details frequency) for proper feeder adjustment. Less than 2" of feed should be visible at the back of the tray. Wet/dry feeders should not exhibit spilled feed.

Examples for Veal:
- Feed Preparation and Handing – Formula feed ingredients will be stored in a dry location. Any reconstituted feed not consumed will be removed or washed from feeders.

- Feed Wastage –
  - Aisles in front and back of the stalls will be scraped or swept (Planner details frequency) to keep free of accumulated feed.
  - Any feed accumulating on the slatted floors (i.e. wooden slatted floors) will be scraped (Planner details frequency).

- Cleaning and Sanitation – The entire inside of the facility will be power washed and disinfected (Planner details frequency).

Examples for Horses:
- Feed Wastage – Unconsumed feed will be removed from around stalls and feeders (Planner details frequency).

- Cleaning and Sanitation – The entire inside of the facility will be power washed or dry cleaned (Planner details frequency).

Examples for all Non-Slotted Flooring Poultry Facilities:
- Feed Wastage – Feeding equipment will be adjusted to ensure the appropriate flow rate of feed into the feeder. Feeder height will be checked (Planner details frequency) and raised as needed to match the height of the birds. When present, feed junction boxes will be monitored (Planner details frequency) for malfunction. Feed spills will be removed after any necessary repairs are performed. Feed height in the feed trough will be monitored (Planner details frequency) and adjusted as needed.

Examples for Poultry Raised on Slotted Flooring:
- Feed Wastage – Feed wastage is generally related to substandard feed and pellet quality and will be monitored (Planner details frequency). Feed refusal behavior will be reported to the feed company; adjustments in feed preparation will be made as needed.

- Cleaning and Sanitation – Buildings will be power washed and disinfected (Planner details frequency).

Examples for Caged Layer Facilities:
- Building Maintenance – High-rise facilities will be power washed (Planner details frequency). Stack houses will be dry cleaned (Planner details frequency).

Examples for Dairy:

- Dust Control – Dust will be removed from stall dividers, feeder surfaces, fans, walls and other surfaces by (wet or dry method) (Planner details frequency and mechanism).

- Calf Hutch Management – Calf hutches will be cleaned and moved to new locations (Planner details frequency).

2. Ventilation is managed to provide sufficient fresh airflow throughout the facility to keep animals and facility surfaces clean and dry. **(Bullets below provide planner guidance).**

Examples for all species:

- Ventilation Components – Ventilation system components including (planner details components) will be checked (Planner details frequency) for functionality.
  - Mechanical Ventilation –The ventilation system will be designed to provide appropriate ventilation during the winter months. As ambient temperature increases, ventilation rate will automatically increase via staged ventilation. Inlet openings will be automatically controlled by a static pressure monitor or by temperature, which will also be integrated into the computer controls.
    - Fans are cleaned and inspected (Planner details frequency).
    - Inlet openings are adjusted to provide adequate air distribution (Planner details frequency).
    - Static pressure monitors are calibrated (Planner details frequency).
    - Curtains are controlled (Planner details frequency and mechanism).
    - Curtains, cables, winches, and other components of the ventilation system are inspected (Planner details frequency).
  - Natural Ventilation – The ventilation system will be designed to provide adequate fresh air while minimizing drafts so that aisles, pen surfaces, and animals remain relatively free of manure. During certain times of the year (particularly during periods of extreme temperatures) bedding may be used to minimize accumulation of manure on pen surfaces and animals.
    - Inlet openings are adjusted to provide adequate air distribution (Planner details frequency).
    - Curtains are manually controlled by (Planner details frequency and mechanism).
    - Curtains, cables, winches, and other components of the ventilation system are inspected (Planner details frequency).

