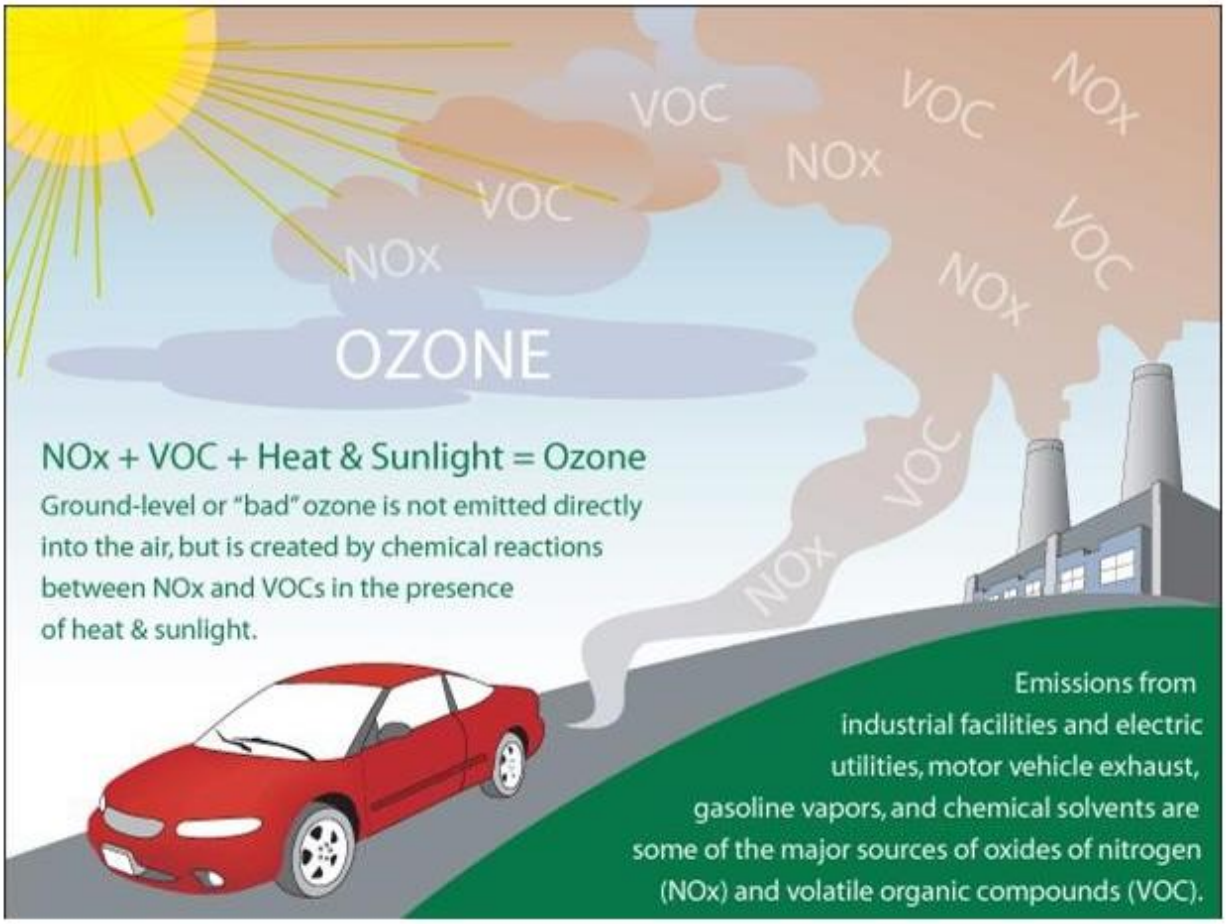
Hello YRCAA,

Thank you so much for Monday's Community Forum. This note provides some follow-up information.

I. Regarding the National Air Emissions Monitoring Study, the EPA has been working on the data and has released *Draft Air Emissions Estimating Methodologies for Animal Feeding Operations*, available at https://www.epa.gov/afos-air/draft-air-emissions-estimating-methodologies-animal-feeding-operations#naems-uem-2020 The Draft *Development of Emissions Estimating Methodologies for Dairy Operations* was published in June 2022 and is available at https://www.epa.gov/system/files/documents/2022-07/Dairy_PreliminaryDraft_report.pdf

From our perspective it is disappointing that the VOC emission data was omitted from the latest iteration of the NAEMS. There is data for ammonia and hydrogen sulfide emissions under a range of conditions.

