General Session

Moderators: Ben Wileman, Brandon Treichler, Dan Altena

Air quality in open-lot dairies and cattle feedyards

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Abstract

The research community is making good progress in understanding the mechanical, biochemical, and atmospheric processes responsible for airborne emissions of particulate matter (PM, or "dust"), gases, and vapors from open-lot livestock production, especially dairies and cattle feedyards. Recent studies in Texas, Kansas, Nebraska, Colorado, California, and Australia have expanded the available data on both emission rates and abatement measures. A national guidance document published by USDA last summer established what researchers believe to be the state of the art in estimating greenhouse-gas emissions from individual facilities. Although the uncertainties associated with our estimates of fugitive emissions are still unacceptably high, we have learned from our recent experience with ammonia that using a wide variety of credible measurement techniques, rather than focusing on 1 so-called "standard" technique, may be the better way to improve confidence in our estimates. The most promising control measures for gaseous emissions continue to be dietary strategies to increase nutrient-use efficiency, with management of corral-surface moisture a close second. For particulate matter, corral-surface management and moisture management may play comparable roles, depending on the mechanical strength of soils and the availability of water, respectively. The cost per unit reduction of emitted mass attributable to these abatement measures varies as widely as the emissions estimates themselves. Therefore, continued emphasis on process-based emissions research to reduce variances in emissions estimates, and to mitigate the contingency of prior, empirically based estimates is necessary. As a general rule, although cattle feedyard emission factors may be considered a reasonable starting point for estimating emissions from open-lot dairies, such estimates should be viewed with suspicion.

Key words: dairy, feedyard, air quality

Résumé

Les chercheurs ont fait de grands progrès dans l'étude des processus mécaniques, biochimiques et atmosphériques qui sont responsables de l'émission de particules fines, de gaz et de vapeur provenant d'élevages de bovins à ciel ouvert tels que les fermes laitières et les parcs d'engraissement des bovins. Des études récentes au Texas, au Kansas, au Nebraska, au Colorado, en Californie et en Australie ont élargi nos connaissances sur les taux d'émission et les mesures de réduction. Un document d'orientation publié par l'USDA l'été dernier a établi, selon les chercheurs, les meilleures méthodes d'estimation des émissions de gaz à effet de serre provenant d'un élevage particulier. Bien que l'incertitude concernant nos estimés d'émissions fugitives soit encore beaucoup trop grande, nous avons appris de notre propre expérience avec l'ammoniac que d'utiliser une vaste panoplie de techniques de mesure crédibles, plutôt que de mettre l'accent sur une méthode soi-disant standard, serait la meilleure façon d'augmenter la confiance dans nos estimés. Les mesures de contrôle les plus prometteuses pour les émissions de gaz impliquent en premier des stratégies d'alimentation pour accroître l'efficacité alimentaire et en proche second la régie de l'humidité des surfaces de l'enclos. Pour les fines particules, la régie des surfaces de l'enclos et de l'humidité peuvent jouer un rôle similaire dépendant de la résistance mécanique des sols et de la disponibilité de l'eau, respectivement. Le coût par unité de réduction de la masse émisse par l'entremise de ces mesures de réduction varie tout autant que les estimés d'émission. Il est donc important de continuer de mettre l'accent sur la recherche des processus gouvernant les émissions afin de diminuer la variance des estimés d'émission et d'atténuer les conséquences des estimés empiriques antérieurs. Même si les facteurs d'émission des parcs d'engraissement de bovins peuvent être considérés comme un bon point de départ pour l'estimation des émissions d'une ferme laitière ouverte, ces estimés devraient être évalués avec circonspection.

Ammonia (NH_3)

The easy, intuitive association between economic losses and NH_3 emissions may be partially responsible for the breadth and intensity of research on fugitive NH_3 during the past decade, resulting in some important conclusions for the open-lot bovine industries. In short, atmospheric NH_3 is wasted protein. Further, we now have what appears to be a rock-solid "rule of thumb" for estimating NH_3 emissions from (at least) cattle feedyards (at least) in the southern High Plains:

> *On an annual basis, a cattle feedyard in the southern High Plains that feeds crude protein (CP) at or below the NRC recommendation (roughly 13.5% of dry matter) will emit half of the fed protein-nitrogen to the atmosphere as NH_3-N.* [29]

On a day-to-day basis, the rule of thumb varies from a winter minimum of about one-third to a summer maximum of about two-thirds, with spring and fall hovering close to the annual value. As one might expect, because the NH_3 emissions are dominated by flux from the manure-covered corral surfaces, the primary seasonal influence is corral surface temperature, which is influenced in turn by seasonal variations in solar radiation, air temperature, and wind speed. The increased summertime emissions seem likely also to result from wintertime *banking*, or a net storage of surplus N in the corral surface resulting from reduced wintertime emissions.