3. Manure will be managed to minimize damp, exposed manure that contributes to odor generation. **(Planner specifically describes how this will be accomplished).**

Examples for Swine:

- Controlling Accumulated Manure –
  - Keeping aisles and pens (if applicable) free of accumulated manure in all phases of production via scraping or sweeping (Planner details frequency).
  - Removal of Manure from the Pens with Partial or Solid Flooring – Manure will be removed from the pens or scraped to the slatted area (Planner details frequency).
  - Removal of Manure from the Pens with Total Slatted Flooring – Manure should drop through the floor continuously; if any manure does not fall through the slats and accumulates, then it will be removed or scraped through the slats (Planner details frequency).

- Cleaning and Sanitation – The entire inside of the facility will be power washed and disinfected (Planner describes when it will occur within the production schedule).

Examples for Veal:

- Controlling Accumulated Manure – **(Planner selects applicable systems)**
  - Removal of Manure in and around the Pens or Stalls. For calves housed on slotted flooring, any accumulated manure on the slats will be scraped through the slats (Planner details frequency).
  - Mechanically conveyed manure will be removed (Planner details frequency).
  - In bedded systems, sufficient bedding will be added (Planner details frequency) to minimize excess manure from sticking to calves.

- Cleaning and Sanitation – The entire inside of the facility will be power washed and disinfected (Planner describes when it will occur within the production schedule).

Examples for Horses:

- Controlling Accumulated Manure –
  - Stalls and aisles will be kept free of accumulated manure in all phases of production by removing manure (Planner details frequency).
  - For confined horses, bedding will be added as needed to minimize excess manure from sticking to horses.

- Moisture Control – Water delivery system will be checked (Planner details frequency) for functionality and leakage to minimize moisture accumulation in the stalls.

- Building Maintenance – The entire inside of the facility will be power washed or dry cleaned (Planner details frequency).

Examples for Floor-Raised Poultry with Litter Manure Handling Systems:

- Moisture Control – Water delivery system and drinkers will be checked daily for leaks. Repairs will be performed as needed. The height of the nipple waterers will be inspected and adjusted as needed (Planner details frequency) to ensure that birds are always reaching up to the waterers. Bell drinkers (when used) will be checked for leakage, overflow and adjusted for height as needed (Planner details frequency).

- Litter Maintenance – Litter will be caked out if needed, (Planner details frequency). Litter will be tilled (Planner details frequency)

Examples for High-Rise Layer Houses:

- Moisture control – Water delivery system and drinkers will be checked for leaks (Planner details frequency). Repairs will be performed as needed. In high-rise houses, the manure pit will be walked (Planner details frequency) to watch for wet spots as indicators of water leakage.

Examples for all Layer Facilities:

- Monitor for Egg Jams – Facilities will be inspected (Planner details frequency) for broken eggs. For systems using egg belts, seams will be monitored (Planner details frequency) for failure. Broken eggs should not be discarded in the manure pit of high rise houses.

- Clean Egg Conveyors – Components of the egg conveyors will be cleaned (Planner details frequency), including the egg belt, the rod conveyor, and escalators and de-escalators.

Examples for Dairy:

- Moisture Control – Water delivery system and drinkers will be checked (Planner details frequency) for leaks. Repairs will be performed as needed.

- Controlling Accumulated Manure – **(Planner selects applicable systems)**
  - Conventional Bedding Systems – When sawdust, straw, corn fodder or similar materials are used for dry cows, lactating cows, and young stock, sufficient bedding will be added on a daily basis to minimize excess manure from sticking to cows. A cleaning schedule will be established to keep bedding free of manure. For some young stock housing systems, manure may be removed (Planner details frequency).
  - Sand Bedding Systems – Sufficient amounts of sand in lying areas will be provided to allow cows to lie comfortably and to minimize manure from sticking to cows. Free stalls will be inspected for accumulated manure (Planner details frequency).
  - Bedded Pack Systems – Animals will be monitored for cleanliness and sufficient bedding will be added to keep at least 80% of exposed manure covered at all times. When bedded pack volume interferes with animal movement or when animals can no longer be kept clean, the bedded pack will be removed and replaced with fresh bedding. This includes bedded material in an around individual calf hutches.
  - Scraper Systems – Manure scrapers will be run at least (Planner details frequency).
  - Flush Systems – Flush gutters will be flushed at least (Planner details frequency).