II. Regarding ozone, both the EPA and WA Ecology post this picture explanation:

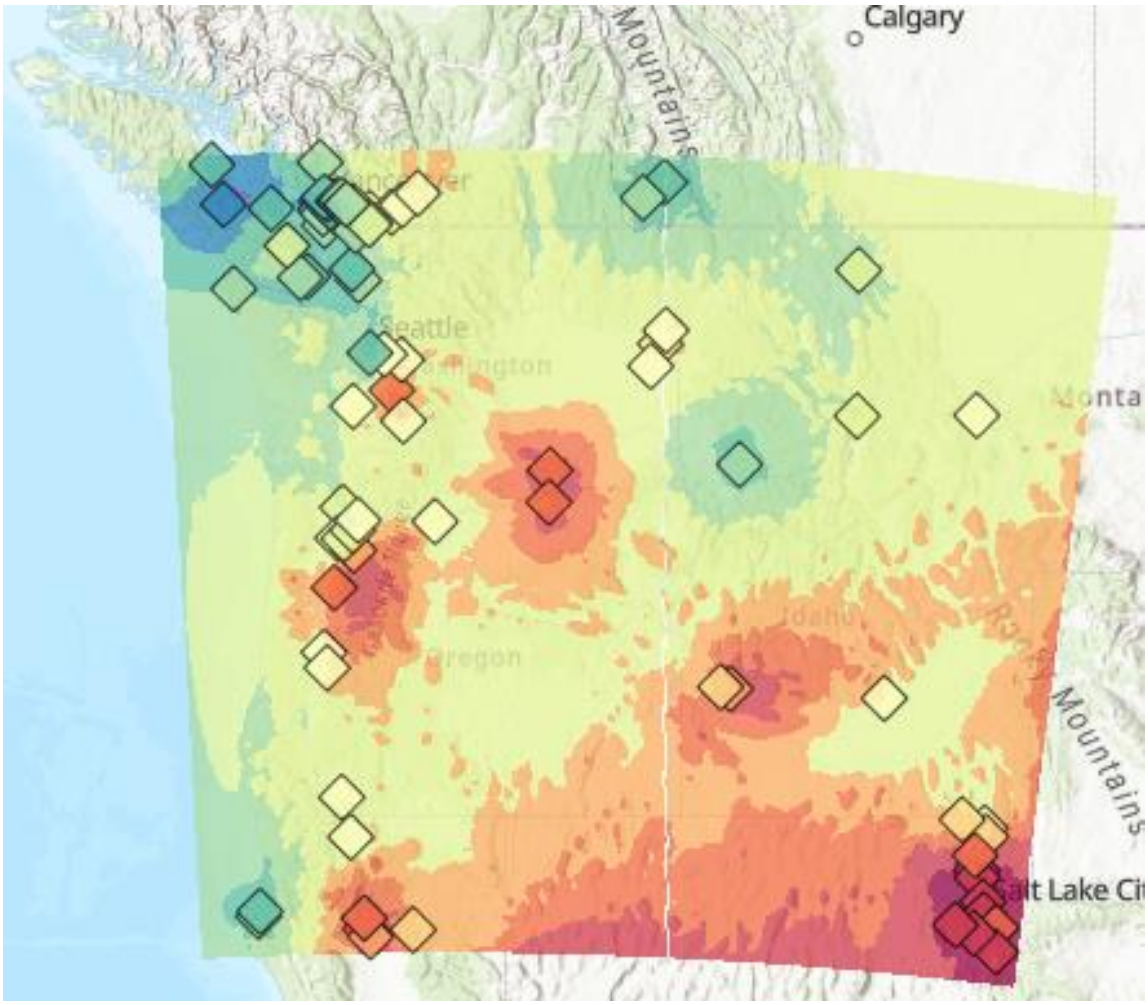


A. WA Ecology and the Benton Clean Air Agency have completed a study of ozone levels in the Tri-Cities area that is available at https://ecology.wa.gov/DOE/files/93/934a2f46-b000-4f9a-837c-a286ccfa615e.pdf Elevated ozone levels extend into Yakima County.

