RESOURCE GUIDE

and

BEST MANAGEMENT PRACTICES

for

DAIRY OPERATIONS

August 2018

YAKIMA REGIONAL CLEAN AIR AGENCY

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INTRODUCTION

The Yakima Regional Clean Air Agency (YRCAA) began working with local beef cattle feedlots in 1993 to minimize fugitive dust emissions from confined cattle feeding operations. This partnership resulted in the agency publishing the Fugitive Dust Control Guidelines and Best Management Practices for Confined Cattle Feeding Operations policy. In 2001 YRCAA again partnered with heifer replacement feeding operators to publish the Fugitive Dust Control Guidelines and Best Management Practices for Confined Heifer Replacement Feeding Operations policy. In 2010 the agency's Board of Directors instructed staff to develop recommendations for addressing fugitive emissions from dairy operations. On February 10, 2011 the YRCAA Board of Directors approved the Air Quality Management and Best Management Practices for Dairy Operations policy as a pilot research project aimed at gathering information, testing the feasibility of implementing the policy, and measuring the effectiveness of the policy. The YRCAA worked with eight producers at fifteen dairy facilities throughout the county who voluntarily participated in the pilot project. The pilot project work was completed in December 2011. In March of 2012 the Board of Directors approved the policy for a one-year trial implementation period to provide opportunity for more dairies to comply with the policy. The trial implementation work was completed in December 2012. From 2012 through 2018 the agency used the policy to conduct inspections of approximately 41 dairies operating 59 milking facilities throughout the county.

The data collected over the initial six year period of the policy forms the basis for this resource guide. This guide can be used by dairy operators to prevent or reduce fugitive emissions of Ammonia (NH3), Nitrous Oxide (N2O), Hydrogen Sulfide (H2S), Volatile Organic Compounds (VOC), Odor, Particulate Matter (PM), Methane (CH4) and Oxides of Nitrogen (NOx) from the nine dairy operational systems of: Nutrition, Feed Management, Milk Parlor, Housing - Freestall Barns, Housing - Drylot Pens, Grazing Management, Manure Management, Land application of Manure, and "other" systems;

PURPOSE

This Resource Guide is intended to:

- Provide a broad, though not all inclusive, set of demonstrated Best Management Practices (BMPs) that can be applied to reduce/prevent fugitive air emissions from dairy operational systems.
- Provide technical tools and information to aid in the reduction and prevention of air emissions from dairy operations.
- Provide dairy operators options for choosing the best BMPs for their specific operational conditions.
- Enable dairy operators to target/prioritize air emission reductions based on the eight listed air pollutants.
- Be used as a tool to help in reducing/preventing air emissions from the various systems within any dairy operation.
- This guide may be used by any dairy operation, whether located in the state of Washington or in other states.

SECTION A – POLLUTANT-SPECIFIC BEST MANAGEMENT PRACTICES

The purpose of this section is to present a list of best management practices (BMPs) for reducing emissions from specific air pollutants or pollutant groups. BMPs as they apply to specific dairy operation systems are presented below.

General Principles

- The principle mechanism by which most BMPs operate is to foster conditions which prevent emissions of pollutants addressed by the use of the BMPs; and

- Nothing in this reference guide should be construed to limit the ability of an Operation to be innovative or to use effective management practices that differ from those offered in this guide.

The following is a list of various BMPs for consideration in reducing emissions from each pollutant or pollutant group. The BMPs have not been prioritized for practicality, economic feasibility, ease of use, or efficacy. These are important factors to consider in the successful selection and implementation of BMPs.

I. Ammonia (NH_3)

NH_3 is formed when urea in the urine and the urease enzyme found in feces and manure laden soils are combined together. The reaction is very quick and the peak to volatilization is just several hours. Volatilization of NH_3 depends primarily on four factors: the protein (N) content in the feed, manure management strategies, the pH of the manure or soil, and the meteorology in general (i.e., temperature and wind speed, etc.). The lifetime of gaseous NH_3 is about 24 hours, after which time the NH_3 typically deposits near its source. This deposition can lead to eutrophication of surface water, airborne fertilization, and changes in ecosystems.

It is the objective of an NH_3 BMP to reduce NH_3 emissions and thus, its negative effects. Tradeoffs in NH_3 reductions must be carefully considered. Tradeoffs are actions which reduce emissions of one pollutant, but cause an increase in another pollutant emission. Tradeoffs could result due to things such as changes in pH or a shift to aerobic conditions. Therefore, the most effective method of reducing NH_3 is to target the source itself. In this case, the source is nitrogen (N) input into the dairy systems. BMPs which reduce NH_3 follow.

1. Reduce the amount of dietary protein (N) in the ration to match, rather than exceed, the animal's needs.

2. Practice phase-feeding.

3. Ensure proper ventilation of freestall barns.

4. Bedding selection and management.

5. Treat recycled lagoon water used for flushing.

6. Remove and spread (harrow) manure frequently.

7. Modify alleyway floors.

8. Provide shade for cattle.

9. Locate feed and water opposite in pens.

11. Use straw bedding in drylot pens.

12. Incorporate wood chips in surface layer.

13. Urease inhibitors.

14. Surface moisture content.

15. Stock appropriate number of animals.

16. Use rotational grazing.

17. Move water and feeding areas frequently.

18. Irrigate pastures immediately after grazing.

19. Manure solids separation.

20. Lagoon or storage covers.

21. Surface aeration of lagoons.

22. Reduce the pH of lagoons and manure piles.

23. Apply N fertilizer below no-till residue.

24. Inject or incorporate fertilizer into soil within 24 hours of application.

25. Apply nutrients according to agronomic recommendations based on soil test results.

26. Do not over-irrigate.

27. Utilize cover crops.

28. Apply during cool weather and on still rather than windy days.

II. Nitrous Oxide (N_2O)

Emissions of N_2O result from two different biological processes. There is a very small amount of N_2O produced during nitrification (the biological aerobic process of converting ammonium to nitrate) though this source is relatively insignificant. The primary pathway of N_2O formation is the anaerobic process of denitrification (the conversion of nitrate to N_2 or nitrogen gas), in which N_2O is an obligatory intermediate product. Therefore, many of the emission reduction strategies are associated with minimizing these anaerobic conditions. BMPs which reduce N_2O follow.

1. Reduce the amount of dietary protein (N) in the ration to match, rather than exceed, an animal's needs.

2. Urease inhibitors.

3. Surface moisture content.

4. Stock appropriate number of animals.

5. Use rotational grazing.

6. Move water and feeding areas frequently.

7. Apply nutrients according to agronomic recommendations based on soil test results.

8. Do not over-irrigate.

9. Utilize cover crops.

III. Hydrogen Sulfide (H_2S)

H_2S is produced in anaerobic environments from the microbial reduction of sulfate or the decomposition of sulfur-containing organic matter in manure. Most atmospheric H_2S is oxidized to sulfur dioxide (SO_2), which is then either dry deposited or oxidized to aerosol sulfate and removed primarily by wet deposition. The residence time of H_2S and its reaction products is of the order of days. BMPs which reduce H_2S follow.

1. Properly manage and minimize overfeeding sulfur in the diet.

2. Bedding selection and management.

3. Surface moisture content management.

4. Manure solids separation.

5. Lagoon or storage covers.

6. Scrub exhaust of enclosed waste containers.

7. Surface aeration of lagoons.

8. Encourage purple sulfur bacterial formation in anaerobic lagoons.

9. Properly manage composted solid manure.

10. Properly manage stockpiled manure.

IV. Volatile Organic Compounds (VOC)

VOCs vaporize easily at room temperature and include fatty acids, nitrogen heterocycles, sulfides, amines, alcohols, aliphatic aldehydes, ethers, *p*-cresol, mercaptans, hydrocarbons, and halocarbons. The major constituents of dairy VOC emissions that have been identified include organic sulfides, disulfides, C_4 to C_7 aldehydes, trimethylamine, C_4 amines, quinoline, dimethylpyrazine, and C_3 to C_6 organic acids, along with lesser amounts of aromatic compounds and C_4 to C_7 alcohols, ketones, and aliphatic hydrocarbons. Fresh manure and fermentation of feedstuffs have been identified as the primary sources of VOC emissions. BMPs which reduce VOC emissions follow.

1. Properly manage ensiled feedstuffs.
2. Store feed in a weatherproof storage structure.
3. Remove spilled and unused feed from feeding area on a regular basis.
4. Remove manure from barns frequently.
5. Modify alleyway floors.
6. Surface moisture content management.
7. Knock down and remove fence line manure.
8. Manure solids separation.
9. Lagoon or storage covers.
10. Surface aeration of lagoons.

V. Odor

Odor from dairies is not caused by a single species but is rather the result of a large number of contributing compounds including NH_3, VOCs, and H_2S. Hundreds of compounds contribute to odor from a dairy. A further complication is that odor involves a subjective human response. Although research is under way to relate olfactory response to individual odorous gases, odor measurement using human panels appears to be the method of choice now and for some time to come. Since odor can be caused by hundreds of compounds and is subjective in human response, estimates of odor inventories are not currently possible. BMPs which reduce odor emissions follow.

1. Properly manage and minimize overfeeding sulfur in the diet.
2. Properly manage ensiled feedstuffs.
3. Store feed in a weatherproof storage structure.
4. Remove spilled and unused feed from feeding area on a regular basis.
5. Ensure proper ventilation of freestall barns.

6. Bedding selection and management.

7. Treat recycled lagoon water used for flushing.

8. Remove manure from barns and pens frequently.

9. Modify alleyway floors.

10. Use straw bedding in drylot pens.

11. Incorporate wood chips in surface layer.

12. Surface moisture content management.

VI. Particulate Matter (PM)

This guide considers particulate matter as $PM_{>10}$, PM_{10} and $PM_{2.5}$. $PM_{>10}$ is commonly defined as airborne particles with aerodynamic equivalent diameters (AEDs) more than 10 µm. PM_{10} is commonly defined as airborne particles with AEDs less than 10 µm. Similarly, $PM_{2.5}$ refers to particles with AEDs less than 2.5 µm. Dairies can contribute directly to primary PM through several mechanisms, including: animal activity; animal housing fans; air entrainment from soil and manure; and indirectly to secondary PM by emissions of NH_3, NO, and H_2S, which are converted to aerosols through reactions in the atmosphere. Particles produced by gas-to-particle conversion generally are small and fall into the $PM_{2.5}$ size range. Key variables affecting the emissions of PM_{10} include the amount of mechanical and animal activity on the soil-manure surface, the moisture content of the surface, and the fraction of the surface material in the 0-10 µm size range.

