

AIR QUALITY MANAGEMENT POLICY
AND
BEST MANAGEMENT PRACTICES
FOR
DAIRY OPERATIONS

Effective July 1, 2013



“CLEAN AIR IS EVERYONE’S RESPONSIBILITY”

Prepared by:

A handwritten signature in blue ink, appearing to read "Gary W. Pruitt".

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BACKGROUND

YRCAA began working with local beef cattle feedlots in 1993 to minimize dust emissions. As a result, a policy was adopted and fugitive dust plans were developed and implemented. Since then, the plans, and their effectiveness, have improved each year. In 2001, YRCAA worked with heifer replacement and calving operations to develop a fugitive dust control policy for dairy heifer feeding operations. Because dairy operations generate fugitive emissions, YRCAA has developed this policy using the same approach it has taken for cattle feedlots, heifer replacement, and calving operations. Implementation of this policy will constitute “reasonable precautions” to minimize air emissions from dairy operations.

This policy only applies to dairies where cows are confined for feeding and milking and where the potential for significant emissions of air pollutants exist. This policy specifically acknowledges that air emissions from dairy operations cannot be eliminated and that all management practices must be economically and technically feasible. As part of the development of the final policy, YRCAA worked with dairies during a pilot project, which implemented the policy through developing and implementing flexible, site-specific Air Quality Management Plans.

Pilot Project

The pilot project was conducted as contemplated in RCW 34.05.313, which states in part: “During the development of a rule or after its adoption, an agency may develop methods for measuring or testing the feasibility of complying with or administering the rule and for identifying simple, efficient, and economical alternatives for achieving the goal of the rule. A pilot project shall include public notice, participation by volunteers who are or will be subject to the rule, a high level of involvement from agency management, reasonable completion dates, and a process by which one or more parties may withdraw from the process or the process may be terminated.”

On February 10, 2011 the YRCAA Board of Directors approved the policy as a pilot research project aimed at gathering information, testing the feasibility of implementing the policy, and measuring the effectiveness of the policy. Packets were sent to every Yakima County dairy with information about the pilot project and an invitation to attend an informational workshop held on March 15, 2011. During the workshop, YRCAA staff explained the policy and presented an example of an Air Quality Management Plan (AQMP) to be submitted by dairy operations.

YRCAA recruited and worked with eight producers at fifteen dairy facilities who voluntarily participated in the pilot project, implementing the policy over ten months. The AQMP was further developed and implemented at each participating dairy. YRCAA staff used the AQMPs that were submitted as a starting point for evaluating BMPs utilized to prevent or reduce air emissions. Two site visits were conducted at each dairy. Inspection reports and score sheets, which served as a means to measure the effectiveness of BMPs utilized, were provided to each participating dairy following the site visits. Technical assistance documents were also developed during the project to aid producers in selecting which BMPs to implement.

The pilot study targeted eight air pollutants for each system within a dairy operation. The pollutants were: Ammonia (NH₃); Nitrous Oxide (N₂O); Hydrogen Sulfide (H₂S); Volatile Organic Compounds (VOC); Odor; Particulate Matter (PM); Methane (CH₄) and Oxides of Nitrogen (NO_x). The systems were: Nutrition; Feed Management; Housing - Freestall Barns, Housing - Drylot Pens; Grazing;

Manure Management; Land Application (Fertilizer and Manure); and Other (those newly identified during the pilot study).

The project work was completed in December, 2011. A final report of the project was prepared and made available to the Board of Directors and the public in January 2012. YRCAA and the project team conducted an effectiveness assessment of the policy, determined modifications necessary, made minor, non-substantive changes and included compliance assistance documents developed during the project.

Trial Implementation

In March of 2012 the Board of Directors approved the policy for a one-year trial implementation period to give opportunity to more dairies to comply with the policy. In 2012 six additional dairy producers submitted Air Quality Management Plans and Agency staff conducted full compliance evaluations at nine facilities operated by the six producers. Findings of the evaluations were similar in all aspects to the findings of the pilot project evaluations. A high level of BMP utilization across all systems was found.

The trial implementation work was completed in December, 2012. A final report of the trial period was prepared and made available to the Board of Directors and the public in March 2013. YRCAA conducted an effectiveness assessment of the policy, determined modifications necessary, and made minor changes to the text for clarification.

Reasons for the Policy

There are many dairy operations in Yakima County which YRCAA has recognized as significant air pollution sources. YRCAA's primary air quality concern regarding dairy operations is the generation of fugitive air emissions from feed, urine, manure and other sources.

In recent years, most dairy operators have instituted various practices to control fugitive air emissions. Such practices are also good animal husbandry and good neighbor practices. Air quality management practices can require a significant commitment of time and resources by owners and operators.

Since air emissions from dairy operations are considered to be fugitive emissions (cannot feasibly be collected and passed through a control device), mitigation must be accomplished by prevention rather than control. This policy is intended to use existing regulations and clarify what constitutes "reasonable precautions" to minimize air emissions from dairy operations. The primary means to accomplish this is to identify pollutant-specific and system-specific best management practices (BMPs) for minimizing emissions and to cause these practices to be implemented according to flexible, site-specific Air Quality Management Plans.

This policy applies only to dairy operations where cows are confined for feeding and milking and the potential for significant emissions of air pollutants exists. 100% of the air emissions from dairy operations cannot be eliminated. This policy and all BMPs contained in this policy have been tested, proven to be effective in mitigating air emissions, and found to be economically and technically feasible.