- Calf Hutch Management – Calf hutches will be cleaned and moved to new locations at least (Planner details frequency).

4. Mortalities will be removed daily and managed appropriately. (Applicable to all species and manure handling systems.) **(Planner describes specific method of mortality collection and disposal).**

5. Feed nutrients will be matched to animal nutrient requirements to avoid excess nutrient excretion. **(Planner specifically describes how this will be accomplished)**

Example for all species:
- Professional nutritionist formulates diets to match animal nutrient requirements.

Examples for Swine:
- Phase Feeding – For Nursery and Grow Finish, nutrient content in the diet will be closely matched to the weight and age of the pigs.

Examples for meat-producing birds:
- Phase feeding – Diet formulation will be matched to bird weight and age.

Manure Storage Facilities Related Odor BMPs

6. Manage Manure Storage Facilities to reduce exposed surface area and off-site odor transfer. **(Planner specifically describes how this will be accomplished)**

Example for Solid Manure Storages – All Species:

- Minimize Storage Volume – Minimize or eliminate solid manure storage through frequent manure application or export (Planner details frequency).
- Manage Surface Water –
    - Keep surface water from entering manure storage area - Grade surrounding area to avoid run on.
    - Keep surface water from leaving the manure storage area - Manage to avoid runoff of liquid from bottom of the stack by covering or mixing in dry material to absorb rainwater.
- Manure Storage Area Cleanliness - A visual inspection of the manure storage area will be completed (Planner details frequency) to ensure that any manure scattered during transport activities is cleaned up in a timely manner.

Examples for Liquid Manure Storage – All applicable Species
- Reduce liquid manure exposure to air - Liquid manure added from the bottom of the storage or through a drop pipe to below liquid level.
- Encourage crust formation on the surface of liquid manure storages - Use high-fiber feeds (dairy / sows), or bedding.
- Minimize agitation odors - Minimize length and duration of manure agitation periods.

Level II Odor BMPs

Level II Odor BMPs are additional, specialized Odor BMPs that provide additional technology, practices, standards and strategies for odor management commensurate with additional potential for odor impacts. For OSI scores of 100 or higher, the operation must implement all applicable Level I Odor BMPs. In addition, they must implement Level II Odor BMPs to address the identified odor source(s) on the operation as determined by the planner in conjunction with the operator, and as approved by the State Conservation Commission.

The plan writer in conjunction with the operator must determine which individual Level II Odor BMP(s) to install and operate based on those which are expected to be effective and feasible from a practical and economic perspective. Only those Level 2 Odor BMPs that are necessary to address the potential offsite impacts of odors associated with the facility under review are required to be included in the odor management plan under Act 38.

Animal Housing Facilities Related Odor BMPs

Air Scrubbers – *Air scrubbers remove a portion of the odorous gases and dust from air exhausted from livestock facilities.*

1. Research Report XI: Air Scrubbers – IL
   Ni, J. and Y. Zhang. 2004. Study XI: Effect of diffusion-coagulation-separation deduster on odor, gases, and dust exhausted from gestation facilities. In Practical approaches to odor reduction from swine facilities in Illinois. University of Illinois.
   http://www.docstoc.com/docs/110016862/PRACTICAL-APPROACHES-TO-ODOR-REDUCTION-FROM-SWINE-FACILITIES-IN

Bedded Pack Systems – *Composted bedded pack systems utilize an aggressive mixing system to maintain the bedded pack as an active compost. This keeps bacteria aerobic and reduces odorous emissions.*

2. Composted Bedded Pack – MN
   Endres, M. and K. Janni. 2007. Compost Bedded Pack Barns for Dairy Cows. University of Minnesota Extension Service.
   http://www1.extension.umn.edu/dairy/facilities/compost-bedded-pack-barns/.

   Additional reference material:
   - http://pubs.ext.vt.edu/442/442-124/442-124.html.