B. Another source of information from an interstate consortium is available at Background Concentrations 2014 - 2017 (arcgis.com) or

https://idahodeq.maps.arcgis.com/apps/MapSeries/index.html?appid=0c8a006e11fe4ec5939804b873098dfe.

Model and monitoring data from July 2013 through June 2017 were used to estimate background concentrations of criteria air pollutant design values for use in air permit engineering. This tool facilitates the retrieval and exploration of the estimated design values at user-specified locations in Washington, Idaho, and Oregon.



III. Here are abstracts from research that shows significant VOC contributions to the ambient air from dairy operations.

A. CARMELITA PROJECT AIR QUALITY ENVIRONMENTAL ASSESSMENTS.

This Air Quality Environmental Assessment discusses regional air quality in the vicinity of the Carmelita Project (Project) site and identifies the sources and quantities of air pollutant emissions expected from the Project. The air quality impacts are assessed in relation to federal and state ambient air quality standards as well as thresholds of significance adopted by the San Joaquin Valley Air Pollution Control District (SJVAPCD). The focus of these regulatory schemes and this analysis is the impact of the Project's air pollutant emissions on human health. Air pollutant emissions may also impact plants, including agricultural crops.

http://www2.co.fresno.ca.us/4510/4360/environmental/Carmelita_DEIR/E-1_E-5_AirQlty.pdf

B. California's Fertile Valley Is Awash in Air Pollution.

The San Joaquin Valley is the land of Big Agriculture. Stretching 250 miles from Bakersfield in the south to Stockton in the north, the San Joaquin comprises the southern two-thirds of the storied Central Valley, a plowed-over promised land covering seven million acres of irrigated fields that generate more than $17 billion a year in crops—with the vast majority coming from three San Joaquin Valley counties. In sum, the region supplies a quarter of the food on American plates.

It is also awash in air pollution. Millions of beef and dairy cattle, millions of acres of dusty crops, and the truck traffic to support these mega-operations generate fine airborne particles that linger and swirl in what is, in effect, a gigantic, pollution-trapping bowl bounded by mountains. Add in prolific use of wood stoves and barbecue pits, the second-hand smog blowing into the valley from cities to the west and the north, and emissions from some of the densest oil fields in the lower 48 states, and the result is some of the worst air pollution in the nation.

https://www.motherjones.com/environment/2018/12/californias-fertile-valley-is-awash-in-air-pollution/

C. Greenhouse gas and ammonia emissions from digested and separated dairy manure during storage and after land application.

Manure management at dairy production facilities, including anaerobic digestion (AD) and solid-liquid separation (SLS), has shown strong potential for the abatement of greenhouse gas (GHG) and ammonia (NH_3) emissions. However, previous study results are inconsistent and the combined effect of AD + SLS remains to be quantified. This study evaluated the effects of AD, SLS, and AD + SLS on GHG and NH_3 emissions during manure storage through land application over nine months. AD and SLS alone significantly ($P < 0.05$) reduced total GHG

emissions for storage and land application compared to untreated manure slurries by 25% and 31%, respectively. The majority of that reduction was from methane during storage. SLS had a greater potential for methane reduction in storage than AD, but the variability in digester performance likely impacts the reduction potential. Digestion with subsequent separation further decreased CH_4 emissions from 3.9 g CO_2-eq to 1.3 g CO_2-eq, but increased emissions of nitrous oxide (N_2O) from 0.6 g CO_2-eq to 2.0 g CO_2-eq during storage eliminating a further reduction of GHG emissions as compared to AD alone. AD resulted in a gas emission tradeoff as it increased NH_3 emissions by 81% during storage, which could be mitigated by subsequent SLS, manure storage covers, or other beneficial management practices.

https://www.sciencedirect.com/science/article/pii/S0167880917300701?via%3Dihub

D. At scale, renewable natural gas systems could be climate intensive: the influence of methane feedstock and leakage rates.