Jurisdiction

This policy is not intended for any dairy operation located outside the jurisdiction of YRCAA. YRCAA jurisdiction is all lands inside Yakima County, excluding those lands within the exterior boundaries of the Yakama Indian Reservation.

POLICY

I. What is the Purpose of the Policy?

The purpose of this policy is to provide guidance and establish requirements for effective prevention and control of air emissions from dairy operations. Objectives to achieve the purpose are:

1. To achieve sufficient prevention of emissions from dairy operations to assure compliance with applicable laws and regulations;
2. To achieve prevention of emissions by describing a menu of system and pollutant-specific best management practices (BMPs) for dairy operations that will be implemented through the use of flexible, site-specific Air Quality Management Plans;
3. To clarify what constitutes "reasonable precautions to prevent" emissions as required by WAC 173-400-040(3); and
4. To inform owners and operators about effective measures for the prevention of air emissions and provide a means by which dairy operations can demonstrate that they are taking reasonable precautions to protect the air quality in Yakima County.

II. Who Must Comply with the Policy?

All dairy operations where animals are confined for feeding and milking and the potential for significant emissions of air pollutants exists, hereinafter referred to as "dairy operation" or "operation." All dairies will be considered as potentially significant sources of air pollution for purposes of gathering information and determining source classification.

III. How Does the Policy Work?

1. A dairy operation must prepare, or cause to be prepared, an annual Air Quality Management Plan (AQMP), submit it to YRCAA for approval, and pay a registration fee. Fees will be approved annually by the Agency Board of Directors;
2. An AQMP must identify BMPs and operational procedures to be used to reduce air emissions from each system of operation, such as nutrition, feed management, milking, housing, grazing, manure management, and manure and fertilizer application;
3. YRCAA and the dairy operators are expected to work together in good faith toward development of an AQMP which is acceptable to both the operation and YRCAA;
4. A dairy operation must fully implement an approved AQMP according to the criteria and/or implementation schedules outlined in the plan;
5. A dairy operation may make modifications to an approved AQMP as long as the effectiveness of the plan is not diminished, as determined by YRCAA; and

6. YRCAA may initiate good faith discussion with a dairy operation to modify any AQMP which is determined by YRCAA not sufficiently effective in minimizing fugitive emissions.

Should a dispute arise as to compliance with this policy, YRCAA may request the Agency Agricultural Task Force to review the dispute and provide guidance.

IV. Where and When Must an AQMP be Submitted?

1. Dairy operations must submit initial AQMPs to the YRCAA within 90 days of the effective date of this policy;
2. Dairy operations must submit AQMP updates annually and pay a registration fee, no later than February 15th; and
3. New or expanding dairy operations must file notice with YRCAA, which includes an Air Quality Management Plan for the new facility or expansion and pay a registration fee. This plan must be approved by YRCAA prior to operating the new facility or expansion.

V. What Must Be Contained in an AQMP?

1. A description of the operation, including:
 - a. A map, aerial photo or drawing of the operation which adequately represents the layout of the operation and provides enough detail to allow YRCAA to adequately review the feasibility and appropriateness of various BMPs for the facility;
 - b. A description of the operational capacity of the operation, including the maximum number of cattle which could be confined;
 - c. A description of the lands where nutrient byproducts from the operation are applied and the application method(s) used;
 - d. Any site-specific features or characteristics which prevent or limit the use of any BMP; and
 - e. Any site-specific features or characteristics which require BMP flexibility or adaptation to meet the needs of the operation.
2. Pollutants and pollutant groups to be addressed under the plan.

Of the following eight pollutants and pollutant groups, those targeted for emission reduction must be identified in the AQMP:

- a. Particulate Matter;
- b. Ammonia (NH₃);
- c. Volatile Organic Compounds (VOCs);

- d. Oxides of Nitrogen (NO_x);
 - e. Hydrogen Sulfide (H₂S);
 - f. Odor;
 - g. Methane (CH₄); and
 - h. Nitrous Oxide (N₂O).
3. A description of BMPs to be used under the AQMP to reduce emissions of the targeted pollutants.
- a. The description must include which BMPs will be applied for emission reductions from the following physical areas:
 - i. milking parlors;
 - ii. sorting alleys;
 - iii. feed alleys;
 - iv. dry lots and free stalls;
 - v. lands where nutrients are applied;
 - vi. storage lagoons;
 - vii. compost areas;
 - viii. feed storage areas;
 - ix. unpaved roadways; and
 - x. any other area or process where emissions may occur.
 - b. The description must include which BMPs will be applied for emission reductions from the following systems:
 - i. nutrition;
 - ii. feed management;
 - iii. housing;
 - iv. grazing management;
 - v. manure management; and
 - vi. land application (both fertilizer and manure application)
 - c. The descriptions must also include:
 - i. a description of the equipment and materials to be used for implementing any BMP, including a description of the normal operational capacity or application rate of any equipment;
 - ii. an operational plan for implementing each BMP;

The operational plan must describe the criteria the operation will use to determine when and for which area of operation to implement each BMP and the criteria for selecting specific BMPs. It is recognized that operations and conditions are variable and that the same BMP may be implemented differently by individual operations. This variability makes the description of how BMPs will be implemented an especially important component of an operation's AQMP.