Biofiltration– *Fan Biofilters use a moist organic substrate that allows aerobic bacteria to thrive on the surfaces and reduce odors from exhaust air streams by metabolizing odorous compounds.*

3. Fan Biofilter Design – MN
   Janni, K., R. Nicolai, S. Hoff, and R. Stenglein. 2011. Biofilters for Odor and Air Pollution Mitigation in Animal Agriculture. Publication Mitigation Strategies: Biofilters. University of Minnesota Extension.
   http://www.extension.org/sites/default/files/BiofiltersforOdor%20FINAL_0.pdf

   Additional reference material:
   - http://www.ipic.iastate.edu/reports/01swinereports/asl-1785.pdf
   - http://www.ipic.iastate.edu/projects/bf/index.htm

Electrostatic Particle Ionization (EPI) – *Dust and odor reductions have been documented.*

4. Electrostatic Particle Ionization

Baumgartner Environics, Inc. 2013.
http://epiair.com/why-epi/epi-data-certifications/

Additional reference material:

- http://www.cabdirect.org/abstracts/20103078570.html;jsessionid=662E220BAD3F8AE6089DB6AFE3B57F2B

Feed Management Plan – *Precision feed management monitors nutrient excretion via a fecal and milk sampling protocol. Dairy and Beef Only. Must be USDA NRCS approved & fully implemented.*

5. Feed Management Plan
   USDA NRCS. 2013.
   http://www.nrcs.usda.gov/wps/portal/nrcs/main/pa/technical/ (Ecological Sciences – Feed Management)

   Additional reference material:

   - electronic Field Office Technical Guide (eFOTG) County Locator webpage:
   Section IV; Conservation Practices; Feed Management Practice Code 592
   http://efotg.sc.egov.usda.gov//efotg_locator.aspx

Oil Sprinkling – *Periodic oil sprinkling on the surfaces of pens and equipment inside livestock facilities helps to prevent odorous compounds from being emitted from accumulated manure and dust.*

6. Oil Sprinkling
   Goodrich, P.R. and G. Shurson. 2001. Best technologies for reducting odor emissions from curtain-sided, deep pit swine finishing buildings. Final report to Minnesota Pork Producers Association.
   http://www.ontariopork.on.ca/portals/0/Docs/Research/Environment/11-01-2001_best%20technologies_fo_reducing_odour.pdf

   Additional reference material:

   - http://www.docstoc.com/docs/80477568/The-Effect-on-Odor-Emissions-when-Sprinkling-Oil-for-Dust-Control

Poultry Litter Amendments – *Addition of litter amendment to poultry houses reduce ammonia*

7. Poultry Litter Amendments.
   Sanjay, S, P. Westerman and J. Parsons. 2006. Poultry Litter Amendments. North Carolina Extension
   https://www.bae.ncsu.edu/programs/extension/publicat/wqwm/poultry/factsheet_agw-657long.pdf

Sulfur Removal from Drinking Water – *Some research has shown that animals consuming water containing high sulfate or sulfide levels in drinking water may excrete manure with more offensive odor characteristics.*

8. Sulfates and Hydrogen Sulfide
   Oram, B., Water Research Center, and B.F. Environmental Consultants Inc. Sulfates and Hydrogen Sulfide: That Rotten Egg / Sulfur Smell, Sulfate Reducing Bacteria (SRB)
   http://www.water-research.net/sulfate.htm.