The diameter of PM is critical to its health and radiative effects. $PM_{2.5}$ can reach and be deposited in the smallest airways (alveoli) in the lungs, whereas larger particles tend to be deposited in the upper airways of the respiratory tract. Smaller particles are also most effective in attenuating visible radiation, causing regional haze. BMPs which reduce PM emissions are listed below.

1. Store feed in a weatherproof storage structure.

2. Remove spilled and unused feed from feeding area on a regular basis.

3. Do not mix feeds during windy times.

4. Ensure proper ventilation of freestall barns.

5. Provide shade for cattle.
6. Locate feed and water opposite in pens.

7. Remove and spread (harrow) manure frequently.

8. Use straw bedding in drylot pens.

9. Incorporate wood chips in surface layer.

10. Surface moisture content management.

11. Properly manage composted solid manure.

12. Properly manage stockpiled manure.

13. Apply N fertilizer below no-till residue.

14. Utilize cover crops.

15. Apply during cool weather and on still rather than windy days.

16. Installation of windbreaks or shelterbelts.

VII. Oxides of Nitrogen (NO_X)

Nitrification in aerobic soils appears to be the dominant agricultural pathway to Nitric Oxide (NO). Direct emissions of NO from dairy manure are believed to be relatively minor, but a fraction of manure nitrogen applied to soils as fertilizer can be emitted as NO.

The fraction of fertilizer nitrogen released as NO depends on the amount and form of nitrogen (reduced or oxidized) applied to soils, the vegetative cover, temperature, soil moisture, and agricultural practices such as tillage. A small fraction of other reduced nitrogen compounds in animal manure can also be converted to NO by microbial action in soils.

NO and nitrogen dioxide (NO_2) are rapidly interconverted in the atmosphere and the sum of all oxidized nitrogen species (except N_2O) in the atmosphere is often referred to as NO_X. The residence time of NO_X is of the order of days in the lower atmosphere, with the principal removal mechanism involving wet and dry deposition. In terms of environmental effects, NO_X is an important (and often limiting) precursor in tropospheric ozone (O_3) production. Furthermore, NO_3^- aerosol is a contributor to PM2.5, and nitrogen deposition in the forms of HNO_3, and aerosol NO_3^- can have ecological consequences.

NO_X is also emitted as a result of combustion processes (especially at higher temperature combustion), primarily as NO and $NO_{2.}$ Since nitrification in soils is important to soil health and crop production, no BMPs are presented to reduce NO_X emissions caused by nitrification in soils. Following are BMPs which reduce combustion-caused emissions of NO_X.

1. Replace or retrofit older internal combustion engines.

2. Utilize alternatives to outdoor burning.

VIII. Methane (CH_4)

CH_4 is produced by microbial degradation of organic matter under anaerobic conditions. The primary source of CH_4 from livestock production is enteric fermentation in ruminant animals. Ruminants (sheep, goats, camels, cattle, and buffalo) have unique, four-chambered stomachs. In one chamber, called the rumen, bacteria break down grasses and other feedstuff and generate CH_4 as one of several byproducts. The production rate of CH_4 is affected by energy intake, which is in turn affected by several factors such as quantity and quality of feed, animal body weight, and age.

CH_4 is also emitted during anaerobic microbial decomposition of manure. The most important factor affecting the amount produced is how the manure is managed, because some types of storage and treatment systems promote an oxygen-depleted (anaerobic) environment. Metabolic processes of methanogens lead to CH_4 production at all stages of manure handling. Liquid systems tend to encourage anaerobic conditions and produce significant quantities of CH_4, while more aerobic solid waste management approaches may produce little or none. Higher temperatures and moist conditions also promote CH_4 production.

Methane is destroyed in the atmosphere by reaction with the hydroxyl (•OH) radical. Because of its long residence time (~8.4 years), CH_4 becomes distributed globally. Methane is a greenhouse gas and, under certain conditions, contributes to global warming with a potential 23 times that of CO_2. Following are BMPs which reduce emissions of CH_4.

1. Increase the level of starch in the diet.

2. Surface moisture content management.

3. Manure solids separation.

4. Lagoon or storage covers.

5. Scrub exhaust of enclosed waste containers.

6. Installation of an anaerobic digester.

7. Reduce the pH of lagoons and manure piles.

8. Properly manage composted solid manure.

SECTION B – SYSTEM-SPECIFIC BEST MANAGEMENT PRACTICES

The purpose of this Appendix is to present a list of BMPs as they apply to reducing emissions from specific dairy systems.

I. Nutrition

1. Reduce the amount of dietary protein (N) in the ration to match, rather than exceed, the animal's needs.
2. Increase the level of starch in the diet.
3. Properly manage and minimize overfeeding of sulfur in the diet.
4. Practice phase-feeding.

II. Feed Management

1. Properly manage ensiled feedstuffs.
2. Store feed in a weatherproof storage structure.
3. Remove spilled and unused feed from feeding area on a regular basis.
4. Do not mix feed during windy times.

III. Milk Parlor

1. Ensure proper ventilation.
2. Use recycled parlor (clean) water used for flushing/cleaning holding areas.
3. Treat recycled water used for flushing/cleaning holding areas.
4. Remove manure from holding areas frequently.

IV. Housing – Freestall Barns

1. Ensure proper ventilation of freestall barns.
2. Bedding selection and management.
3. Treat recycled lagoon water used for flushing.
4. Remove manure from barns frequently.
5. Modify alleyway floors to separate urine and feces.

V. Housing – Drylot Pens

1. Provide shade for cattle.
2. Locate feed and water opposite in pens.
3. Remove and spread (harrow) manure frequently.
4. Use straw bedding in drylot pens.
5. Incorporate wood chips in surface layer.
6. Urease inhibitors.
7. Surface moisture content management.
8. Knock down and remove fence line manure.

VI. Grazing Management

1. Stock appropriate number of animals.
2. Use rotational grazing.
3. Move water and feeding areas frequently.
4. Irrigate immediately after grazing.

VII. Manure Management

1. Manage solids separation.
2. Lagoon or storage covers.
3. Scrub exhaust of enclosed waste containers.
4. Installation of an anaerobic digester.
5. Surface aeration of lagoons.
6. Reduce the pH of lagoons and manure piles.
7. Encourage purple sulfur bacterial formation in anaerobic lagoons.
8. Properly manage composted solid manure.
9. Properly manage stockpiled manure.

VIII. Land Application – Manure and/or Chemical Fertilizer

1. Apply N fertilizer below no-till residue.

2. Inject or incorporate fertilizer into soil within 24 hours of application.

3. Apply nutrients according to agronomic recommendations based on soil test results.

4. Do not over-irrigate.

5. Utilize cover crops.

6. Apply during cool weather and on still rather than windy days.

7. Installation of windbreaks or shelterbelts.

SECTION C - DESCRIPTIONS OF BEST MANAGEMENT PRACTICES (BMPs) FOR AIR EMISSION REDUCTION ON DAIRY OPERATIONS

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The purpose of this document is to present brief descriptions of available best management practices (BMPs) for controlling air emissions from dairy operations. The descriptions are presented in a system-specific manner which includes Nutrition, Feed Management, Housing (Freestall Barns), Housing (Drylot Pens), Grazing, Manure Management, and Land Application (Fertilizer and Manure). Not all components or BMPs presented here may apply to your farm. Pollutants impacted by each BMP are presented in parenthesis. These descriptions are not intended to provide detailed information as to how the BMPs should be implemented. It is expected that exact implementation will vary from farm to farm. When applicable, tradeoffs, limitations, or both are listed for each BMP.

***Definitions**: NH_3 – ammonia; N_2O – nitrous oxide; H_2S – hydrogen sulfide; CH_4 – methane; VOC – volatile organic compounds; PM – particulate matter.*

I. Nutrition

1. Properly Manage Level of Dietary Protein (%CP) in Diet to Match, Rather Than Exceed, an Animal's Needs (NH_3, N_2O, Odor)

The most effective and practical way of reducing NH_3 emissions is through proper feeding of dietary nitrogen (N). In the diet, the primary source of N is protein. Excess dietary nitrogen is excreted in the urine as urea, which reacts with the fecal enzyme urease and volatilizes as NH_3. In general, available research data has demonstrated that properly managed feeding of dietary protein N will result in an NH_3 reduction. Studies show that the maximum nitrogen retention efficiency in cows is approximately 50% (1), with the typical efficiency at 38%, so small changes can have a big effect. For example, reducing the protein in the diet from 19 to 14% has shown to reduce urinary urea excretion and subsequent NH_3 emission by 33% (2), with no reduction in milk production. The recommended level of CP in the diet is approximately 16%, with considerations made for MUN and herd efficiency factors.

Added advantages of ensuring proper levels of protein in the diet, in addition to reducing NH_3 emissions, include:1) reduced operating costs considering protein is the most expensive component of the feeds, 2) healthier animals, and 3) improved nitrogen to phosphorus (N:P) ratio for crops when manure is applied to crop land.

2. Increase the Level or Quality of Starch in the Diet (CH_4)

Increasing the level of starch or rapidly fermentable carbohydrates in the diet impacts the rumen pH and microbial population, both of which regulate methane production (3, 4). Since methane emission is the byproduct of incomplete digestion, higher quality diets will allow animals to better digest their feed, be more efficient, and decrease methane production potential. The recommended level of starch in the diet is approximately 23-26%.