- iii. a description of which pollutant or pollutant group will be reduced as a result of implementing each BMP;
 - iv. a method of monitoring and recording the implementation of each BMP; and
 - v. the person responsible at the facility for the operation's AQMP and its implementation.
4. A schedule for future BMP implementation, if applicable.

If an operation intends to implement additional BMPs in the future, target dates for implementation of each BMP should be included in the AQMP.

VI. How are AQMPs Developed and Approved?

1. An operation is responsible for preparing an AQMP and submitting the plan or update to YRCAA for approval on or before February 15th. Technical assistance may be used in developing the plan. Assistance will be provided by YRCAA. However, an operation may choose to employ a technical service provider;
2. Within 30 days, YRCAA staff must review the plan and notify the operation of plan approval in writing or request additional information or propose alternative practices to approve the plan. Failure of YRCAA to notify the operation or request additional information shall not constitute approval;
3. Operations must respond to agency requests for information or modification of the plan within 30 days;
4. The approval process may include good faith discussion, evaluation, collection of information, and other efforts to resolve differences of opinion about the plan, so long as reasonable progress toward the development and approval of the operation's AQMP is being made; and
5. If agreement on an operation's AQMP cannot be reached after thorough good faith evaluation of alternatives and consideration of plan effectiveness, costs, and other pertinent matters, YRCAA may initiate compliance action, such as a notice of violation, assurance of discontinuance or corrective action order, only if a violation of regulation (not the policy) exists.

The purpose of good faith negotiation is to share information and resolve differences of opinion regarding an operation's AQMP. Both the operation and YRCAA need to be able to exchange information freely and in good faith. Information obtained by YRCAA in the course of negotiation is not obtained for the purpose of any future enforcement activity.

VII. How and What Changes Can be Made to an Approved AQMP?

An operation may make modifications to an approved AQMP as long as the modification(s) do not pose a potential to diminish the effectiveness of the plan. Substantive modifications to a plan must be documented, YRCAA must be notified of the changes, and YRCAA must approve the changes. Substantive modifications include but are not limited to:

1. significant changes in operational procedures;
2. changes in BMP selection, including discontinuance of any BMP; and
3. changes in criteria used to determine BMP implementation (as stated in the BMP operational plan).

Non substantive changes are changes which do not have the potential to diminish the effectiveness of an approved plan. Such changes may be made without notification to YRCAA, but must be included in the next annual AQMP update.

VIII. How Will the YRCAA Determine When an AQMP is Adequate?

In considering whether an AQMP is adequate to achieve the purpose of this policy, YRCAA may consider:

1. whether the plan utilizes BMPs identified in Appendix B of this policy;
2. the ability of the proposed BMPs to maintain conditions which adequately minimize emissions;
3. other measures in the plan which may be effective in minimizing emissions, but which are not recognized BMPs;
4. the adequacy of the operational plan, including the criteria used to begin, end and apply the proposed BMPs;
5. evidence that proposed measures have been effective in similar conditions; and
6. whether the plan addresses all requirements of Section V of this policy.

IX. How Will Compliance and Effectiveness of the AQMP be Determined?

1. Compliance - After an AQMP has been approved, YRCAA will conduct a full compliance evaluation, including a site visit, to determine if the BMPs and operational plans are in effect. Frequency of subsequent site visits will be determined as provided

in Subsection 5.5, Compliance Monitoring Strategy, YRCAA Administrative Code, Part B. Additional site visits may be conducted if requested by an operation. If evaluation determines that the AQMP is not fully implemented or reasonable precautions are not being taken to prevent emissions, YRCAA may initiate compliance action such as a notice of violation, assurance of discontinuance or corrective action order, only if a violation of regulation (not the policy) exists.

2. Effectiveness - After the plan is in place, results of the full compliance evaluation will be used to evaluate the effectiveness of the plan in reducing emissions. If results of the full compliance evaluation indicate that the plan is not effective in reducing emissions, YRCAA will request information from the operation or propose additional or alternative BMPs. As with the development of the initial plan, YRCAA and the operation will work together in good faith to revise the AQMP to increase its effectiveness in reducing emissions.

X. When and How Will This Policy Be Evaluated?

1. This policy will be evaluated as needed and no less frequently than every two years;
2. The evaluation of the policy will be conducted jointly by YRCAA staff and the Agricultural Task Force and will be based on its effectiveness at reducing air emissions and reasonableness of implementation; and
3. The YRCAA Board of Directors will approve any changes to the policy.

APPENDIX A

STATUTORY AND REGULATORY REFERENCE

This Section is intended to provide the regulatory framework for Dairy operations. Other statutes or regulation may apply, but the references listed below have the most significant bearing on the industry.