Renewable natural gas (RNG) is a fuel comprised of essentially pure methane, usually derived from climate-neutral (e.g. biogenic or captured) carbon dioxide (CO_2). RNG is proposed as a climate friendly direct substitute for fossil natural gas (FNG), with the goal of enabling diverse natural gas users to continue operating without substantial infrastructure overhauls. The assumption that such substitution is climate friendly relies on a major condition that is unlikely to be met: namely, that RNG is manufactured from waste methane that would otherwise have been emitted to the atmosphere. In practice, capturable waste methane is extremely limited and is more likely to be diverted from a flare than from direct atmospheric release in a climate-conscious policy context, which means that RNG systems need to be more destructively efficient than a flare to provide climate benefits versus the likely alternative management strategy. Assuming demand levels consistent with the goal of using existing FNG infrastructure, RNG is likely to be derived from methane that is either intentionally produced or diverted from a flare, so essentially any methane leakage is climate additional. Further, in a decarbonizing system, RNG will likely compete with lower-emissions resources than FNG and thus provides fewer net emissions benefits over time. Anticipated leakage is climatically significant: literature estimates for methane leakage from biogas production and upgrading facilities suggest that leakage is in the 2%–4% range (mass basis), up to as much as 15%. Policy makers should consider that under reasonable leakage and demand assumptions, RNG could be climate intensive.

https://iopscience.iop.org/article/10.1088/1748-9326/ab9335

E. Interest in California Dairy Manure Methane Digesters Follows the Money.

California's 1.7 million dairy cows are the largest source of methane in the state, and the biggest concentration of dairy-related methane in the country. So, when the state focused on reducing greenhouse gas (GHG) by adopting rules for methane emissions in 2017, dairies were in the spotlight. California's legislated goal for 2030 is to reduce dairy manure methane emissions by 40% below 2013 levels. One of the means of achieving that goal has been on-farm dairy manure

methane digesters. Digesters not only help reduce dairy manure methane emissions, they capture renewable natural gas (RNG). When biogas is upgraded to natural gas specifications and used in the transportation sector of the California fuel market, it is 25-30 times more valuable than fossil natural gas. California has used a carrot approach to dairy digesters, as a state law currently prohibits methane regulations on dairies and cattle farms until 2024. The state's Dairy Digester Research and Development Program (DDRDP) has awarded more than $183 million grants for 108 digester projects (Exhibit 1). (For perspective, 255 digesters are operating on U.S. livestock farms as of March 2020, according to the latest data tracked by EPA's AgSTAR program.) This wave of digester developments on California dairy farms has spurred interest in the technology nationwide. Dairy producers outside California may be watching for long-term environmental mandates in their states, but it's the immediate financial incentives and energy market opportunities that are grabbing attention.

https://www.cobank.com/documents/7714906/7715329/Interest-in-California-Dairy-Manure-Methane-Digesters-Follows-the-Money-Aug2020.pdf/be11d7d6-80df-7a7e-0cbd-9f4ebe730b25?t=1603745079998

F. Emission of volatile organic compounds from silage: Compounds, sources, and implications.

Silage, fermented cattle feed, has recently been identified as a significant source of volatile organic compounds (VOCs) to the atmosphere. A small number of studies have measured VOC emission from silage, but not enough is known about the processes involved to accurately quantify emission rates and identify practices that could reduce emissions. Through a literature review, we have focused on identifying the most important compounds emitted from corn silage (the most common type of silage in the US) and the sources of these compounds by quantifying their production and emission potential in silage and describing production pathways.
We reviewed measurements of VOC emission from silage and assessed the importance of individual silage VOCs through a quantitative analysis of VOC concentrations within silage. Measurements of VOC emission from silage and VOCs present within silage indicated that alcohols generally make the largest contribution to emission from corn silage, in terms of mass emitted and potential ozone formation. Ethanol is the dominant alcohol in corn silage; excluding acids, it makes up more than half of the mean mass of VOCs present. Acids, primarily acetic acid, may be important when emission is high and all VOCs are nearly depleted by emission. Aldehydes and esters, which are more volatile than acids and alcohols, are important when exposure is short, limiting emission of more abundant but less volatile compounds. Variability in silage VOC concentrations is very high; for most alcohols and acids, tolerance intervals indicate that 25% of silages have concentrations a factor of two away from median values, and possibly much further. This observation suggests that management practices can significantly influence VOC concentrations. Variability also makes prediction of emissions difficult.