3. Properly Manage and Minimize Overfeeding Sulfur in the Diet (H_2S, Odor)

A reduction in sulfur intake to maintenance levels will decrease excretion of sulfur compounds and thus, the emission of odorous gases such as hydrogen sulfide (H_2S). The recommended level of sulfur in the diet is 0.2-0.4% depending on stage of growth or lactation.

4. Practice Group and/or Stage of Lactation Feeding (NH_3)

Group feeding is the separation of cattle into groups (i.e., high milk cows, low milk cows, dry cows, heifers, and calves) based on the dietary needs of each group. The goal is to feed only the necessary nutrient levels, such as protein, for growth and/or milk production to each group. Phase-feeding is very effective in reducing NH_3 emissions because it matches the protein needs of each group more precisely without over or under feeding a nutrient to the whole herd. Phase feeding is synonymous with precision feeding and is both environmentally responsive and economical.

II. Feed Management

1. Properly Manage Ensiled Feedstuffs (VOC, Odor)

Due to the release of low molecular weight organic compounds during fermentation, silage has been found to be a significant source of volatile organic compounds (VOCs), which are responsible for odor in livestock operations. Properly covering, confining, and reducing the release of VOCs from silage storage can result in significant reduction of VOCs and odor emissions. Covered silage piles need to be properly managed during access to minimize VOCs emissions. The primary method of achieving this is to minimize the surface area of the face and the duration of face exposure where and when feed is accessed, respectively. The access face should be covered immediately after the required amount of silage has been obtained.

2. Store Feed in a Sheltered Storage Structure (VOC, Odor, PM)

Since moisture is primary to fermentation and fermentation primary to VOC and odor emission, it is important to minimize the potential for feed becoming wet via rainwater. Weatherproof storage will prevent feed from becoming wet and diminish potential for spoilage and fermentation. Store feed in a covered bunker with proper drainage, or cover exposed feed piles during the wet season. A feed bunker covered on three sides will also reduce PM emission by limiting wind exposure to and erosion of the pile.

3. Regularly Remove Spilled and Unused Feed from Feeding Area (VOC, Odor, and PM)

Spilled and unused feed is a source of VOC, odor, and PM emissions. Removal of such feed from the storage and loading areas at least every two weeks, or more frequently during wet periods, will significantly diminish the potential for VOCs, odor, and PM emissions.

4. Manage or Minimize the Mixing of Feed During Windy Times (PM)

Mixing, grinding, and chopping of feed during windy times can be a significant source of PM emissions, as well as a waste of feed. Avoiding such activities, or performing them in a sheltered area during wind events, will diminish the potential for PM emission and subsequent transport from the feed processing area.

III. Milk Parlor

1. Ensure Proper Ventilation (NH_3, Odor, and PM)

Temperature is a very important factor in the rate of NH_3 volatilization. As the ambient temperature increases, NH_3 emission increases. Studies show that an increase in ambient housing temperature from 50 to 75º F results in a 46% increase in NH_3 emissions (5). Thus, reducing the temperature inside of enclosed parlor and holding areas with proper ventilation and/or cooling reduces the NH_3 volatilization potential and reduces animal health effects, which can lower milk production. Odor and PM emissions are likewise reduced by this BMP by circulating air and removing stagnant odor and airborne PM from the enclosed areas.

2. Use Recycled Parlor (Clean) Water Used for Flushing/Cleaning Parlor (NH_3, Odor)

Using clean water, recycled parlor water, or most dilute water from a multi-stage lagoon system will decrease the reintroduction of odorant materials and reduce emissions. Recycling concentrated liquid manure through the holding area may increase both NH_3 and odor emissions and should be avoided.

3. Treat Recycled Water Used for Flushing/Cleaning Holding Area (NH_3, Odor)

For holding pens and parlors that practice flushing as a means of manure removal, treatment in the form of additives that discourage NH_3 hydrolysis (i.e., pH reducers, urease inhibitors, or biological additives) can help reduce ammonia and odor emissions.

4. Remove Manure from Holding Area Frequently (NH_3, VOC, Odor)

Ammonia volatilization is a function of the mixing time of manure on the stall floor right after it is deposited. The production of NH_3 begins immediately and peaks only a few hours after mixing. Odor and VOC production also occurs immediately after manure deposition and continues until removal. Thus, an effective way of reducing emissions from parlors and holding areas is by removing manure at frequent intervals.

Typically, manure removal from parlors and holding areas is performed with a flush system. Studies have shown that a flush system is more effective at reducing NH_3 volatilization over a scrape system, and that more frequent manure removal, every 2-4 hours, reduces odor and NH_3 (6). Whether using a flush or scrape system, the most effective system is one that removes all manure from the alleyway without leaving piles on the edges or reducing it to a film on the surface. These inefficiencies can lead to an increase in NH_3 volatilization via increased mixing and surface exposure. This BMP is also effective in reducing, VOC, and odor emissions.

IV. Housing – Freestall Barns

1. Ensure Proper Ventilation of Freestall Barns (NH_3, Odor, and PM)

Temperature is a very important factor in the rate of NH_3 volatilization. As the ambient temperature increases, NH_3 emission increases. Studies show that an increase in ambient housing temperature from 50 to 75º F results in a 46% increase in NH_3 emissions (5). Thus, reducing the temperature inside of freestall barns with proper ventilation and/or cooling of the barns reduces the NH_3 volatilization potential and reduces animal heat stress, which can lower milk production. Odor and PM emissions are likewise reduced by this BMP by circulating air and removing stagnant odor and airborne PM from the barn.

2. Bedding Selection and Management (NH_3, H_2S, Odor)

The use of non-absorbent bedding materials may help reduce NH_3 and odor emissions when managed well. The most common bedding materials used in dairy barns include: sand, wood shavings, chopped straw, and recycled manure. Among these listed materials, studies have shown, for example, that sand-bedding results in the lowest NH_3 emissions when managed correctly (scraped daily, restocked weekly, and completely cleaned out annually). Sand is non-absorbent and allows urine to infiltrate through it, which reduces urine’s contact time with ambient air. In contrast, composted manure-bedding does not allow urine to percolate through and, therefore, results in higher ammonia emissions than sand-bedding.

In general, however, proper management of *any* type of bedding including: frequent restocking, daily removal of solid manures, and annual bed change, will significantly reduce the potential of NH_3 volatilization from all bedding types. Hydrogen sulfide, which can form under anaerobic bedding conditions, and odor emissions are similarly reduced by this BMP. Most of all, keeping cows from defecating on the bedding material through proper sizing of freestalls has a significant reduction in emission potential by eliminating manure deposition on the beds in the first place.

3. Treat Recycled Lagoon Water Used for Flushing (NH_3, Odor)

For barns that practice flushing as a means of manure removal from alleyways, treatment in the form of solids removal or use of additives that discourage NH_3 hydrolysis (i.e., pH reducers, urease inhibitors, or biological additives) can help reduce ammonia and odor emissions. Using the cleanest or most dilute water from a multi-stage lagoon system will decrease the reintroduction of odorant materials and reduce emissions as well. Recycling concentrated liquid manure through the barn may increase both NH_3 and odor emissions and should be avoided.
Tradeoffs/Limitations: Infrastructure and additive cost.

4. Remove Manure from Barns Frequently (NH_3, VOC, Odor)

Ammonia volatilization is a function of the mixing time of manure on the stall floor right after it is deposited. In addition, the thin-spread manure provides more surface area, which exacerbates the respective emissions. The production of NH_3 begins immediately and peaks only a few hours after mixing. Odor and VOC production also occurs immediately after manure deposition and continues until removal. Thus, an effective way of reducing emissions from barns is by removing the manure at frequent intervals (every 2 to 4 hours (6)).

5. Manure Removal Technology and Efficiency (NH_3, VOC, Odor)

Typically, manure removal is performed with a scrape or vacuum system at milking times when cattle are out of the barn, but can occur more frequently with the use of a flush system or automatic scrapers. Studies have shown that a flush system is more effective at reducing NH_3 volatilization over a scrape system, and that more frequent manure removal, every 2 to 4 hours, reduces odor and NH_3 (6). However, the most effective system is one that removes all manure from the alleyway without leaving piles on the edges or reducing it to a thin film on the surface. These inefficiencies can actually lead to an increase in NH_3 volatilization via increased mixing and surface exposure. This BMP is also effective in reducing, VOC, and odor emissions.

6. Alleyway Floor Texture and Type (NH_3, VOC, Odor)

In freestalls, most manure is excreted in alleyways where the mixing rate is highest. Minor changes or modifications to the floor surface that reduce the contact time of urine and feces could make a significant difference in NH_3 emission. Modification to a 3% sloped floor, over a level (0%) one, encourages transport of urine away from solid manure and could reduce NH_3 emission by 21% (7, 8). A double slope with a gutter in the middle to trap the urine could reduce emission by 50% compared to solid floors (7). Grooved concrete floors that allow urine to collect in channels will help in reduction of NH_3, since the main objective is to separate the urine from the feces and reduce contact time. Besides reducing emission potential, surface texture or permeable matting will aid in traction and increased hoof health. This BMP is also effective in reducing, VOC and odor emissions.
Tradeoffs/Limitations: Modification with this BMP may not be possible for existing barns. New construction should consider these guidelines.

V. Housing – Drylot Pens

1. Provide Shade for Cattle (NH_3, PM)

Ammonia volatilization is dependent on the mixing of urea and the urease enzyme from urine and feces, respectively. By spreading out the distribution of urine and feces over the pen surface, the mixing potential is reduced. The installation of a shade structure in the center of the pen will aid in distribution of defecation events as the animals follow the shade during the day, dispersing manure and reducing the opportunity for mixing. This also helps to control course PM by more uniform surface wetting and compaction, and aids in reduction of animal heat stress.

2. Sitting of Water Trough Within Pen (NH_3, PM)

Placing the water-trough and feed bunk at opposite sides of the pen, or rotating the locations (when applicable), helps to spread feces and urine over a larger area of the pen surface, reducing the opportunity for mixing. This also helps to control coarse PM by more uniform surface wetting and compaction. Conversely, locating the water trough near the feed bunk concentrates surface wetting to a collected area (i.e., feed alley) and limits the movement of animals across a potentially dry pen, thus limiting course PM production.
Tradeoffs/Limitations: This BMP may not be possible for all pen designs.

