AIR QUALITY ISSUES WITH THE DAIRY FORAGE SYSTEM

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ABSTRACT

California is the nation's leading dairy state. Unfortunately, it is also home to two of the three worst air-sheds with respect to ozone (smog) pollution. California is also the second largest contributor of Greenhouse Gases (GHG; e.g., methane) in the nation. Current regulatory estimates suggest that dairy cows in central California emit smog-forming, so-called volatile organic gases (VOCs) at rates higher than those from vehicles, and thus contribute significantly to the region's extreme ozone non-attainment status. During decades of VOC studies at UC Riverside and UC Berkeley, researchers identified plants as one of the most significant VOCs sources (e.g., oak trees emitting isoprenes). It is estimated that approximately 6% of net primary crop production in the San Joaquin Valley is fed to and consumed by dairy cows, which then carry out enteric fermentation leading to emission of VOCs during eructation.

To investigate dairy cow and waste emissions, experiments were conducted in environmental chambers at UC Davis to simulate emissions from freestall cow housing conditions. State-of-the-art analytical equipment was used to measure a suite of smog-forming VOCs emitted from dry and lactating dairy cows and their waste. Furthermore, greenhouse gases (methane, and nitrous oxide) and ammonia were measured. The total emissions for all measured organic carbonaceous gases (VOCs and methane) was dominated by methane. When cows were present in the chambers, VOCs were less than one percent of total organic gas (TOG), which is a factor of 10 smaller than that historical estimates used currently by the air regulatory agencies. Certain feed materials like silage emitted considerable amounts of VOCs (i.e. alcohols), which needs to be investigated further. Current air regulatory estimates for VOC emissions appear to be overestimated while greenhouse gas emission estimates (i.e. methane) are underestimated. Furthermore, the ozone-forming-potential (OFP) of the most abundant VOCs measured in our experiment is only about 20% those of typical combustion or plant-derived VOCs. This implies dairy cattle and their fresh waste have a smaller effect on ozone formation but a larger effect on GHG than currently assumed by air quality agencies in California.

Key Words: dairies, air emissions

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INTRODUCTION

The major air pollution in California is generated by 1) cities along the coast (i.e. Bay Area, L.A.) and in the Central Valley, 2) mobile sources (i.e. cars and trucks) along the traffic arteries, and 3) agriculture. As the Central Valley becomes more urbanized (Figure 1), it will become a larger contributor to mobile source (vehicle) emissions.

Figure 1: Urban encroachment next to dairy.

Substantial pollution moving inland from the ocean also comes from proximate sources such as container ships, and even from far distant sources such as Asian industry and agriculture. As the prevailing West wind moves from the ocean inland (i.e. Bay area), it brings polluted air up into the Central Valley where it combines with emissions from valley urban centers, vehicles and agriculture.

As sated above, California is the second largest contributor of Greenhouse Gases (GHG) in the nation. In terms of their contribution to global warming, the main non-CO_2 GHGs are methane (CH_4) and nitrous oxide (N_2O). These gases represent 7% and 6% respectively to the state total GHG with global warming potential 21 times CO_2 in the case of methane and 310 times for nitrous oxide. The former is generated during enteric fermentation by ruminant animals, decomposition of animal manure and waste disposed in landfills. Although N_2O is also produced through nitrification and denitrification of urine and manure when they are decomposed in an aerobic environment, the amounts are almost negligible. However, N_2O is also generated by animal manure when this is applied as soil fertilizer as well as runoff and leaching into surface and groundwater.

Landfills represent the largest source of CH_4 in the state, generating 42% of the 31.6 million metric tons of carbon dioxide equivalent ($MMTCO_2$). The dairy industry is believed to come in second, contributing 38% of total methane emissions, with manure management and enteric fermentation from ruminants as the main sources. While the

later is a natural digestive process which takes place in ruminant animals and results in the release of CH_4 via exhalation or eructation, there are many alternative management practices to reduce manure emissions.

The California Dairy Industry and Air Emissions

The dairy industry is the largest Ag commodity in the state of California. Most of the state's dairy cows reside in the San Joaquin Valley. The valley is currently in non-attainment of the federal and state air quality regulations for ozone. Dairies are listed as the valley's major source for ozone producing VOC. Other emissions from dairies include ammonia, methane, and hydrogen sulfide. The state's regional air districts quantify and regulate emissions from dairies and use pollutant-specific emission factors to determine the contribution from cattle to the various emissions inventories (e.g., 160 lb CH_4/ cow/ year is one emission factor used). Due to the large environmental and economic implications of regulating emissions on this scale, it is of the utmost importance that air quality regulatory agencies use the most accurate emissions estimates available.