A. STATUTORY AUTHORITY

1. The Washington Clean Air Act (the Act), RCW 70.94.011 states that it is public policy to preserve, protect and enhance the air quality for current and future generations and the intent is to protect human health and safety, including the most sensitive members of the population.
2. Dairy operations are sources of air pollution per RCW 70.94.030 and subject to the provisions of the Act except as exempted in Section 640.
3. RCW 70.94.141 empowers Local Authorities to:
 - a. Adopt and amend its rules;
 - b. Issue orders and take administrative actions to enforce the Act;
 - c. Require access to information specific to the emission and control of air pollutants;
 - d. Secure necessary scientific and technical services;
 - e. Prepare and develop comprehensive plans to prevent and control air pollution;
 - f. Encourage voluntary cooperation to achieve the purposes of the Act;
 - g. Encourage and conduct studies, investigation and research relating to air pollution causes, effects, prevention, abatement and control; and
 - h. Advise, consult and cooperate with agencies, departments, educational institutions, political subdivisions, industries, other states, inter-local agencies, the United States government, and with interested persons or groups.
4. RCW 70.94.151 authorizes local authorities to:
 - a. Classify air pollution sources; and
 - b. Require registration, reporting and payment of registration fees.
5. RCW 70.94.152 authorizes local authorities to require submittal of application to construct or modify an air pollution source and approve such application prior to construction or modification.
6. RCW 70.94.154 authorizes and describes a Reasonably Available Control Technology (RACT, as defined in 70.94.030(20)) determination.
7. RCW 70.94.380 mandates Local Authorities to have requirements for the control of air emissions that are no less stringent than those of the state.

B. STATE REGULATIONS

Dairy operations are sources of air pollution and are subject to the provisions of WAC 173-400 and WAC 173-460, which require controls to minimize emissions.

C. LOCAL REGULATIONS

YRCAA Regulation 1, Section 1.03 declares agency policy to implement the Washington Clean Air Act by:

1. Protecting human health and safety;
2. Preventing injury to plant and animal life and property;
3. Fostering comfort and convenience;
4. Promoting economic and social development;

5. Facilitating the enjoyment of natural attractions;
6. Preventing or minimizing the transfer of air pollution to other resources;
7. Ensuring equity and consistency with the Federal Clean Air Act (FCAA) and the Washington Clean Air Act (WCAA);
8. Educating and informing the citizens of Yakima County on air quality matters;
9. Maintaining accurate and current policies, regulations, and rules;
10. Performing administrative actions in a timely and effective manner;
11. Cooperating with the local governments, the Yakama Nation, organizations or citizens on air quality matters;
12. Developing strategies to avoid, reduce or prevent air pollution through innovative solutions, early planning and integration of air pollution control in the work of other agencies and businesses;
13. Preparing guidelines which interpret, implement and enforce regulations; and
14. Providing reasonable business and technical assistance to the community.

Section 1.04 declares that all activities, persons and businesses are subject to Regulation I, unless granted a variance or specifically exempted in the regulation.

Section 1.05 provides for the appointment of an advisory council to advise and consult with the Board.

Section 2.03 adopts and incorporates certain state and federal codes and regulations that may be applicable to dairy operations.

Section 3.00 requires operations and maintenance plans to prevent avoidable emissions.

Section 4.01 requires any source with a significant emission, as defined in Table 4.01-2 to register the source annually with the agency and pay the appropriate registration fee.

Section 5.02 provides for civil penalties to be assessed to any person who violates any of the provisions of YRCAA Regulation 1, the WCAA, any permit, order or condition of approval issued by the agency up to \$12,000 per day per violation.

APPENDIX B – POLLUTANT-SPECIFIC BEST MANAGEMENT PRACTICES

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

General Principles

- The principle mechanism by which most BMPs operate is to maintain conditions which prevent emissions of pollutants addressed by the use of the BMPs; and
- Nothing in this policy 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 policy.

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 (NH₃)

NH₃ 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 NH₃ 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 NH₃ is about 24 hours, after which time the NH₃ 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 NH₃ BMP to reduce NH₃ emissions and thus, its negative effects. Tradeoffs in NH₃ 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 NH₃ is to target the source itself. In this case, the source is nitrogen (N) input into the dairy systems. BMPs which reduce NH₃ 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 (N₂O)

Emissions of N₂O result from two different biological processes. There is a very small amount of N₂O produced during nitrification (the biological aerobic process of converting ammonium to nitrate) though this source is relatively insignificant. The primary pathway of N₂O formation is the anaerobic process of denitrification (the conversion of nitrate to N₂ or nitrogen gas), in which N₂O is an obligatory intermediate product. Therefore, many of the emission reduction strategies are associated with minimizing these anaerobic conditions. BMPs which reduce N₂O 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 (H₂S)

H₂S is produced in anaerobic environments from the microbial reduction of sulfate or the decomposition of sulfur-containing organic matter in manure. Most atmospheric H₂S is oxidized to sulfur dioxide (SO₂), which is then either dry deposited or oxidized to aerosol sulfate and removed primarily by wet deposition. The residence time of H₂S and its reaction products is of the order of days. BMPs which reduce H₂S 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, C₄ to C₇ aldehydes, trimethylamine, C₄ amines, quinoline, dimethylpyrazine, and C₃ to C₆ organic acids, along with lesser amounts of aromatic compounds and C₄ to C₇ 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 NH₃, VOCs, and H₂S. 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 policy 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 follow.

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 (NO₂) are rapidly interconverted in the atmosphere and the sum of all oxidized nitrogen species (except N₂O) 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 (O₃) production. Furthermore, NO₃⁻ aerosol is a contributor to PM_{2.5}, and nitrogen deposition in the forms of HNO₃, and aerosol NO₃⁻ can have ecological consequences.

NO_x is also emitted as a result of combustion processes (especially at higher temperature combustion), primarily as NO and NO₂. 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 (CH₄)

CH₄ is produced by microbial degradation of organic matter under anaerobic conditions. The primary source of CH₄ 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 CH₄ as one of several byproducts. The production rate of CH₄ 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.