3. Remove and/or Spread (Harrow) Manure Frequently (NH_3, PM)

Ammonia emissions from open drylot pens are due to infrequent manure removal. There are two types of in-pen manure management: (i) spreading or harrowing, and (ii) complete manure removal. In general, manure in drylot pens should be completely cleaned out every one to three months. The reduction in the quantity of manure results in less ammonia volatilization and also minimizes PM (dust) production from animal hoof action on the loose manure pack. More frequent (monthly, weekly) removal of manure from areas where manure deposition is highest (i.e., sleeping areas, feed bunks) is desirable. Installation of concrete alleyways adjacent to feed-bunks aids in daily collection of manure and further reduces ammonia volatilization potential. The daily harrowing of pens should be practiced to spread out the manure pack, but should only be done during times of the day when PM production will not be an issue, such as the early morning.

4. Use Straw Bedding in Drylot Pens (NH_3, PM, Odor)

The application of a layer of straw bedding to drylot pens is commonly used as a wintertime management tool to reduce pen wetness and provide animals with a dry layer. However, the addition of straw bedding also aids in the separation of urine and feces to reduce ammonia volatilization, and in reduction of particulate (PM) production from the pen surface. This practice can be utilized year-round for increased ammonia, PM, and odor reductions.

5. Incorporate Wood Chips into Surface Layer (NH_3, PM, Odor)

Incorporating woodchips (1/2 inch diameter average) into the pen surface layer will manage moisture content and encourage aeration of the manure pack. The increase in aeration reduces ammonia, odor, and PM. Woodchips should be placed approximately four inches thick in areas where animals tend to congregate and/or deposit manure (i.e., sleeping areas, under shades, near feed-bunks). These areas should also be harrowed daily to encourage aeration and reduce compaction of the surface layer, and restocked with woodchips as needed.

Additionally, if manure is harvested from pens for composting, the addition of woodchips to the pen increases the carbon content of the compost and eliminates the extra step of adding and mixing the woodchips later in the process.

5. *Urease Inhibitors (NH_3, N_2O)*

Reduction of NH_3 from drylot pens can be achieved through enzymatic treatment with urease inhibitors, which inhibit the urease enzyme in feces from reacting with urea and volatilizing as NH_3. Several inhibitors are available such as N-(n0butyl) thiophosphoric triamide (NBPT), which is the most effective in preventing the hydrolysis of urea. Urease inhibitors can either be fed to cattle in feed rations or surface applied to the pen surface. Similar to surface acidifiers, urease inhibitor effectiveness is highly variable and can be very costly to achieve significant reductions. This BMP is also relatively effective in reducing N_2O emissions by limiting nitrification. <u>Tradeoffs/Limitations</u>: Can be very expensive to install and maintain effectiveness of surface treatments.

7. *Surface Moisture Content Management (NH_3, N_2O, VOC, Odor, CH_4, H_2S, Odor, PM)*

Over-application of water on a dry pen surface activates the hydrolysis and nitrification process, leading to ammonia volatilization and nitrous oxide “bursts”, respectively. Water should only be applied to pen surfaces as a dust (PM) mitigation tool and be applied such that it forms a cohesive moist layer on the surface, but does not penetrate too deeply into the surface. The dust (PM) from a dry pen is inversely proportional to the pen surface moisture content. Increasing the pen-surface moisture content binds surface manure and soil particles to limit the production of dust. Too much moisture, however, encourages the production of odorous compounds. A compromise surface moisture level of approximately 28% has been suggested to balance odor and dust (10). Maintaining this moisture level can be accomplished through regular water application, surface bonding additives, use of straw or wood chips to the surface layer, construction of a shade structure, and pen layout and design. This practice requires routine monitoring of surface moisture content.

On the extreme end, standing water should also be avoided. Standing water promotes anaerobic conditions, which are responsible for odor, CH_4, H_2S, and VOC emissions. Standing water can be mitigated by grading pens to a minimum 3% slope to channel water away from the pen and into a collection area. Contained runoff can then be treated or land applied. Daily harrowing of pens, filling of holes, and center piling will reduce pen conditions that encourage surface-ponding.

8. *Knockdown and Remove Fence Line Manure (NH_3, VOC, Odor)*

Over time, manure builds up along fence lines. This build-up of manure along fence lines provides opportunity for anaerobic decomposition (odor) and fly proliferation. Manure should be knocked down and either spread or removed when build-up is greater than 12 inches deep.

VI. Grazing Management

1. *Stock Appropriate Number of Animals (NH_3, N_2O)*

Overstocking of cattle increases NH_3 volatilization from pastures by increasing the concentration of manure on the field and reducing the amount of plant cover and N uptake. Stocking animals at appropriate rates and intervals for each field will reduce over application of manure and maintain pastures.

2. *Use Rotational Grazing (NH_3, N_2O)*

Practicing rotational grazing will help maintain pasture forage growth and health, which will maximize plant uptake of manure and reduce the potential of NH_3 or N_2O emission. Pastures should be evaluated on a regular basis for plant height and quality, and animals should be removed when plants are less than three inches in height or stem density is less than 85%.

3. *Move Water and Feeding Areas Frequently (NH_3, N_2O)*

Since the volatilization of NH_3 is dependent on the mixing of urine (urea) and feces (urease), dispersing these events evenly over a pasture surface can help reduce NH_3 volatilization. Animals on pasture tend to concentrate elimination behaviors around the water trough, feeding, and/or sleeping areas. Studies show that the number of elimination events that occur in a location is highly correlated with the time spent at the location (18). Therefore, distribution of manure deposition can be effected via management and layout of the pasture environment. Moving water-troughs and feed-stations periodically to new locations will disperse cattle activity and thus manure deposition. This will also prevent plant suffocation and trampling in heavily populated areas of the pasture.

4. *Irrigate Immediately after Grazing (NH_3)*

Irrigating pastures following grazing will help incorporate manure into the soil and reduce ammonia volatilization potential. Over irrigation can, however, increase NH_3 volatilization and N_2O emission.

VII. Manure Management

1. *Manure Solids Separation (NH_3, VOC, Odor, H_2S, CH_4)*

Solid separation is the removal of the solid portion of the manure waste stream from the liquid portion. The liquid portion is transferred to the storage vessel (i.e., lagoon, tank) and the solid portion is stockpiled, composted, or land applied. Solid separation systems include: screens, rotary drums, centrifugal tanks, earthen pits, weeping walls, settling basins, screw-presses, and others. Approximately 25% of the total manure N is removed with the solids (1); the remaining N stays with the liquid portion of the manure. Solid separation reduces potential of NH_3, VOC, Odor, H_2S, CH_4 emissions from post-separation liquid storages.

2. *Lagoon or Storage Covers (NH_3, H_2S, VOC, Odor, CH_4)*

The emission rate from the surface of a lagoon is influenced by environmental factors such as ambient temperature, relative humidity, surface wind velocity, and precipitation. To control the effects of these factors, addition of a cover to the lagoon is necessary. Lagoon covers range from floating plastics, synthetic or natural peat, straw, polystyrene, and natural dry matter. When properly installed and managed well, any of these covers can reduce NH_3 losses by 80-90% (1), in addition to controlling odor, H_2S, and CH_4 losses. Any cracks in the cover should be taken care of immediately because they will compromise the efficiency of the cover.

The establishment of a natural crust on the lagoon surface, typically formed by the movement and cohesion of solids to the lagoon surface, can reduce ammonia losses by up to 50% (11). The formation of a natural crust will occur when the lagoon has a high solids-content, the ambient air is dry, and there is little precipitation to break the crust. While natural covers can reduce NH_3 and H_2S emissions, they need to be monitored for odor, which can emanate from the crust itself.

In general, covers *must* be checked regularly and maintained to prevent leakage and loss of pollutants from the cover. Secondary treatment methods of captured gas either via bio-filters, flaring, scrubbing, or other method should be maintained and operated effectively to minimize emission of untreated pollutants.
Tradeoffs/Limitations: Cost and maintenance time of covers can be high.

3. Scrub Exhaust of Enclosed Waste Containers (CH_4, Odor, H2S)

Using bio-filters to scrub the exit air from enclosed manure storage facilities can significantly reduce NH_3, H_2S, odor, and CH_4 emissions. Bio-filters vary in style, function, and effectiveness. A technical assistant is necessary to design and implement this BMP effectively.
Tradeoffs/Limitations: This practice requires technical assistance to install and maintain.

4. Proper Operation and Maintenance of Anaerobic Digester (CH_4)

Anaerobic digestion (AD) converts manure into biogas (CH_4 and CO_2), which can subsequently be used for providing energy or heating on the dairy or for sale back into the electric grid. The two common types of digesters found on dairy operations are the plug flow type or the complete mixed digesters. The former is more appropriate for operations with scrape manure systems, while the latter is more suitable for dairies with manure flushing systems. The overarching goal of AD is to reduce methane emission from manure. Other gases produced during AD (H_2S, CO_2) can be scrubbed from the exhaust to provide natural, gas grade CH_4. Although AD reduces CH_4, H_2S, and odor emissions from AD effluent, the digestion process increases the ammonia volatilization potential from the AD effluent. This BMP requires technical assistance and has a high cost associated with installation and operation.
Tradeoffs/Limitations: Increases ammonia volatilization potential from effluent; high cost of installation; and requires technical assistance to install and operate properly.

5. Surface Aeration of Lagoons (NH3, H2S, VOCs)

The biodegradable organic materials in manure can be oxidized to stable end products by aerobic bacteria. These microorganisms require oxygen to affect this process. In general, if enough oxygen is provided, the end products of aeration are odor-free. The main problem is the cost of providing adequate oxygen for this process.

