A Program to Determine Reactive Organic Gas Emissions From Different Manure Handling Methods at California Dairies.

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Abstract

A study of ROG emissions related to dairy operations was conducted at two Central California locations in 2003-04. Results from that study were presented at the '05 EPA Emissions Inventory Conference. The monitoring and modeling methods developed for that project will be applied to a more comprehensive study to be conducted in 2005-08. The development of that program will be the focus of this paper.

Introduction

Modeling of ambient samples collected upwind and downwind of various components of the two dairies in the 2003-05 study indicated there were differences that might be attributed to different management and techniques for collecting, separating, storing and disposing of the liquid and solids from the cows. There were not enough sites or sampling events in the initial study to provide more than an indication that these differences might exist. In order to evaluate different methods of manure handling at dairies with regard to the emissions of ROG, a more intensive study to include additional sites and additional monitoring methods was proposed and funded by the CARB with matching funding from the CSU Agricultural Research Initiative. A monitoring project to collect N and C data at the same sites was funded by the University of New Hampshire from a USDA grant.

Six dairies with different manure handling systems have been selected for a three year monitoring program that began Fall '05. The sites will be sampled three times, winter, early summer and early fall, each year to determine emission differences due to weather and other factors related to seasonal variation. The monitoring program will include day and night or continuous sampling to determine diurnal emission differences. Emissions will be estimated using both ambient canister sampling (upwind and downwind) as well as flux chambers at appropriate locations. The components of the dairies to be monitored include the animal housing, manure collection system, manure separation, treatment and storage systems, feed storage, and land application of effluent and solids. Emissions will be modeled using the Gaussian plume dispersion model, ISC-ST v.3.

Analysis of the canister air samples in the preliminary study was done according to US EPA TO-15 guidelines utilizing a GC-MS system at CSU Fresno. That analytical system will continue to be employed in the new study but the primary analysis will be done at the University of California Irvine by Dr. Donald Blake. TO-15 analytical procedures were developed to study products of combustion rather than gasses from biological processes. TO-15 requires a standard gas for quantification of the components in the sample. Many of the components of the dairy canister samples are not found in the TO-15 standard and therefore cannot be identified or quantified accurately. The first samples analyzed at UC Irvine are being used for speciation of the samples from various dairy operations with the objective of developing an analytical process and gas standards optimized for dairy emissions.

Rational:

The agricultural process in California with the highest economic value is the use of a dairy cow to turn forage into milk and cheese. That process, like any other, is not completely efficient. In addition to milk, cows convert feed into manure, urine, digestive gasses, and more cows. The first two of these, manure and urine, are viewed in a number of ways. The dairyman sees them as waste to be removed from the dairy. The public and regulatory agencies see them as potential pollutants of air and water. Agronomists and soil scientists view them as valuable resources to be recycled for crop nutrition. Dairy operations are evolving to meet each of these needs, ideally to the benefit of everyone.

There are nearly 3000 diaries in the state and each must collect and deal with the solids and liquid that the cows eliminate. There are many different ways to accomplish that task and the particular method will often affect the volume and composition which affects both emissions and nutritional content of the manure as used for crop fertility. The combination of solids and liquid from the manure and urine produced by the dairy cows will be referred to as "dairy manure" for purposes of this discussion. There are several components of the diary manure that may or may not be separated from each other in the process of collection, treatment and disposal. These components are currently being evaluated in this and other research projects to determine the potential for water and air pollution and to evaluate different practices to minimize the environmental impact of dairy operations.

Dairies can be classified by the different methods used to collect, treat and dispose of manure. There are three basic types of dairies with regard to method of manure collection and a variety of technologies to separate it into its components and treat them. In nearly every case, the treatment is completed by the application of solids or liquid to crop land where the organic matter can be mineralized and the plant nutrients released for crop uptake. The particular method of separation and treatment will affect the quantity and quality of the manure for use as fertilizer.

The oldest of the three basic manure handling systems used on California diaries is the open lot operation where the animals are kept in a large corral or pasture. The manure is deposited over the entire area, though it may be concentrated around shade structures, feeding and watering troughs. Periodically, manure in the corral is scraped into a pile to compost or is hauled out to be spread. The liquid in the manure either evaporates or leaches into the soil prior to collection. This type of dairy operation is becoming less common for large operations since it requires the most land and affords the least opportunity to manage the manure.