CH₄ 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 CH₄ production at all stages of manure handling. Liquid systems tend to encourage anaerobic conditions and to produce significant quantities of CH₄, while more aerobic solid waste management approaches may produce little or none. Higher temperatures and moist conditions also promote CH₄ production.

Methane is destroyed in the atmosphere by reaction with the hydroxyl (\bullet OH) radical. Because of its long residence time (~8.4 years), CH₄ becomes distributed globally. Methane is a greenhouse gas and, under certain conditions, contributes to global warming with a potential 23 times that of CO₂. Following are BMPs which reduce emissions of CH₄.

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.

APPENDIX C – 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.

APPENDIX D - 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 (NH₃)*

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 NH₃ 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 (NH₃, Odor, and PM)*

Temperature is a very important factor in the rate of NH₃ volatilization. As the ambient temperature increases, NH₃ emission increases. Studies show that an increase in ambient housing temperature from 50 to 75° F results in a 46% increase in NH₃ emissions (5). Thus, reducing the temperature inside of enclosed parlor and holding areas with proper ventilation and/or cooling reduces the NH₃ 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 (NH₃, 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 NH₃ and odor emissions and should be avoided.

3. Treat Recycled Water Used for Flushing/Cleaning Holding Area (NH₃, Odor)

For holding pens and parlors that practice flushing as a means of manure removal, treatment in the form of additives that discourage NH₃ hydrolysis (i.e., pH reducers, urease inhibitors, or biological additives) can help reduce ammonia and odor emissions.

4. Remove Manure from Holding Area Frequently (NH₃, 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 NH₃ 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 NH₃ volatilization over a scrape system, and that more frequent manure removal, every 2-4 hours, reduces odor and NH₃ (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 NH₃ 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 (NH₃, Odor, and PM)

Temperature is a very important factor in the rate of NH₃ volatilization. As the ambient temperature increases, NH₃ emission increases. Studies show that an increase in ambient housing temperature from 50 to 75° F results in a 46% increase in NH₃ emissions (5). Thus, reducing the temperature inside of freestall barns with proper ventilation and/or cooling of the barns reduces the NH₃ 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 (NH₃, H₂S, Odor)

The use of non-absorbent bedding materials may help reduce NH₃ 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 NH₃ 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 NH₃ 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 (NH₃, 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 NH₃ 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 NH₃ and odor emissions and should be avoided.

Tradeoffs/Limitations: Infrastructure and additive cost.

4. Remove Manure from Barns Frequently (NH₃, 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 NH₃ 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 (NH₃, 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 NH₃ volatilization over a scrape system, and that more frequent manure removal, every 2 to 4 hours, reduces odor and NH₃ (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 NH₃ volatilization via increased mixing and surface exposure. This BMP is also effective in reducing, VOC, and odor emissions.

6. Alleyway Floor Texture and Type (NH₃, 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 NH₃ emission. Modification to a 3% sloped floor, over a level (0%) one, encourages transport of urine away from solid manure and could reduce NH₃ 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 NH₃, 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 (NH₃, 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 coarse PM by more uniform surface wetting and compaction, and aids in reduction of animal heat stress.

2. *Sitting of Water Trough Within Pen (NH₃, 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 coarse PM production.

Tradeoffs/Limitations: This BMP may not be possible for all pen designs.

3. *Remove and/or Spread (Harrow) Manure Frequently (NH₃, 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 (NH₃, 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 (NH₃, 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 (NH₃, N₂O)*

Reduction of NH₃ 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 NH₃. 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 N₂O emissions by limiting nitrification.

Tradeoffs/Limitations: Can be very expensive to install and maintain effectiveness of surface treatments.

7. *Surface Moisture Content Management (NH₃, N₂O, VOC, Odor, CH₄, H₂S, 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, CH₄, H₂S, 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 (NH₃, 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 (NH₃, N₂O)*

Overstocking of cattle increases NH₃ 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 (NH₃, N₂O)*

Practicing rotational grazing will help maintain pasture forage growth and health, which will maximize plant uptake of manure and reduce the potential of NH₃ or N₂O 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 (NH₃, N₂O)*

Since the volatilization of NH₃ is dependent on the mixing of urine (urea) and feces (urease), dispersing these events evenly over a pasture surface can help reduce NH₃ 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 (NH₃)*

Irrigating pastures following grazing will help incorporate manure into the soil and reduce ammonia volatilization potential. Over irrigation can, however, increase NH₃ volatilization and N₂O emission.

VII. Manure Management

1. *Manure Solids Separation (NH₃, VOC, Odor, H₂S, CH₄)*

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 NH₃, VOC, Odor, H₂S, CH₄ emissions from post-separation liquid storages.