The most important acids, alcohols, and aldehydes present in silage are probably produced by bacteria (and, in the case of ethanol, yeasts) during fermentation and storage of silage. Aldehydes may also be produced aerobically by spoilage microorganisms through the oxidation of alcohols. Abiotic reactions may be important for production of methanol and esters. Although silage

additives appear to affect VOC production in individual studies, bacterial inoculants have not shown a consistent effect on ethanol, and effects on other VOCs have not been studied. Production of acetic acid is understood, and production could be minimized, but a decrease could lead to an increase in other, more volatile and more reactive, VOCs. Chemical additives designed for controlling yeasts and undesirable bacteria show promise for reducing ethanol production in corn silage.
More work is needed to understand silage VOC production and emission from silage, including: additional measurements of VOC concentrations or production in silage of all types, and an exploration of the causes of variability; accurate on-farm measurements of VOC emission, including an assessment of the importance of individual ensiling stages and practices that could reduce emission of existing VOCs; and work on understanding the sources of silage VOCs and possible approaches for reducing production.

https://www.sciencedirect.com/science/article/pii/S1352231013003403#bbib7

G. Mobile Source and Livestock Feed Contributions to Regional Ozone Formation in Central California.

A three-dimensional air quality model with 8 km horizontal resolution was applied to estimate the summertime ozone (O_3) production from mobile sources and fermented livestock feed in California's San Joaquin Valley (SJV) during years 2000, 2005, 2010, 2015, and 2020. Previous studies have estimated that animal feed emissions of volatile organic compounds (VOCs) have greater O_3 formation potential than mobile-source VOC emissions when averaging across the entire SJV. The higher spatial resolution in the current study shows that the proximity of oxides of nitrogen (NO_x) and VOC emissions from mobile sources enhances their O_3 formation potential. Livestock feed VOC emissions contributed 3–4 ppb of peak O_3 (8-h average) in Tulare County and 1–2 ppb throughout the remainder of the SJV during the CCOS 2000 July–August episode. In total, livestock feed contributed ~3.5 tons of the ground level peak O_3 (8 h average) in the SJV region, and mobile VOC contributed ~12 tons in this episode. O_3 production from mobile sources is declining over time in response to emissions control plans that call for cleaner fuels and engines with advanced emissions controls. Projecting forward to the year 2020, mobile-source VOC emissions are predicted to produce ~3 tons of the ground level peak O_3(8-h average) and livestock feed VOC emissions are predicted to contribute ~2.5 tons making these sources nearly equivalent.

https://pubs.acs.org/doi/10.1021/es203369p

H. Measurement of non-enteric emission fluxes of volatile fatty acids from a California dairy by solid phase micro-extraction with gas chromatography/mass spectrometry.

Dairies are a major source of volatile organic compounds (VOCs) in California's San Joaquin Valley; a region that experiences high ozone levels during summer. Short-chain carboxylic acids, or volatile fatty acids (VFAs), are believed to make up a large fraction of VOC emissions from these facilities, although there are few studies to substantiate this. In this work, a method using

a flux chamber coupled to solid phase micro-extraction (SPME) fibers followed by analysis using gas chromatography/mass spectrometry was developed to quantify emissions of six VFAs (acetic acid, propanoic acid, butanoic acid, pentanoic acid, hexanoic acid and 3-methyl butanoic acid) from non-enteric sources. The technique was then used to quantify VFA fluxes from a small dairy located on the campus of California State University Fresno. Both animal feed and animal waste are found to be major sources of VFAs, with acetic acid contributing 70–90% of emissions from the sources tested. Measured total acid fluxes during spring (with an average temperature of 20 °C) were 1.84 ± 0.01, 1.06 ± 0.08, $(1.3 \pm 0.5) \times 10^{-2}$, $(1.7 \pm 0.2) \times 10^{-2}$ and $(1.2 \pm 0.5) \times 10^{-2}$ g m^{-2} h^{-1} from silage, total mixed rations, flushing lane, open lot and lagoon sources, respectively. VFA emissions from the sources tested total 390 ± 80 g h^{-1}. The data indicate high fluxes of VFAs from dairy facilities, but differences in the design and operation of dairies in the San Joaquin Valley as well as seasonal variations mean that additional measurements must be made to accurately determine emissions inventories for the region.