To reduce the cost of aeration, surface aeration is suggested as a method for mitigation of odor and other gases from anaerobic lagoons, which are released from incomplete manure decomposition. Surface aeration can complement anaerobic digestion by acting as a biological-blanket, aerobically degrading odorous compounds from the layer of anaerobic decomposition below. The aerobic bacteria in this blanket consume odorous volatile compounds and releases odor-free gases into the air. For example, this layer oxidizes ammoniacal nitrogen (NH_4^+, NH_3) into nitrate (NO_3^-), and oxidizes sulfur containing compounds such as H_2S into elemental sulfur (S) or sulfates (SO_4^{2-}). This process thus mitigates emissions of NH_3 and H_2S as well other volatile organic odorous compounds that may try to escape from the anaerobic zone below the aerobic blanket.
Tradeoffs/Limitations: High cost associated with running aerators; reduced effectiveness in lagoon with high solids content.

6. Reduce the pH of Lagoons and Manure Piles (NH_3, CH_4)

The pH of stored manure, liquid or solid, greatly affects the rate of H_2S and NH_3 volatilization. If the pH of liquid manure stored in a lagoon or tank is maintained above 8 (basic), ammonia volatilization increases and losses may be up to 70% of the total nitrogen entering the lagoon (1). Additionally, in solid manure, the urease enzyme is very active at a pH between 6.8 and 7.6, amplifying the volatilization process from manure piles. At a pH below 6 (acidic), NH_3 is bound in solution or tied-up and little NH_3 volatilization will occur from liquid or solid manure, respectively. Methane emission is also reduced at a pH below 6.5. On the other hand, low pH in the lagoon may result in elevated H_2S emissions and loss of efficiency of the anaerobic process, which may result in increased odor emissions. Reduction of manure pH in lagoons and manure piles is achieved by addition of acidifying compounds such as alum or acids. However, due to the

natural buffering capacity of manure, large amounts of acidifiers are required to reduce pH and frequent monitoring is necessary.
Tradeoffs/Limitations: Decrease ammonia and methane, but increases hydrogen sulfide and odor production; high cost; and only effective over short-periods.

7. Purple Sulfur Bacterial Formation in Lagoons (H_2S, Odor)

Purple sulfur bacteria (PSB) are photosynthetic, anaerobic bacteria that grow in the presence of carbon dioxide (carbon source), nitrate (nitrogen source), and hydrogen sulfide (13). Purple sulfur bacteria oxidize the hydrogen sulfide in the lagoon for photosynthesis and produce elemental sulfur or sulfate as a photosynthetic by-product (14), both of which are less odorous than hydrogen sulfide. Since PSB are photosynthetic, the use and/or optimization of a solid separator can aid in light penetration and the proliferation of PSB in a lagoon. The conditions conducive to natural PSB formation are an anaerobic lagoon with low solids content and a pH in the 7.0 to 8.5 range (15). Population of PBS in a lagoon is very difficult to induce and typically happens naturally. Therefore, maintenance of an existing population is the most effective H_2S reduction method for lagoons.
Tradeoffs/Limitations: PSB conditions decrease hydrogen sulfide and odor production, but may increase ammonia volatilization; difficulty in inducing PSB formation.

8. Properly Manage the Composting of Solid Manure (H_2S, Odor, PM, CH_4)

The effectiveness of the composting process is highly dependent on good management of pile characteristics including temperature, moisture, carbon to nitrogen ratio (C:N), and aeration. Low temperature, high moisture, and low aeration will lead to anaerobic conditions inside the manure pile and increase odor, H_2S, and CH_4 emissions. A shift from anaerobic to aerobic process can cause a nitrification/denitrification cycle that can increase N_2O losses. Low C:N (below 12:1), high temperature, and high aeration of the compost pile will increase NH_3 volatilization, which can be up to 90% total N loss under these conditions (12). Low moisture will increase PM emissions. A C:N above 12:1, and optimally around 30:1, will have reduced NH_3 emissions, while still supporting an active composting process.

9. Properly Manage Stockpiled Manure (H_2S, Odor, PM)

Stockpiled manure can easily become anaerobic from compaction, too much moisture, or organic matter breakdown if not managed properly. Anaerobic piles will emit odor, H_2S, and CH_4. Stockpiles should be stored in a covered area to avoid over saturation with rainwater, or periodically turned to decrease compaction and achieve even moisture levels throughout the pile.

VIII. Land Application – Manure and/or Chemical Fertilizer

1. Apply N Fertilizer Below No-Till Residue (NH_3, PM)

The practice of no-till crop harvesting is beneficial in reducing soil erosion from wind (PM) and water transport, and increasing or maintaining soil tilth. The stubble left behind creates a surface cover that helps protect against soil loss. When applying fertilizer the following year to new crops, the fertilizer should be applied under the crop residue, not on top. Appling fertilizer on top of the residue increases exposure to ambient conditions and NH_3 volatilization losses.

2. Inject or Incorporate Fertilizer/Manure into Soil within 24 Hours of Application (NH_3, Odor)

All fertilizer or manure should be injected, incorporated, or applied as close to the ground surface as possible to mitigate NH_3 and odor emissions. Nitrogen applied to crop land is susceptible to volatilization if left on the soil and leaf surfaces, or sprayed from some height above the soil surface. Incorporation of manure immediately after application (within 24 hours) via chisel or irrigation (or precipitation event under 0.15 inches) is suggested for annual crop fields and can reduce ammonia losses by up to 98% (1). Application of manure with an aerator, sleighfoot or other below leaf canopy surface applicator (i.e., drop hose irrigation) is recommended for forage fields to reduce NH_3 and odor. All of these methods work by moving fertilizer and/or manure into the soil profile away from the surface where volatilization and odor emissions occur. In addition to reducing emission losses, this method conserves more nitrogen in the soil, increasing efficiency and reducing fertilizer costs.

Application of manure using a "big gun" or overhead sprinkler has the highest rate of ammonia loss out of all application methods. The sprinkler exposes more manure surface area to the ambient air, allowing a significant portion of the total nitrogen to be volatilized as NH_3 before the liquid manure even reaches the soil surface. Furthermore, sprinkler application also enhances transport and dispersion of emissions especially during windy conditions. Broadcast application, which also exposes manure surface area to the ambient air, also has high NH_3 losses (20 to 30% of total N) if not immediately followed by manure-incorporation.

For certain crops, controlled-release fertilizers or fertigation is an effective way to deliver chemical fertilizer to the plants at specific rates and times. This is an effective way to match crop needs and fertilization delivery to reduce the amount of N available for volatilization. These are more costly methods and require installation of necessary irrigation infrastructure. Tradeoffs/Limitations: Deep injection of manure decreases NH_3 volatilization, but may increase N_2O emissions via denitrification.

3. Apply Nutrients According to Agronomic Recommendations Based on Soil and Manure Test Results (NH_3, N_2O)

Application of chemical fertilizer and manure nutrients should always be made at agronomic rates to avoid excess application that exacerbates N losses. Agronomic application is the application of nutrients to meet crop needs. Agronomic application rate is determined by knowing the nutrient content of the soil (soil test), the nutrient content of the manure (manure test), and the crop nutrient needs at the time of application (estimated or historical value). By matching crop needs to available nutrients, over application of nitrogen and subsequent NH_3 and N_2O emission can be avoided. A nutrient planner can help determine agronomic rate and plan annual applications to match crop needs.

4. Do Not Over-irrigate (NH_3, N_2O)

Irrigation increases soil water content and may increase N_2O emissions when over applied by promoting anaerobic conditions and increasing denitrification. When combined with nitrogen from fertilizer or manure application, the rates of emissions are increased. Irrigation to very dry soil can also increase N_2O and/or NH_3 emission by microbial action. Irrigate at recommended levels and timing throughout the growing season.

6. Utilize Cover Crops (NH_3, N_2O, PM)

Cover crops reduce the amount of surface exposed and provide root structures to hold soil in place. The use of cover crops, instead of leaving fields bare/fallow, decreases wind erosion (PM) and losses of NH_3 and N_2O by providing surface cover and nutrient uptake, respectively. Cover crops also reduce nitrate leaching during the wet season by taking up soil nitrate.

6. Apply During Cool Weather and on Still Rather than Windy Days (NH_3, Odor, PM)

Temperature, humidity, wind speed, and precipitation all influence the rate of NH_3, PM, and odor losses. Ammonia loss increases exponentially with rising temperatures, and increases with greater wind speeds. PM losses also increase with increasing temperatures which dry out the soil, and increased wind speed that moves soil and manure particles from the surface into the ambient air. Therefore, the application of manure during cool, still weather will decrease the amount of PM and NH_3 volatilized from the manure (16). Appling in the early morning or late evening will not only reduce NH_3 volatilization, but will also reduce the transport of PM and odor to surrounding neighbors. Light precipitation (less than 0.15 inches) following application can also decrease NH_3 volatilization by binding NH_3 in the aqueous phase and moving it into the soil profile.

IX. Other

1. Installation of Windbreaks or Shelterbelts (NH_3, Odor, PM)

Windbreaks or shelterbelts could be either natural (e.g., a line of trees) or artificial (e.g., a solid brick or hay bale wall). Windbreaks mitigate emissions through multiple pathways. One, windbreaks break or slow the wind and thus reduces the transport of emitted gases, particulates, and odor from the dairy. A windbreak, composed of trees or a physical barrier, will partially reduce wind speeds for a distance of roughly 30 times its height (17). Two, windbreaks promote mixing and dispersion of emitted gases and odor, which dilute the respective emissions, with respect to the receiver. Three, windbreaks intercept particulates and odor, which subsequently break down as in the case of odorous compounds, or is deposited on site as in the case of particulates. The effectiveness of a windbreak, therefore, depends on its placement, height, spacing or porosity, and prevailing direction of wind and its fluctuations. Windbreak structures ranging even in modest heights ranging from 20 to 30 feet can provide significant mitigation of odor and particulate problems (19). These structures can be installed on individual systems (barns, lagoons, compost or manure piles, etc) in the dairy or on the entire dairy.