2. *Lagoon or Storage Covers (NH₃, H₂S, VOC, Odor, CH₄)*

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 NH₃ losses by 80-90% (1), in addition to controlling odor, H₂S, and CH₄ 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 NH₃ and H₂S 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 biofilters, 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 (CH₄, Odor, H₂S)*

Using bio-filters to scrub the exit air from enclosed manure storage facilities can significantly reduce NH₃, H₂S, odor, and CH₄ 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 (CH₄)*

Anaerobic digestion (AD) converts manure into biogas (CH₄ and CO₂), 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 (H₂S, CO₂) can be scrubbed from the exhaust to provide natural, gas grade CH₄. Although AD reduces CH₄, H₂S, 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 (NH₄⁺, NH₃) into nitrate (NO₃⁻), and oxidizes sulfur containing compounds such as H₂S into elemental sulfur (S) or sulfates (SO₄²⁻). This process thus mitigates emissions of NH₃ and H₂S 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 (NH₃, CH₄)*

The pH of stored manure, liquid or solid, greatly affects the rate of H₂S and NH₃ 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), NH₃ is bound in solution or tied-up and little NH₃ 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 H₂S 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 PSB 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. Applying 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 (NH₃, Odor, PM)

Temperature, humidity, wind speed, and precipitation all influence the rate of NH₃, 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 NH₃ volatilized from the manure (16). Applying in the early morning or late evening will not only reduce NH₃ 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 NH₃ volatilization by binding NH₃ in the aqueous phase and moving it into the soil profile.

IX. Other

1. Installation of Windbreaks or Shelterbelts (NH₃, 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 coarse 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 (NO_x)

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

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APPENDIX E: DAIRY BMPs QUICK REFERENCE TABLE

BMP # (NOTE)	Best Management Practice	Ammonia (NH₃)	Nitrous Oxide (N₂O)	Hydrogen Sulfide (H₂S)	Volatile Organic Compounds (VOCs)	Odor	Particulate Matter (PM)	Methane (CH₄)	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 (NH₃)	Nitrous Oxide (N₂O)	Hydrogen Sulfide (H₂S)	Volatile Organic Compounds (VOCs)	Odor	Particulate Matter (PM)	Methane (CH₄)	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.								

APPENDIX E: DAIRY BMPs QUICK REFERENCE TABLE

BMP # (NOTE)	Best Management Practice	Ammonia (NH₃)	Nitrous Oxide (N₂O)	Hydrogen Sulfide (H₂S)	Volatile Organic Compounds (VOCs)	Odor	Particulate Matter (PM)	Methane (CH₄)	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 C

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

APPENDIX F - 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 to be 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.).

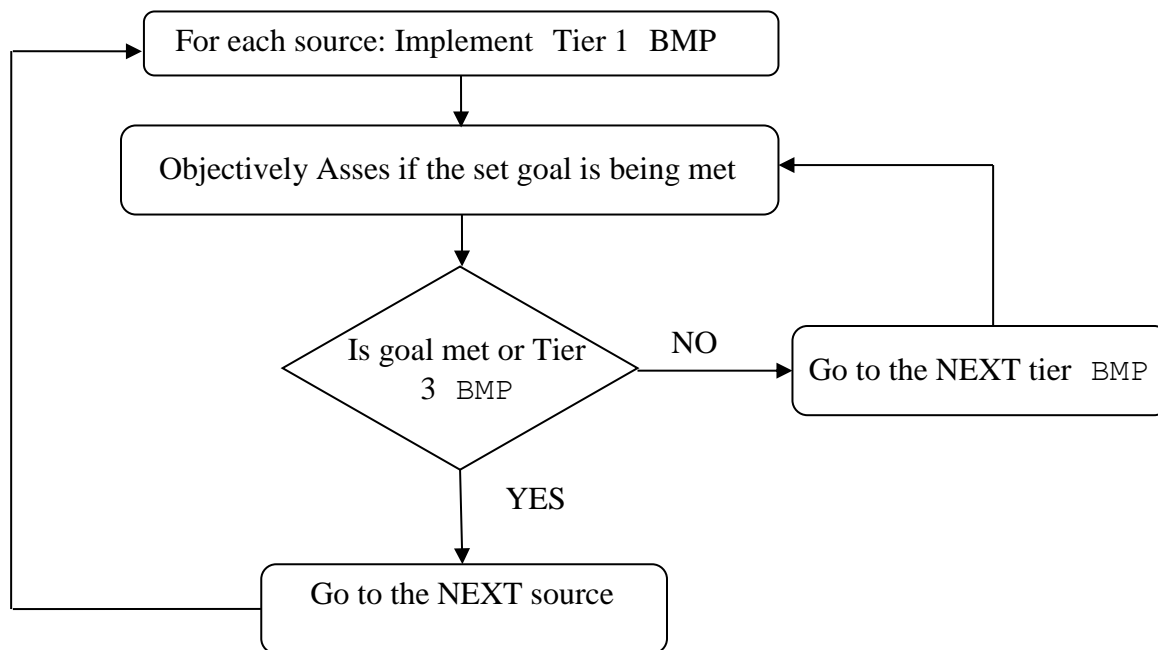
IV. Define the emissions mitigation goal for each of the sources.

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: NH₃, CH₄, H₂S, N₂O.
2. Feed Management: VOC, PM, Odor.
3. Milk Parlor: NH₃, VOC, Odor, H₂S.
4. Housing - Freestall Barns: NH₃, VOC, Odor, CH₄, H₂S.
5. Housing - Drylot Pens: NH₃, PM, Odor, H₂S, CH₄, VOC, N₂O.
6. Grazing Management: NH₃, N₂O.
7. Manure Management – Liquid: NH₃, H₂S, CH₄, Odor, VOC; Solid: NH₃, H₂S, PM, CH₄.
8. Land Application: NH₃, PM, Odor, N₂O.
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 (NH₃)
 - 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 (CH₄)
 - a. Manure Management
 - b. Nutrition
3. Hydrogen Sulfide (H₂S)
 - 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 (N₂O)
 - 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 easy 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 document) 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 (NH₃, N₂O, Odor); Properly Manage and Minimize Overfeeding Sulfur in the Diet (H₂S, Odor).
- b. *Tier 2* - Practice Group and/or Stage of Lactation Feeding (NH₃).
- c. *Tier 3* - Increase the Level or Quality of Starch in the Diet (CH₄); Utilize feed additives to maximize efficiency (NH₃, H₂S, CH₄).