https://www.sciencedirect.com/science/article/abs/pii/S1352231008005232

I. Methane emissions from dairy lagoons in the western United States.

Methane generation from dairy liquid storage systems is a major source of agricultural greenhouse gas emissions. However, little on-farm research has been conducted to estimate and determine the factors that may affect these emissions. Six lagoons in south-central Idaho were monitored for 1 yr, with CH_4 emissions estimated by inverse dispersion modeling. Lagoon characteristics thought to contribute to CH_4 emissions were also monitored over this time period. Average emissions from the lagoons ranged from 30 to 126 kg/ha per day or 22 to 517 kg/d. Whereas we found a general trend for greater emissions during the summer, when temperatures were greater, events such as pumping, rainfall, freeze or thaw of lagoon surfaces, and wind significantly increased CH_4 emissions irrespective of temperature. Lagoon physicochemical characteristics, such as total solids, chemical oxygen demand, and volatile solids, were highly correlated with emission. Methane prediction models were developed using volatile solids, wind speed, air temperature, and pH as independent variables. The US Environmental Protection Agency methodology for estimating CH_4 emissions from manure storage was used for comparison of on-farm CH_4 emissions from 1 of the lagoon systems. The US Environmental Protection Agency method underestimated CH_4 emissions by 48%. An alternative methodology, using volatile solids degradation factor, provided a more accurate estimate of annual emissions from the lagoon system and may hold promise for applicability across a range of dairy lagoon systems in the United States.

https://www.sciencedirect.com/science/article/pii/S0022030217305799

J. Generating Methane Gas From Manure.

At first glance, the idea of generating methane gas has considerable merit because it appears to offer at least a partial solution to two pressing problems — the environmental crisis and the

energy shortage. Unfortunately, present-day large-scale methane generation requires rather high investments in money and management, which considerably reduces the idea's practicality. This guide is intended to provide quantitative information so that the feasibility of methane generation can be evaluated for a given situation.

https://extension.missouri.edu/publications/g1881

K. Methane Generation From Livestock Waste.

ADVANTAGES AND DISADVANTAGES OF METHANE GENERATION

Advantages. The main one is that a useful end-product, methane gas, is produced. Also, the odor potential of a well digested livestock waste is considerably reduced. Although digested waste has slightly less fertilizer value than nondigested waste, it is more readily available to plants. It is simply converted to a more useful form.

Disadvantages. There are several that must be carefully considered in assessing the potential of on fore-arm methane generation. * A methane digester is large and expensive. The expense stems from the fact that it must be well-insulated, air-tight and supplied a source of heat. The size of a conventional digester is equal to 15-20 times the daily waste volume produced, or more if the waste is diluted before digestion. The volume of waste that must be disposed of increases accordingly if dilution water is used. * A very high level of management is required. A methane digester can be extremely sensitive to environmental changes, and a biological upset may take months to correct. Methane generation ceases or is very low during an upset. * Start-up--usually the most critical phase of methane generation-is difficult. Methane-producing bacteria are very slow-growing, and several weeks are required to establish a large bacterial population. * Methane is difficult to store, since at normal temperatures the gas can be compressed but not liquefied without special, very expensive equipment. * Finally, methane can form an explosive mixture if exposed to air.

https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2046&context=agext

L. Reactive Organic Gas Emissions from Livestock Feed Contribute Significantly to Ozone Production in Central California.