In 2002, the state of California updated its inventory for GHG emissions for the years 1990-1999 without including some potentially significant contributions from cattle in the inventory. Although the inventory did include estimates for CH_4 and N_2O from manure management, there was no estimate of the contribution of either CO_2 or CH_4 directly emitted by the cows (i.e., sources other than manure). Because methane has a 21 times larger forcing potential than CO_2, small inaccuracies in its estimates may affect the validity of any model, and because it is produced in smaller amounts, it may be a more attractive target for regulation than CO_2. As California moves closer to establishing laws on GHG emissions that will undoubtedly affect the dairy industry, it is important that all GHG sources be considered and accurately accounted for.

A study in Stuttgart (Germany) found that the amount of CH_4 originating in a cow's digestive system (rumen) is about 223 g CH_4/ head/ day, or between 200 and 250 g CH_4/ head/ day (Jungbluth, 2001). The equates to an annual emission factor of about 180 lb CH_4/head/yr, which is only slightly higher than the emission factor CARB has previously used for methane, 160 lb CH_4/head/yr. The same study also found emission factors of 1.6 g N_2O/head/day, or about 1.3 lb N_2O/head/yr (Jungbluth, 2001). The study did not measure CO_2 emissions from animal housing. Table 1 provides emission factors for CH_4 from other studies.

Table 1- Emission factors for CH_4 from dairy facilities (Jungbluth, 2001).

Kind of animals	CH_4 emission factor	Notes	Authors
Calculations based on physiology or respiration chambers			
Dairy cattle	260 g animal $^{-1}$ day^{-1}*	CH_4 = 5.5% from GE	Crutzen et al., 1986
Heifer 6–24 month	140 g LU^{-1} day^{-1}*	CH_4 = 6.5% from GE	
Dairy cattle, dry period	139 g LU^{-1} day^{-1}*	CH_4 = 5.5% from GE, W_{av} = 633 kg	Holter and Young,
Dairy cattle, lactating	268 g LU^{-1} day^{-1}*	CH_4 = 5.2% from GE, W_{av} = 559 kg	1992
Dairy cattle	257 g LU^{-1} day^{-1}*	153 trials in respiration chambers M_{av} = 17 kg day^{-1}, W_{av} = 583 kg	Kirchgessner et al., 1991
Data based on measurements in dairy cattle facilities			
Tied-stall 118 animals	327 g LU^{-1} day^{-1}*	Emissions only from animals	Kinsman et al., 1995
	21 g LU^{-1} day^{-1}*	Emissions only from manure M_{av} = 28.5 kg day^{-1}, W_{av} = 602 kg	
Tied-stall 12 animals	194 g LU^{-1} day^{-1}	Emissions from animals & manure M_{av} = 18.5 kg day^{-1}, W_{av} = 584 kg	Amon et al., 1998
Loose housing system	320 g LU^{-1} day^{-1}	Emissions from animals & manure, air flow rate measured with tracer gas, natural ventilation, daily grazing	Sneath et al., 1997
Loose housing system	267–390 g LU^{-1} day^{-1}	Emissions from animals & manure, natural ventilation, air flow rate measured with tracer gas	Seipelt et al., 1999

*Recalculated data; GE, gross energy intake; M_{av}, average milk yield; W_{av}, average animal weight; LU, livestock unit = 500 kg.

In order to obtain accurate emission factors, it is necessary to account for any potential changes in the environment, such as diurnal or seasonal effects (Jungbluth, 2001). It is also necessary to use extremely exact equipment to take measurements.

Current UCD Dairy Air Quality Research Thrusts

Our dairy air quality experiments were conducted at the Animal Science Department at the University of California, Davis. The objective was to accurately quantify VOCs, ammonia, and GHG emitted from animals and waste.
Environmentally-controlled chambers (14.5ft ×9.3ft ×34.5ft) were used to simulate freestall housing conditions for 12 groups of 3 cows/group. Fresh air flow was provided by forced ventilation at 1330 ft^3 min^{-1}. Food and water troughs were provided for the cows to consume as desired. The cows' excreta accumulated on the concrete floor until the chamber was cleaned.

Pumps pulled chamber inlet or outlet air at controlled flow rates from the appropriate vents on the chamber ceiling, through Teflon tubes to the analytical instruments. Sample air was directed to analytical equipment.

Preliminary results from our experiments suggest that a much higher percentage of the methane, CO_2, and VOCs is actually produced by the cows rather than their fresh waste. This finding may suggest that controlling these pollutants that are produced directly by

the animal needs increased attention to arrive at cost effective management strategy for reducing emissions. Since this production occurs when cows digest plant matter, it is more difficult to manage than methane from manure.
While VOC emissions were lower than current regulatory estimates suggest, GHG emissions were significantly higher, which might become relevant if California starts regulating gases that contribute to global warming.

A significant source of VOC emissions during our studies were from feedstuff, namely alcohol emissions from silage. However, additional research is needed to quantify silage emissions and to compare emissions from different silage types.