Other indirect benefits that accrue from installation of windbreaks, especially of the natural kind include: (i) alleviation of complaints which are sometimes influenced by visual images of the dairy, and (ii) enhanced landscape aesthetics of the dairy.

2. Vehicle Road Condition Management (PM)

Vehicle traffic on on-farm dirt roads can be a significant source of course particulate matter. Feed trucks, manure tankers, maintenance vehicles, etc. are constantly moving around the facility. Watering roads or applying a surface binder can significantly reduce the incidence of PM production from on-farm vehicle traffic. This should be conducted during dry times of the year and during high traffic times.

3. Engine Selection and Efficiency (NOx)

Engines used on-site for power generation should be energy efficient and properly maintained to minimize the production of NOx from combustion processes.

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SECTION D: DAIRY BMPs QUICK REFERENCE TABLE

BMP # (NOTE)	Best Management Practice	Ammonia (NH_3)	Nitrous Oxide (N_2O)	Hydrogen Sulfide (H_2S)	Volatile Organic Compounds (VOCs)	Odor	Particulate Matter (PM)	Methane (CH_4)	Oxides of Nitrogen (NO_X)
I. Nutrition									
I.1	Properly manage level of dietary protein (%CP) in diet to match, rather than exceed animal's needs.								
I.2	Increase the level or quality of starch in the diet.								
I.3	Properly manage and minimize overfeeding of sulfur in the diet.								
I.4	Practice group and/or stage of lactation feeding.								
II. Feed Management									
II.1	Properly manage ensiled feedstuffs.								
II.2	Store feed in a sheltered area or storage structure.								
II.3	Regularly re-pile or remove spilled and unused feed from feeding area.								
II.4	Manage or minimize feed mixing during windy times.								
III. Milking Parlor									
III. 1	Ensure proper ventilation.								
III. 2/3	Use recycled (clean) or treated water for flushing parlor.								
III. 2/3	Use recycled (clean) or treated water for cleaning holding pen.								
III. 4	Remove manure from barns frequently.								
IV. Housing - Freestall Barns									
IV. 1	Ensure proper ventilation.								
IV. 2	Bedding selection and management.								
IV. 3	Treat recycled lagoon water used for flushing.								
IV. 4	Remove manure from barns frequently.								
IV. 5	Manure removal technology and efficiency.								
IV. 6	Alleyway floor texture and type.								

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BMP # (NOTE)	**Best Management Practice**	**Ammonia (NH_3)**	**Nitrous Oxide (N_2O)**	**Hydrogen Sulfide (H_2S)**	**Volatile Organic Compounds (VOCs)**	**Odor**	**Particulate Matter (PM)**	**Methane (CH_4)**	**Oxides of Nitrogen (NO_X)**
V. Housing - Drylot Pens									
V. 1	Provide shade for cattle.								
V. 2	Sitting of water trough within pen.								
V. 3(a)	Remove manure frequently.								
V. 3(b)	Spread (harrow) manure frequently.								
V. 4	Use straw bedding in pen (seasonal).								
V. 5	Incorporate wood chips in surface layer.								
V. 6	Use urease inhibitors.								
V. 7	Surface moisture content management.								
V. 8	Knock down and remove fence line manure.								
VI. Grazing Management									
VI.1	Stock appropriate number of animals.								
VI.2	Use rotational grazing.								
VI.3	Move water and feeding areas frequently.								
VI.4	Irrigate immediately after grazing.								
VII. Manure Management									
VII. 1	Manure solids - mechanical separation.								
VII. 1	Manure solids - settling basin.								
VII. 2	Lagoon or storage covers (natural or composite).								
VII. 3	Scrub exhaust of enclosed waste containers.								
VII. 4	Proper maintenance of installed methane digester.								
VII. 5	Surface aeration of lagoons.								
VII. 6	Reduce the pH of lagoons and manure piles below 6.								
VII. 7	Purple sulfur bacterial formation in anaerobic lagoons.								
VII. 8	Properly manage the composting of manure.								

SECTION D: DAIRY BMPs QUICK REFERENCE TABLE

BMP # (NOTE)	Best Management Practice	Ammonia (NH_3)	Nitrous Oxide (N_2O)	Hydrogen Sulfide (H_2S)	Volatile Organic Compounds (VOCs)	Odor	Particulate Matter (PM)	Methane (CH_4)	Oxides of Nitrogen (NO_X)
VII. 9	Properly manage stockpiled manure.								
	VIII. Land Application - Manure or Chemical Fertilizer								
VIII. 1	Apply N fertilizer below no-till residue.								
VIII. 2(a)	Corn - Inject fertilizer/manure into soil at application.								
VIII. 2(b)	Forage - Manure/fertilizer application method and/or incorporation practice.								
VIII. 3	Apply nutrients according to agronomic recommendations based on soil and manure test results.								
VIII. 4	Do not over-irrigate.								
VIII. 5	Utilize cover crops in winter crop rotation.								
VIII. 6	Apply during cool weather on still rather than windy days.								
	IX. Other								
IX. 1	Installation of windbreaks or shelterbelts.								
IX. 2	Vehicle road condition management.								
IX. 3	Engine selection and efficiency.								

Note: The BMP numbers correspond to the BMP numbers in Appendix D

This table provides a graphical depiction of which pollutants can be mitigated by implementing each BMP, within each system.
Used in conjunction with Appendix D, it provides a quick reference for selecting BMPs which target specific pollutants, specific systems, or both.

SECTION E - AIR QUALITY BMP SELECTION MATRIX

The matrix presented here provides a tool for selecting best management practices (BMPs) for air quality emission reduction. For detailed descriptions of respective BMPs, refer to the sister-document entitled "Descriptions of Best Management Practices (BMP)". This current document is neither intended to provide detailed information as to how the BMPs should be selected (or implemented), nor is it the only feasible approach on selection (or implementation) of BMPs. It is expected that exact selection or implementation will vary from farm to farm. When applicable, be mindful of tradeoffs, limitations, or both for each BMP.

***Definitions**: NH_3 = ammonia; N_2O = nitrous oxide; H_2S = hydrogen sulfide; CH_4 = methane; VOC = volatile organic compounds; PM = particulate matter.*

The following matrix outlines the process for identifying sources of emissions on your facility and how to choose and implement BMPs to mitigate those emissions. Use this chart and the detailed example that follows it as guides when developing your Air Quality Management Plan.

I. List the sources of emissions on the dairy.

II. For each source, list the expected pollutants in order of importance
(Example: VOCs for silage storage area; PM for dry open feedlots; etc.).

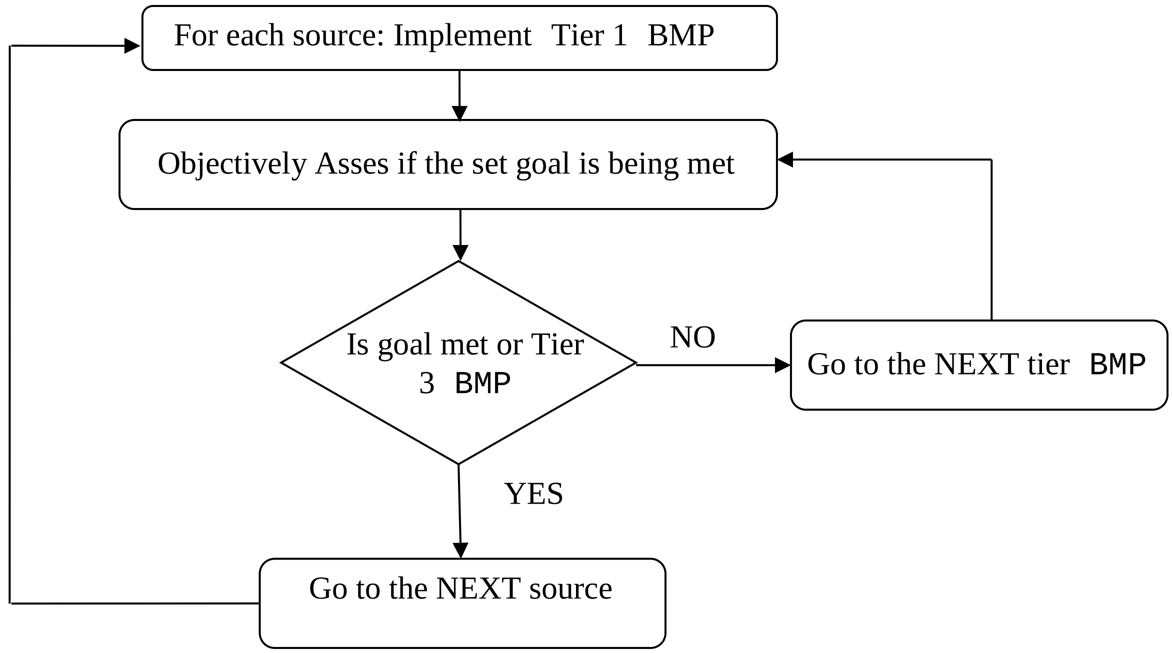
III. List the sources in order of importance with respect to expected or projected emission level
(Example: Open anaerobic lagoons because of their size and open nature, are likely be to more important with respect to air emissions than sand-settling basins; broadcast (big gun) land application is likely to have greater impact on air quality than injection; etc.).

IV. Define the emissions mitigation goal for each of the sources.
The goal for individual sources, for example, could be:

1. To address existing regulations – either local, State, or federal
2. To minimize nuisance lawsuits
3. To champion environmental stewardship
4. To address the most important pollutant in terms of volume or health impact
5. To address other goals

V. Depending on the goal for each source, list three BMPs to address the goal based on a three-tier-system with respect to effectiveness, cost, ease of implementation, compatibility with other BMPs, and in compatibility with your nutrient management plans.

1. Tier 1 being the least expensive and easy to implement
2. Tier 3 being the most advanced and most expensive to implement



List the sources of emission on the dairy. The following sources are the most common areas of air pollutant emission on a dairy operation. Not all areas may apply to your farm. Select the sources that do apply and list the specific factors (i.e., production areas) within that source that can contribute to air pollutant emission (e.g., Manure Storage may have manure holding pit, lagoon, and compost pile as areas within the source that can contribute emissions).