   Additional reference material:

   - http://www.water-research.net/odor.htm
   - http://www.ces.purdue.edu/extmedia/WQ/WQ-11.html

Windbreak Wall/ Air Dams – *Designs have proven effective in reducing both downwind dust particle concentrations and odor concentration.*

9. Windbreak Wall / Air Dam

Liang, Y., K. W. VanDevender, and G. T. Tabler. 2010. Field Evaluation of Windbreak Effect on Airflow Downwind of Poultry Housing Tunnel Fans. International Symposium on Air Quality and Manure management for Agriculture Conference Proceedings. Dallas, TX. https://elibrary.asabe.org/abstract.asp?aid=32656&t=1

Additional reference material:

- http://www.scribd.com/doc/11508605/Give-Me-a-Break-A-Windbreak

Windbreak Shelter Belts – *Windbreak shelterbelts are multiple rows of trees and fast-growing vegetation planted near the exhaust stream from livestock facilities. This serves to increase turbulence and mixing with fresh air to help dilute odorous compounds before they travel downwind from the facility, and the foliage on some species has been shown to absorb certain compounds, including ammonia.*

10. Windbreak Shelterbelt
    USDA NRCS. electronic Field Office Technical Guide (eFOTG) County Locator webpage: http://efotg.sc.egov.usda.gov/efotg_locator.aspx Section IV; Conservation Practices; Windbreak/Shelterbelt Establishment (FT) (380):
    - PA 380 Establishment Standard
    - Technical Note 1 - Plant Species for Odor Management around Poultry Production Facilities
    - PA 380 Conservation Practice Job Sheet

Manure Storage Facilities Related Odor BMPs

Solid Manure Systems Odor BMPs

Manure Combustion – *Manure may be directly burned, typically for electricity generation or to heat water.*

11. Combustion of Manure
    Chesapeake Bay Program. 2008. CBP/TRS-289-08. Turning Chesapeake Bay Watershed Poultry Manure and Litter into Energy. http://www.chesapeakebay.net/documents/cbp_17018.pdf

    Additional reference material:
    - http://tammi.tamu.edu/ (Manure to Energy: Understanding Processes, Principles and Jargon E428)

Manure Composting – *Composting manure involves mixing manure with a dry material with a high carbon: nitrogen ratio and keeping the material aerobic to reduce odor emissions.* ***– I****ncluding records of temperature increase and turning*

12. Composting Manure and Other Organic Materials
    Wortmann, C.S., and C. A. Shapiro. 2012. Composting Manure and Other Organic Materials. Publication G1315. University of Nebraska. http://www.ianrpubs.unl.edu/epublic/live/g1315/build/g1315.pdf.

Solid Manure Storage Systems Management – *Manure storage enclosed by three walls to prevent wind stripping and covered with a roof or tarp to prevent precipitation from soaking the pile.*

13. Manure Storage Systems
    Jones, D. and A. Sutton. 2007. CAFOs Manure Storage Systems. Publication ID-352. Perdue University.

www.extension.purdue.edu/extmedia/ID/cafo/ID-352.pdf

Additional reference material:

- http://www.lpes.org/ (Minimizing Odor Generation Lesson 41 – Emission Control Strategies for Building Sources)

Liquid Manure Systems Odor BMPs

Aeration – *Aeration systems mix air into the manure to increase aerobic bacteria and reduce odor emissions.*

14. Mechanically Aerated Lagoons
    Merkle, James A. 1981. Managing Livestock Wastes. pp 234-245.
    http://www.google.com/search?sourceid=navclient&ie=UTF-8&rlz=1T4GFRC_enUS215US216&q=avi+publishing+company+merkel+managing+livestock+wastes.

Anaerobic Digestion – *Anaerobic digestion removes some of the volatile organic compounds from manure and converts them to methane (biogas).*

15. EPA AgSTAR Digester Program
    Office of Air and Radiation. 2002. Managing Manure with Biogas Recovery Systems; Improved Performance at Competitive Costs. Publiction EPA-430-F-02-004. Environmental Protection Agency. http://www.epa.gov/agstar/documents/manage.pdf.