The San Joaquin Valley (SJV) in California currently experiences some of the highest surface ozone (O_3) concentrations in the United States even though it has a population density that is an order of magnitude lower than many urban areas with similar ozone problems. Previously unrecognized agricultural emissions may explain why O_3 concentrations in the SJV have not responded to traditional emissions control programs. In the present study, the ozone formation potentials (OFP) of livestock feed emissions were measured on representative field samples using a transportable smog chamber. Seven feeds were considered: cereal silage (wheat grain and

oat grain), alfalfa silage, corn silage, high moisture ground corn (HMGC), almond shells, almond hulls, and total mixed ration (TMR = 55% corn silage, 16% corn grain, 8% almond hulls, 7% hay, 7% bran + seeds, and 5% protein + vitamins + minerals). The measured short-term OFP for each gram of reactive organic gas (ROG) emissions from all livestock feed was 0.17−0.41 g-O_3 per g-ROG. For reference, OFP of exhaust from light duty gasoline powered cars under the same conditions is 0.69 ± 0.15 g-O_3 per g-ROG. Model calculations were able to reproduce the ozone formation from animal feeds indicating that the measured ROG compounds account for the observed ozone formation (i.e., ozone closure was achieved). Ethanol and other alcohol species accounted for more than 50% of the ozone formation for most types of feed. Aldehydes were also significant contributors for cereal silage, high moisture ground corn, and total mixed ration. Ozone production calculations based on feed consumption rates, ROG emissions rates, and OFP predict that animal feed emissions dominate the ROG contributions to ozone formation in the SJV with total production of 25 ± 10 t O_3 day^{-1}. The next most significant ROG source of ozone production in the SJV is estimated to be light duty vehicles with total production of 14.3 ± 1.4 t O_3 day^{-1}. The majority of the animal feed ozone formation is attributed to corn silage. Future work should be conducted to reduce the uncertainty of ROG emissions from animal feeds in the SJV and to include this significant source of ozone formation in regional airshed models.

https://pubs.acs.org/doi/full/10.1021/es902864u

M. Emissions of volatile organic compounds (VOCs) from concentrated animal feeding operations (CAFOs): chemical compositions and separation of sources.

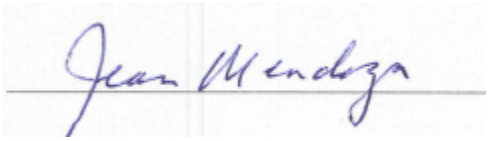
Concentrated animal feeding operations (CAFOs) emit a large number of volatile organic compounds (VOCs) to the atmosphere. In this study, we conducted mobile laboratory measurements of VOCs, methane (CH4) and ammonia (NH3) downwind of dairy cattle, beef cattle, sheep and chicken CAFO facilities in northeastern Colorado using a hydronium ion time-of-flight chemical-ionization mass spectrometer (H3O + ToF-CIMS), which can detect numerous VOCs. Regional measurements of CAFO emissions in northeastern Colorado were also performed using the NOAA WP-3D aircraft during the Shale Oil and Natural Gas Nexus (SONGNEX) campaign. Alcohols and carboxylic acids dominate VOC concentrations and the reactivity of the VOCs with hydroxyl (OH) radicals. Sulfur-containing and phenolic species provide the largest contributions to the odor activity values and the nitrate radical (NO3) reactivity of VOC emissions, respectively. VOC compositions determined from mobile laboratory and aircraft measurements generally agree well with each other. The high time resolution mobile measurements allow for the separation of the sources of VOCs from different parts of the operations occurring within the facilities. We show that the emissions of ethanol are primarily associated with feed storage and handling. Based on mobile laboratory measurements, we apply a multivariate regression analysis using NH3 and ethanol as tracers to determine the relative importance of animal related emissions (animal exhalation and waste) and feed related emissions (feed storage and handling) for different VOC species. Feed storage and handling contribute significantly to emissions of alcohols, carbonyls, carboxylic acids and sulfur-

containing species. Emissions of phenolic species and nitrogen-containing species are predominantly associated with animals and their waste.

https://acp.copernicus.org/articles/17/4945/2017/acp-17-4945-2017.pdf

We understand how time consuming it is to read and digest all this information. But a comprehensive understanding of air emissions from dairies is essential for addressing air quality in Yakima County. Thanks for reading.

Sincerely,



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