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 (NH₃, Odor); Ensure Proper Ventilation (NH₃, Odor, and PM).
- b. *Tier 2* - Remove Manure from Parlor and Holding Area Frequently (NH₃, VOC, Odor).
- c. *Tier 3* - Treat Recycled Water Used for Flushing/Cleaning Holding Area (NH₃, Odor);

4. Housing - Freestall Barns

- a. *Tier 1* - Remove Manure from Barns Frequently (NH₃, VOC, Odor); Ensure Proper Ventilation of Freestall Barns (NH₃, Odor, and PM).
- b. *Tier 2* - Bedding Selection and Management (NH₃, H₂S, Odor); Manure Removal Technology and Efficiency (NH₃, VOC, Odor).
- c. *Tier 3* - Treat Recycled Lagoon Water Used for Flushing (NH₃, Odor); Alleyway Floor Texture and Type (NH₃, VOC, Odor); Manure Removal Technology and Efficiency (NH₃, VOC, Odor).

5. Housing - Drylot Pens

- a. *Tier 1* - Spread (Harrow) Manure Frequently (NH₃, PM); Surface Moisture Content Management (NH₃, N₂O, VOC, Odor, CH₄, H₂S, Odor, PM).
- b. *Tier 2* - Remove Manure Frequently (NH₃, PM); Incorporate Wood Chips in Surface Layer (NH₃, PM, Odor); Use Straw Bedding in Drylot Pens (NH₃, PM, Odor); Knockdown and Remove Fence Line Manure (VOC, Odor).
- c. *Tier 3* - Urease Inhibitors (NH₃, N₂O); Provide Shade for Cattle (NH₃, PM); Siting of Water Trough within Pen (NH₃, PM).

6. Grazing Management

- a. *Tier 1* - Stock Appropriate Number of Animals (NH₃, N₂O); Use Rotational Grazing (NH₃, N₂O).
- b. *Tier 2* - Move Water and Feeding Areas Frequently (NH₃, N₂O).
- c. *Tier 3* - Irrigate Immediately after Grazing (NH₃).

7. Manure Management

- a. *Tier 1* - Manure Solids Separation (NH₃, VOC, Odor, H₂S, CH₄); Properly Manage the Composting of Solid Manure (H₂S, Odor, PM, CH₄); Properly Manage Stockpiled Manure (H₂S, Odor, PM).
- b. *Tier 2* - Lagoon or Storage Covers (NH₃, H₂S, VOC, Odor, CH₄); Scrub Exhaust of Enclosed Waste Containers (CH₄, Odor, H₂S).
- c. *Tier 3* - Installation and Proper Operation of an Anaerobic Digester (CH₄); Surface Aeration of Lagoons (NH₃, H₂S, VOCs); Reduce the pH of Lagoons and Manure Piles (NH₃, CH₄); Encourage Purple Sulfur Bacterial Formation in Anaerobic Lagoons (H₂S, Odor).