    Additional reference material:
    - http://www.manuremanagement.cornell.edu/Pages/Topics/Anaerobic_Digestion/AD-Fact_Sheets.html
    - http://pubs.cas.psu.edu/freepubs/pdfs/G77.pdf
    - https://attra.ncat.org/attra-pub/summaries/summary.php?pub=307
    - http://extension.psu.edu/natural-resources/energy/waste-to-energy/biogas

Manure Covers – *Biocovers work very much like biofilters. Organic material is applied to the surface of a liquid manure storage. Aerobic bacteria thrive on the surfaces and reduce odors by metabolizing the compounds that are volatilized from the surface of the liquid manure. – Permeable covers allow gases and water to pass through a membrane. – Impermeable non-biological covers trap odorous gasses for electricity production or flaring.*

16. Biocovers
    Lorrimor, J. and E. Edwards. 1998. Biocovers. Iowa State University Extension.
    http://www.extension.iastate.edu/Publications/PM1754C.pdf.

17. Permeable & Impermeable Non-Biological Covers for Manure Storages
    Nicolai, R. and S. Pohl. 2004. Covers for manure storage units. South Dakota State University. FS 925-D.
    http://pubstorage.sdstate.edu/AgBio_Publications/articles/FS925-D.pdf.

    Additional reference material:
    - http://www.ext.colostate.edu/pubs/livestk/01631b.html

Manure Pit Additives – *Manure additives are intended to reduce the production of odorous compounds, usually by enzymatic or bacterial action.*

18. A review of microbiology in swine manure odor control – *This article provides a comprehensive summary of what we know about bacterial populations in manure systems and our limitations in altering those populations.* Zhu, Jun. 2000.
    Agric. Ecosystems and the Environment. 78:93-106. * This material is protected by Copyright. In compliance with copyright laws, this material may be purchased from the holder of the copyright. *This link provides one way to purchase this material:
    http://www.ingentaconnect.com/content/els/01678809/2000/00000078/00000002/art00116

19. Evaluation of Commercial Manure Additives
    Johnson, Jack. 1997. Final Report "Evaluation of Commercial Manure Additives". Agriculture Utilization Research Institute. http://agrienvarchive.ca/bioenergy/download/manadeva.pdf

20. Odor Solutions Initiative
    Heber, Albert et. al. 2001. Odor Solutions Initiative. National Pork Producers Council.
    www.alken-murray.com/EZ5pitadditives_purdue.pdf

21. Practices to reduce ammonia emissions from livestock operations – *Although ammonia is a relatively small contributor to odor from livestock facilities, this article provides information on how ammonia emissions can be reduced.* Powers, Wendy 2004.
    Iowa State University Extension. Ames, IA. Available at:
    http://www.extension.iastate.edu/Publications/PM1971a.pdf.

22. Swine Manure Odor Reduction Efficacy of a Humic Amendment – *Specific manure additive (ManureMax- JDMV Holdings, Inc.) with bench top data indicating odor reduction potential. Field trials in progress.*
    R.C. Brandt, E.F. Wheeler, H.A. Elliott, and R.E. Mikesell Jr. 2011. Swine Manure Odor Reduction Efficacy of a Humic Amendment. Abstract for American Chemical Society 242nd ACS National Meeting and Exposition: AGRO Division, Denver CO. Session: Agriculture and Air Quality: Emission Measurements and Models
    http://www.agrodiv.org/documents/denver11/Agriculture%20and%20Air%20Quality/Ag%20Air%20Qual_Brandt-Robin.pdf

Solids Separation for Manure – *Separating solids from manure provides opportunities for further treatment or handling of this odorous component of manure.*

23. Solids Separation of Animal Manure.
    Sheffield, R., J Barker, and D Rashash. North Carolina State University.
    http://www.bae.ncsu.edu/programs/extension/manure/technologies/solids.pdf.

    Additional reference material:
    - http://www.sera17.ext.vt.edu/Documents/BMP_physical_manure.pdf.
    - http://www.extension.iastate.edu/Publications/PM1754I.pdf.

Note: All products and technologies listed here have been evaluated by independent, 3rd party sources. Scientific data are available to prove odor reduction. Additional products and technologies will be added as independent data becomes available. Companies interested in evaluating and obtaining independent data on new products or technologies should contact Dr. Robin Brandt (814-865-2809) at the Penn State Odor Lab for further information.

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