The second manure management method is the free stall barn where the cows each have a stall that is elevated and lined with bedding. They can enter and leave the free stalls at will as they are fed and milked. The barns are usually long with a lane between the line of stalls and the feeding area where forage is delivered by a truck. There is usually a corral adjacent to the barn that the cows use in good weather. The feeding area is a long, sloped, concrete paved lane where the cows stand as the feed is delivered. A large percentage of the manure is deposited on this lane as the animals eat. The lane is flushed with a large flow of water at least twice each day, often when the cows are out being milked, to remove the accumulation of manure. The flush lane drains to a sediment trap where the mineral solids are settled out. After that, there are a variety of separation and treatment techniques. This free stall/flush lane dairy is the most common type of large dairy in California's Central Valley. Frequent flushing of the area where the animals stand has advantages for animal health and is an effective method of manure removal. The primary disadvantage is the large volume of water required. After some type of separation process, the liquid and remaining solids are usually stored in a single or a series of ponds called lagoons. Water is pumped from a lagoon for subsequent flushing and eventually is spread on cropland.

The third manure handling method is an old technique, long used in small operations, updated with new technology for collecting manure without diluting it in flush water. Some operations that have been constructed with free stalls and flush lanes will scrape into a pit or vacuum the fresh manure into a tank without adding water. This reduces the volume considerably and requires much less area for the treatment process. It may also be combined with treatments such as digestion to generate methane and reduce air emissions by quickly removing the manure and treating it in an enclosed tank or chamber.

The common free stall/flush lane dairies employ a variety of methods to separate the solids from the flush water. Most dairies have a sand trap or processing pit as the first step in managing the flush water. Soil tracked in from the corrals by the cows or sand, when it is used as bedding in the stalls, is removed from flush water in a settling basin before it can plug the screens or fill up lagoons. The remaining organic solids plus the liquid can be separated by further settling, floating, screens or a combination of these. The coarse, partially digested fibers are often removed from the flush water by a sloping screen. The flush water is delivered to the top of the screen and runs down the surface. Water and fine solids pass through and are piped to the lagoon system while the coarse solids fall off the bottom or are scraped off and piled to dry. These fiber solids are primarily cellulose with very little value for plant nutrition. They are often returned to the corrals or free stalls for bedding where their absorbent qualities are useful. Some of these coarse solids will find their way back into the flush system and the rest will eventually be collected and spread on fields.

Screen separators generally pass most of the fine solids along with the water. The separation efficiency is usually no more than 35%. More efficient separation can be achieved with very fine screens, settling ponds or other structures where the flush water is held for sufficient time to allow the slow separation of the various components. This may be the initial lagoon, a large sloped slab or a shallow pit with perforated sides called a “weeping wall”. The separation efficiency of these methods is generally greater than screens but they take up considerable area and require more labor to remove the separated solids from the structure. The coarse and fine solids tend to be mixed together from such a system which increases the significance of solids spreading for crop nutrition.

Some dairies with a need to use the coarse material for bedding and the fine material for nutrient recycling or those wishing to reduce the organic content of the lagoon water may use a combination of screens and settling to remove the coarse and fine solids separately. The resulting water is about 0.1% - 0.3% solids and will often support a bloom of photosynthetic bacteria that are able to thrive in the less anaerobic lagoon conditions. These lagoons often acquire a red or rose color and are reported to have less odor and, possibly, a reduction in other emissions. Use of water from these red lagoons will need to account for the decreased nutrient content with respect to a crop fertility program. The need to increase the percentage of low concentration lagoon water in the irrigation stream is helped by the fact that these systems often have a larger volume of water in the lagoons.

Current status:

The CARB funded project that began Fall, ’05 will expand the preliminary study to additional sites and a more comprehensive sampling and analytical program. Six sites will be selected to be monitored three times each year for three years. Two of the sites will be the dairies that have been monitored since 2003. The other four locations will differ in their methods of collecting and processing the manure and those differences should relate to potentially reducing emissions of ROG.

Dairies selected for the study include:

1. A “typical” free stall, flush lane dairy that is the most common type of large, modern operation in California.

2. The second type is similar to the first but has a series of lagoons and more complex management, similar to USDA guidelines for an anaerobic lagoon.
3. A lagoon complex designed and operated according to USDA guidelines for an aerobic lagoon with no artificial aeration devices.
4. A lagoon complex designed and operated according to USDA guidelines for an aerobic lagoon that includes artificial aeration devices.
5. A tank type digester system to digest manure slurry prior to land application of the liquid and solid material.
6. A dairy that collects the fresh manure by scraping rather than flushing and applies it quickly by injection below the soil surface on adjacent cropland.

The first year of the project will focus on development of the monitoring, analytical and modeling procedures. The initial sampling began in October, '05 and was completed by March, '06. The first sampling period to be used for modeling of emissions is expected to occur May-June, '06. Results from the first year of monitoring and modeling, along with results from the speciation of the samples in the UC Irvine lab will be presented at next year's conference.

References

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Key Words

Reactive Organic Gas
Dairy Operations
Ozone Precursors