1. Nutrition
2. Feed Management
3. Milk Parlor
4. Housing - Freestall Barns
5. Housing - Drylot Pens
6. Grazing Management
7. Manure Management
8. Land Application
9. Other

For each source, list the expected pollutants in order of importance. For each source, the pollutants of concern have been listed below in general order of importance. Your farm may have a different order. When in doubt, use the order listed below.

1. Nutrition: NH_3, CH_4, H_2S, N_2O.
2. Feed Management: VOC, PM, Odor.
3. Milk Parlor: NH_3, VOC, Odor, H_2S.
4. Housing - Freestall Barns: NH_3, VOC, Odor, CH_4, H_2S.
5. Housing - Drylot Pens: NH_3, PM, Odor, H_2S, CH_4, VOC, N_2O.
6. Grazing Management: NH_3, N_2O.
7. Manure Management – Liquid: NH_3, H_2S, CH_4, Odor, VOC; Solid: NH_3, H_2S, PM, $CH_{4.}$
8. Land Application: NH_3, PM, Odor, N_2O.
9. Other

List the sources in order of importance with respect to expected or projected emission level. For each pollutant of concern, the primary sources that emit that pollutant have been listed below in order of importance. Your farm may have a different order; when in doubt, use the order listed below. For each source, identify and list the specific factors that are contributing to that pollutant (these should have been listed in **I.** above).

1. Ammonia (NH_3)
    a. Nutrition
    b. Housing - Freestall Barns
    c. Housing - Drylot Pens
    d. Milk Parlor
    e. Land Application
    f. Manure Management
    g. Grazing Management
    h. Feed Management
2. Methane (CH_4)
    a. Manure Management
    b. Nutrition
3. Hydrogen Sulfide (H_2S)
    a. Manure Management
    b. Housing - Drylot Pens
    c. Nutrition
4. Volatile Organic Compounds (VOC)
    a. Feed Management
    b. Housing - Freestall Barns
    c. Housing - Drylot Pens
    d. Milk Parlor
    e. Manure Management
5. Particulate Matter (PM)
    a. Housing - Drylot Pens
    b. Land Application
    c. Feed Processing
    d. Manure Management
6. Nitrous Oxide (N_2O)
    a. Nutrition
    b. Housing - Drylot Pens
    c. Land Application
    d. Grazing Management
7. Odor
    a. Land Application

b. Manure Management
c. Housing - Drylot Pens
d. Housing - Freestall Barns
e. Milk Parlor
f. Feed Management
g. Nutrition

Define the emissions mitigation goal for each of the sources. Emission mitigation goals are going to be specific to your farm, objectives, and source emissions. List goals for each source.

The goal for individual sources, for example, could be:

- To address existing regulations – either local or federal
- To minimize nuisance lawsuits
- To champion environmental stewardship
- To address the most important pollutant in terms of volume or health impact
- To address other goals

Depending on the goal for each source, list three BMPs to address the goal based on a three-tier-system with respect to effectiveness, cost, ease of implementation, compatibility with other BMPs, and in compatibility with your nutrient management plans. Tier 1 being the least expensive and easiest to implement. Tier 3 being the most advanced and most expensive to implement. Tier 1, 2, and 3 level BMPs have been listed for each source on a dairy farm. This list correlates to the BMPs listed in the "Descriptions of Best Management Practices (BMP)" document. This list is not exhaustive and tier level BMPs may vary for your individual farm. Refer to Table 1 (at the end of this Appendix) for a selection matrix guide for choosing tier level BMPs for each source.

1. Nutrition
    a. *Tier 1* - Properly Manage Level of Dietary Protein (%CP) in Diet to Match, Rather Than Exceed, an Animal's Needs (NH_3, N_2O, Odor); Properly Manage and Minimize Overfeeding Sulfur in the Diet (H_2S, Odor).
    b. *Tier 2* - Practice Group and/or Stage of Lactation Feeding (NH_3).
    c. *Tier 3* - Increase the Level or Quality of Starch in the Diet (CH_4); Utilize feed additives to maximize efficiency (NH_3, H_2S, CH_4).

2. Feed Management
    a. *Tier 1* - Regularly Remove Spilled and Unused Feed from Feeding Area (VOC, Odor, and PM); Manage or Minimize the Mixing of Feed During Windy Times (PM).
    b. *Tier 2* - Properly Cover and Manage Ensiled Feedstuffs (VOC, Odor).
    c. *Tier 3* - Store Feed in a Sheltered Storage Structure (VOC, Odor, PM).

3. Milk Parlor
    a. *Tier 1* - Use Recycled Parlor (Clean) Water Used for Flushing/Cleaning Parlor and Holding Area (NH_3, Odor); Ensure Proper Ventilation (NH_3, Odor, and PM).
    b. *Tier 2* - Remove Manure from Parlor and Holding Area Frequently (NH_3, VOC, Odor).
    c. *Tier 3* - Treat Recycled Water Used for Flushing/Cleaning Holding Area (NH_3, Odor);

4. Housing - Freestall Barns
    a. *Tier 1* - Remove Manure from Barns Frequently (NH_3, VOC, Odor); Ensure Proper Ventilation of Freestall Barns (NH_3, Odor, and PM).
    b. *Tier 2* - Bedding Selection and Management (NH_3, H_2S, Odor); Manure Removal Technology and Efficiency (NH_3, VOC, Odor).
    c. *Tier 3* - Treat Recycled Lagoon Water Used for Flushing (NH_3, Odor); Alleyway Floor Texture and Type (NH_3, VOC, Odor); Manure Removal Technology and Efficiency (NH_3, VOC, Odor).

5. Housing - Drylot Pens
    a. *Tier 1* - Spread (Harrow) Manure Frequently (NH_3, PM); Surface Moisture Content Management (NH_3, N_2O, VOC, Odor, CH_4, H_2S, Odor, PM).
    b. *Tier 2* - Remove Manure Frequently (NH_3, PM); Incorporate Wood Chips in Surface Layer (NH_3, PM, Odor); Use Straw Bedding in Drylot Pens (NH_3, PM, Odor); Knockdown and Remove Fence Line Manure (VOC, Odor).
    c. *Tier 3* - Urease Inhibitors (NH_3, N_2O); Provide Shade for Cattle (NH_3, PM); Siting of Water Trough within Pen (NH_3, PM).

6. Grazing Management
    a. *Tier 1* - Stock Appropriate Number of Animals (NH_3, N_2O); Use Rotational Grazing (NH_3, N_2O).
    b. *Tier 2* - Move Water and Feeding Areas Frequently (NH_3, N_2O).
    c. *Tier 3* - Irrigate Immediately after Grazing (NH_3).

7. Manure Management
    a. *Tier 1* - Manure Solids Separation (NH_3, VOC, Odor, H_2S, CH_4); Properly Manage the Composting of Solid Manure (H_2S, Odor, PM, CH_4); Properly Manage Stockpiled Manure (H_2S, Odor, PM).
    b. *Tier 2* - Lagoon or Storage Covers (NH_3, H_2S, VOC, Odor, CH_4); Scrub Exhaust of Enclosed Waste Containers (CH_4, Odor, H2S).
    c. *Tier 3* - Installation and Proper Operation of an Anaerobic Digester (CH_4); Surface Aeration of Lagoons (NH3, H2S, VOCs); Reduce the pH of Lagoons and Manure Piles (NH_3, CH_4); Encourage Purple Sulfur Bacterial Formation in Anaerobic Lagoons (H_2S, Odor).

8. Land Application – Manure and/or Chemical Fertilizer
    a. *Tier 1* - Apply Nutrients According to Agronomic Recommendations Based on Soil and Manure Test Results (NH_3, N_2O); Inject or Incorporate Fertilizer into Soil within 24 Hours of Application (NH_3, Odor); Do Not Over-irrigate (NH_3, N_2O); Apply During Cool Weather and on Still Rather than Windy Days (NH_3, Odor, PM).
    b. *Tier 2* - Utilize Cover Crops (NH_3, N_2O, PM); Apply N Fertilizer below No-Till Residue (NH_3, PM).
    c. *Tier 3* - Installation of Windbreaks or Shelterbelts (Odor, PM).

9. Other
   a. *Tier 1* - Installation of Windbreaks or Shelterbelts (NH_3, Odor, PM).
   b. *Tier 2* - Vehicle Road Condition and Management (PM).
   c. *Tier 3* - Engine Selection and Efficiency (NOx).

Table 1. BMP selection matrix based on source and tier level mitigation

Sources of emission on a dairy	Expected pollutants for each source in order of importance	Suggested BMPs for emissions reduction Tier 1	Suggested BMPs for emissions reduction Tier 2	Suggested BMPs for emissions reduction Tier 3
Nutrition	NH_3, CH_4, H_2S, N_2O	Properly Manage Level of Dietary Protein (%CP) in Diet to Match, Rather Than Exceed, an Animal's Needs (NH_3, N_2O, Odor) Properly Manage and Minimize Overfeeding Sulfur in the Diet (H_2S, Odor)	Practice Group and/or Stage of Lactation Feeding (NH_3)	Increase the Level or Quality of Starch in the Diet (CH_4) Utilize feed additives to maximize efficiency (NH_3, H_2S, CH_4)
Feed Management	VOC, PM, Odor	Regularly remove Spilled and Unused Feed from Feeding Area (VOC, Odor, PM) Manage or Minimize the Mixing of Feed During Windy Times (PM)	Properly Cover and Manage Ensiled Feedstuffs (VOC, Odor)	Store Feed in a Sheltered Storage Structure (VOC, Odor, PM)
Milk Parlor	NH_3, VOC, Odor, H_2S	Use Recycled Parlor (Clean) Water Used for Flushing/Cleaning Parlor and Holding Area (NH_3, Odor); Ensure Proper Ventilation (NH_3, Odor, and PM)	Remove Manure from Parlor and Holding Area Frequently (NH_3, VOC, Odor)	Treat Recycled Water Used for Flushing/Cleaning Holding Area (NH_3, Odor)
Housing – Freestall Barns	NH_3, VOC, Odor, CH_4, H_2S	Remove Manure from Barns Frequently (NH_3, VOC, Odor); Ensure Proper Ventilation of Freestall barns (NH_3, Odor, and PM)	Bedding Selection and Management (NH_3, H_2S, Odor) Manure Removal Technology and Efficiency (NH_3, VOC, Odor)	Treat Recycled Lagoon Water Used for Flushing (NH_3, Odor) Alleyway Floor Texture and Type (NH_3, VOC, Odor) Manure Removal Technology and Efficiency (NH_3, VOC, Odor)
Housing – Drylot Pens	NH_3, PM, Odor, H_2S, CH_4, VOC, N_2O	Spread (Harrow) Manure Frequently (NH_3, PM) Surface Moisture Content Management (NH_3, N_2O, VOC, Odor, CH_4, H_2S, Odor, PM)	Remove Manure Frequently (NH_3, PM) Incorporate Wood Chips in Surface Layer (NH_3, PM, Odor) Use Straw Bedding in Drylot Pens (NH_3, PM, Odor) Knockdown and Remove Fence Line Manure (VOC, Odor)	Urease Inhibitors (NH_3, N_2O) Provide Shade for Cattle (NH_3, PM) Sitting of Water Trough within Pen (NH_3, PM)