8. Land Application – Manure and/or Chemical Fertilizer

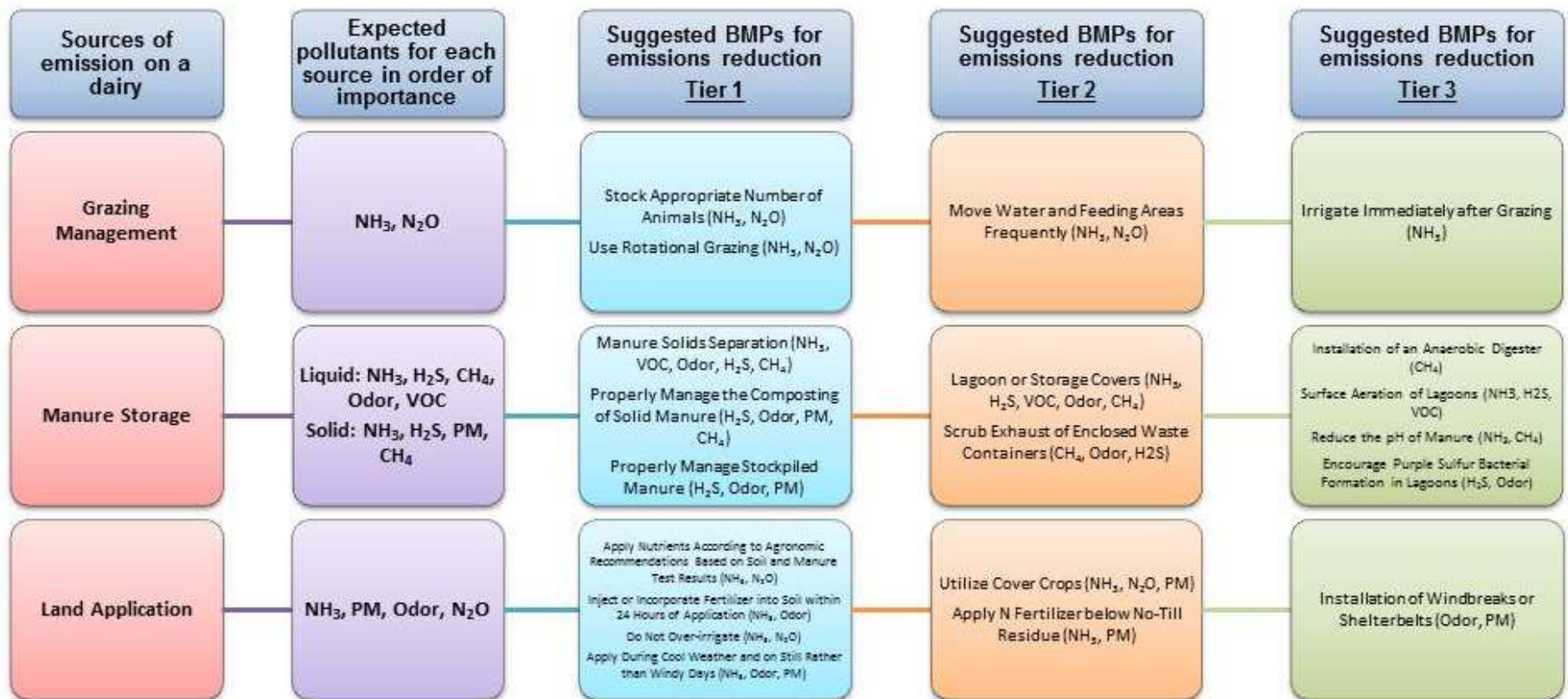
- a. *Tier 1* - Apply Nutrients According to Agronomic Recommendations Based on Soil and Manure Test Results (NH₃, N₂O); Inject or Incorporate Fertilizer into Soil within 24 Hours of Application (NH₃, Odor); Do Not Over-irrigate (NH₃, N₂O); Apply During Cool Weather and on Still Rather than Windy Days (NH₃, Odor, PM).
- b. *Tier 2* - Utilize Cover Crops (NH₃, N₂O, PM); Apply N Fertilizer below No-Till Residue (NH₃, PM).
- c. *Tier 3* - Installation of Windbreaks or Shelterbelts (Odor, PM).

9. Other

- a. *Tier 1* - Installation of Windbreaks or Shelterbelts (NH₃, Odor, PM).
- b. *Tier 2* - Vehicle Road Condition and Management (PM).
- c. *Tier 3* - Engine Selection and Efficiency (NO_x).

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 <u>Tier 1</u>	Suggested BMPs for emissions reduction <u>Tier 2</u>	Suggested BMPs for emissions reduction <u>Tier 3</u>
Nutrition	NH ₃ , CH ₄ , H ₂ S, N ₂ O	Properly Manage Level of Dietary Protein (%CP) in Diet to Match, Rather Than Exceed, an Animal's Needs (NH ₃ , N ₂ O, Odor) Properly Manage and Minimize Overfeeding Sulfur in the Diet (H ₂ S, 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 ₂ S, 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 ₂ S	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 ₂ S	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 ₂ S, 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 ₂ S, CH ₄ , VOC, N ₂ O	Spread (Harrow) Manure Frequently (NH ₃ , PM) Surface Moisture Content Management (NH ₃ , N ₂ O, VOC, Odor, CH ₄ , H ₂ S, 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 ₂ O) Provide Shade for Cattle (NH ₃ , PM) Sitting of Water Trough within Pen (NH ₃ , PM)



APPENDIX G: BMP SCORE SHEET

Facility: 0		Date: 0				Version 8; 10/28/11			
AQ BMP SCORE SHEET									
<p>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 documentation 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.</p>									
Overall Score (%) & Grade:				Good		Adequate	Poor - Needs improvement		
				#DIV/0!	#DIV/0!	100-90%	90-80%	80-70%	70-60%
				A	B	C	D	E	
BMP #	Best Management Practice	Ammonia (NH ₃)	Nitrous Oxide (N ₂ O)	Hydrogen Sulfide (H ₂ S)	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 (~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		

APPENDIX G: BMP SCORE SHEET

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			
<i>Category Level of BMP Implementation (%)</i>		#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			
<i>Category Level of BMP Implementation (%)</i>		#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			
<i>Category Level of BMP Implementation (%)</i>		#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	
<i>Category Level of BMP Implementation (%)</i>		#DIV/0!	NA	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	NA

APPENDIX G: BMP SCORE SHEET

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		
<i>Category Level of BMP Implementation (%)</i>		<i>#DIV/0!</i>	<i>#DIV/0!</i>	<i>#DIV/0!</i>	<i>#DIV/0!</i>	<i>#DIV/0!</i>	<i>#DIV/0!</i>	<i>#DIV/0!</i>	<i>NA</i>
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
<i>Category Level of BMP Implementation (%)</i>		<i>#DIV/0!</i>	<i>NA</i>	<i>#DIV/0!</i>	<i>NA</i>	<i>#DIV/0!</i>	<i>#DIV/0!</i>	<i>NA</i>	<i>#DIV/0!</i>
Overall Level of BMP Effectivity by Pollutant (%)		-	-	-	-	-	-	-	-