APPENDIX A: BMP Selection Matrix

Sources of emission on a dairy	Expected pollutants for each source in order of importance	Suggested BMPs for emissions reduction <u>Tier 1</u>	Suggested BMPs for emissions reduction <u>Tier 2</u>	Suggested BMPs for emissions reduction <u>Tier 3</u>
Grazing Management	**NH_3, N_2O**	Stock Appropriate Number of Animals (NH_3, N_2O) Use Rotational Grazing (NH_3, N_2O)	Move Water and Feeding Areas Frequently (NH_3, N_2O)	Irrigate Immediately after Grazing (NH_3)
Manure Storage	**Liquid: NH_3, H_2S, CH_4, Odor, VOC** **Solid: NH_3, H_2S, PM, CH_4**	Manure Solids Separation (NH_3, VOC, Odor, H_2S, CH_4) Properly Manage the Composting of Solid Manure (H_2S, Odor, PM, CH_4) Properly Manage Stockpiled Manure (H_2S, Odor, PM)	Lagoon or Storage Covers (NH_3, H_2S, VOC, Odor, CH_4) Scrub Exhaust of Enclosed Waste Containers (CH_4, Odor, H2S)	Installation of an Anaerobic Digester (CH_4) Surface Aeration of Lagoons (NH3, H2S, VOC) Reduce the pH of Manure (NH_3, CH_4) Encourage Purple Sulfur Bacterial Formation in Lagoons (H_2S, Odor)
Land Application	**NH_3, PM, Odor, N_2O**	Apply Nutrients According to Agronomic Recommendations Based on Soil and Manure Test Results (NH_4, N_2O) Inject or Incorporate Fertilizer into Soil within 24 Hours of Application (NH_4, Odor) Do Not Over-irrigate (NH_4, N_2O) Apply During Cool Weather and on Still Rather than Windy Days (NH_4, Odor, PM)	Utilize Cover Crops (NH_3, N_2O, PM) Apply N Fertilizer below No-Till Residue (NH_3, PM)	Installation of Windbreaks or Shelterbelts (Odor, PM)

Facility: 0 **Date:** 0 **(Version 8; 10/28/11)**

AQ BMP SCORE SHEET

Description of Score Sheet - Scores entered in the gray boxes range from 0 to 5 for each pollutant (5 being optimum implementation). Scores for each BMP are based on the visual evaluation and/or documention of practices assessed during inspections. For descriptions of BMPs listed, refer to the document "Descriptions of Best Management Practices (BMPs)" (YRCAA, 2011). **How to use this table** - 1) Review your overall score. A score above 80% is good, between 70-80% is adequate, and below 70% is poor and should be evaluated for improvements. 2) Review the score (%) for each category (i.e., Nutrition, Housing, etc.) and each pollutant (i.e., Ammonia, Nitrous Oxide, etc.). The values listed in the "*Category Level of BMP Implementation (%)*" row gives the relative effectiveness of the BMPs for that specific category as implemented at your facility at the time of inspection. A value below 70% should be evaluated and you should consider making improvements in that category. 3) Look at the individual score given to each BMP. Use these to identify the areas where improvements can be made.

			Good		Adequate	Poor - Needs improvement	
Overall Score (%) & Grade:	**#DIV/0!**	**#DIV/0!**	100-90%	90-80%	80-70%	70-60%	<60%
			A	**B**	**C**	**D**	**E**

BMP #	Best Management Practice	Ammonia (NH_3)	Nitrous Oxide (N_2O)	Hydrogen Sulfide (H_2S)	Volatile Organic Compounds (VOCs)	Odor	Particulate Matter (PM)	Methane (CH4)	Oxides of Nitrogen (NOX)
	I. Nutrition								
I. 1	Properly manage level of dietary protein (~16%CP)	0	0			0			
I. 2	Increased level or quality of starch in diet (23-26%)				0			0	
I. 3	Manage and minimize overfeeding of sulfur-containing feed			0		0			
I. 4	Practice group and/or stage of lactation feeding	0	0	0		0		0	
	Category Level of BMP Implementation (%)	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***NA***	***#DIV/0!***	***NA***
	II. Feed Management								
II. 1	Properly manage ensiled feedstuffs	0			0	0	0		
II. 2	Store feed in a sheltered storage structure				0	0	0		
II. 3	Regularly remove spilled and unused feed from feeding area	0			0	0	0		
II. 4	Manage or minimize feed mixing during windy times						0		
	Category Level of BMP Implementation (%)	***#DIV/0!***	***NA***	***NA***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***NA***	***NA***
	III. Milk Parlor								
III. 1	Ensure proper ventilation	0							
III. 2/3	Use recycled (clean) or treated water for flushing parlor	0		0	0	0			
III. 2/3	Use recycled (clean) or treated water for cleaning holding pen	0		0	0	0			
III. 4	Remove manure from holding area frequently	0			0	0			
	Category Level of BMP Implementation (%)	***#DIV/0!***	***NA***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***NA***	***NA***	***NA***
	IV. Housing - Freestall Barns								
IV. 1	Ensure proper ventilation	0							
IV. 2	Bedding selection and management	0				0	0		

IV. 3	Treat recycled lagoon water used for flushing	0		0	0	0			
IV. 4	Remove manure from barns frequently	0			0	0			
IV. 5	Manure removal technology and efficiency	0		0	0	0			
IV. 6	Alleyway floor texture and type	0				0			
	Category Level of BMP Implementation (%)	***#DIV/0!***	***NA***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***NA***	***NA***
	V. Housing - Drylot Pens								
V. 1	Provide shade for cattle	0				0	0		
V. 2	Sitting of water trough within pen	0		0		0	0		
V. 3 (a)	Remove manure frequently	0			0	0	0	0	
V. 3 (b)	Spread (harrow) manure frequently	0			0	0	0	0	
V. 4	Use straw bedding in pen (seasonal)	0				0	0	0	
V. 5	Incorporate wood chips into surface layer	0				0	0	0	
V. 6	Utilize urease inhibitors	0	0			0			
V. 7	Surface moisture content management	0	0	0	0	0	0	0	
V. 8	Knock down and remove fence line manure	0		0		0			
	Category Level of BMP Implementation (%)	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***NA***
	VI. Grazing Management								
VI. 1	Stock appropriate number of animals	0	0			0	0		
VI. 2	Use rotational grazing	0	0			0			
VI. 3	Move water and feeding areas frequently	0	0			0			
VI. 4	Irrigate immediately after grazing	0	0		0	0			
	Category Level of BMP Implementation (%)	***#DIV/0!***	***#DIV/0!***	***NA***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***NA***	***NA***
	VII. Manure Management								
VII. 1	Manure solids - mechanical separation	0		0		0			
VII. 1	Manure solids - settling basin	0		0		0		0	
VII. 2	Lagoon or storage covers (natural or composite)	0		0	0	0		0	
VII. 3	Scrub exhaust of enclosed waste containers	0		0	0	0		0	
VII. 4	Proper maintenance of installed methane digester				0	0		0	
VII. 5	Surface aeration of lagoons	0		0	0	0			
VII. 6	Reduce the pH of lagoons and manure piles below 6	0		0		0			
VII. 7	Purple sulfur bacterial formation in lagoons	0		0		0			
VII. 8	Properly manage the composting of manure			0		0	0		
VII. 9	Properly manage stockpiled manure			0		0	0	0	
	Category Level of BMP Implementation (%)	***#DIV/0!***	***NA***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***NA***

VIII. Land Application - Manure or Chemical Fertilizer									
VIII. 1	Apply N fertilizer below no-till residue	0	0	0		0	0		
VIII. 2(a)	Corn - Inject fertilizer/manure into soil at application	0	0	0	0	0	0	0	
VIII. 2(b)	Forage - Manure/fertilizer application method and/or incorporation practice	0	0	0	0	0	0	0	
VIII. 3	Apply nutrients according to agronomic recommendations based on soil and manure test results	0	0			0			
VIII. 4	Do not over-irrigate	0	0						
VIII. 5	Utilize cover crops in winter crop rotation	0	0				0		
VIII. 6	Apply during cool weather and on still rather than windy days	0		0	0	0	0		
	Category Level of BMP Implementation (%)	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***#DIV/0!***	***NA***
IX. Other									
IX. 1	Installation of windbreaks or shelterbelts	0		0		0	0		
IX. 2	Vehicle road condition management						0		
IX. 3	Engine selection and efficiency								0
	Category Level of BMP Implementation (%)	***#DIV/0!***	***NA***	***#DIV/0!***	***NA***	***#DIV/0!***	***#DIV/0!***	***NA***	***#DIV/0!***
	Overall Level of BMP Effectivity by Pollutant (%)	-	-	-	-	-	-	-	-