The magnitude of economic losses associated with fugitive NH_3 emissions is impressive. Using the spot price of urea (~45% N, assuming adjunct ingredients) as an illustrative benchmark, say $275 per ton, gross annual emissions of NH_3-N amount to losses of roughly $27/yr per head of feedyard capacity. For a 40,000-head feedyard, that is on the order of a million dollars a year in purchased nitrogen going off to the atmosphere.

Of course, a certain amount of that so-called "wasted nitrogen" is biologically irreducible, by which I mean principally this—a beef steer that does not urinate is not alive anyway. So I hesitate to make too much of the economic significance of this apparent "waste" of nitrogen, particularly for a biological system, in which keeping the livestock alive and producing is the first order of business. The proportion of that $27/hd-yr that is actually wasted, in a biological sense, is essentially the amount of progress still available for nutritionists and geneticists and breeders to make on our behalf. Those specialists have their marching orders.

Finally, the wide use of by-product feeds, especially distillers' grains (DG), is probably the most important development in both the economics and the environmental significance of NH_3 emissions from cattle feeding. As you all know better than I, it does not take much DG in the diet to exceed the 13.5% threshold in dietary CP on which our "rule of thumb" is predicated. Nearly all of the nitrogen fed beyond that threshold will be lost as NH_3, and would best be priced at the rate associated with DG market prices, not feed-grade urea. As with all such calculations and "rules of thumb," your mileage may vary.

With the grand caveat clearly in view – *all bovines are not created equal* – it is reasonable to suppose that a similarly credible rule of thumb will eventually apply to open-lot dairies[5,20] as well. But as front-line, scientific practitioners, AABP members, regulators, policy makers, and so forth need to remember that the specific, numeric values in a dairy "rule of thumb" are likely to differ from those associated with cattle feeding, primarily because the nitrogen-use efficiencies of the 2 animals are different. The principles at work, however, are not in significant dispute, and once the urinary nitrogen is excreted, the subsequent processes don't really care whether it came from a dairy cow or a beef steer.

Hydrogen Sulfide (H_2S)

As a major environmental pollutant from open-lot cattle feeding, hydrogen sulfide (H_2S) does not appear to merit a lot of attention, as recent research[18,25] has shown. The primary rationale for public interest in H_2S in the last decade has had at least 4 components:

1. Occupational exposure to H_2S in enclosed livestock facilities has been responsible for numerous on-farm fatalities, and its toxicity at high concentrations is widely known;
2. Many states have adopted ambient air quality standards for H_2S and have executed enforcement actions against suspected sources;
3. The list of "hazardous substances" subject to monitoring and reporting requirements under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA[a]) and the Emergency Planning and Community Right-to-Know Act (EPCRA[b]) includes H_2S and its higher-profile cousin and conversational sidekick, NH_3; and
4. Any industry that emits a gaseous pollutant prominently associated with the petroleum industry, including H_2S, is inevitably painted with the same brush in popular conversation.

As it pertains to open-lot livestock production, whereas NH_3 is emitted more or less continually from a manure-covered corral surface, H_2S behaves much differently and tends to be associated with episodic, short-term, rainfall-driven bursts from runoff holding ponds. As a result, calculating emission fluxes from concentration measurements and atmospheric-turbulence data (e.g., using dispersion modeling) is fraught with greater difficulty and uncertainty. Although it is not completely clear that H_2S emissions can be reliably scaled with animals-on-feed numbers, the emission factors most frequently used in EPCRA reporting instruments for open-lot bovine facilities[14,16,17] are in the range of 0.005 to 5.0 lb of H_2S per 1,000 head per day. Because of the highly rainfall-driven nature of H_2S emissions processes, emission factors vary dramatically across climate zones, facility designs, and manure-management systems. Abatement measures for H_2S from open-lot facilities would center, accordingly, on runoff management, pond dewatering, and enhancing corral-surface drainage. In addition, sulfur-rich by-product feeds like DG and high-sulfate drinking water may be managed in the context of dietary requirements.

The notoriety of a potentially lethal air pollutant like H_2S, which has long been known as a by-product of livestock agriculture, together with a spate of federal litigation against livestock and poultry facilities under CERCLA and EPCRA, put H_2S emissions from animal agriculture under close scrutiny. Researchers responded with a few notable studies[19,27] that, at least for now, and at least for open-lot livestock production, have put the H_2S question on a low simmer. Longer-term studies of chronic health effects associated with very low levels of H_2S[26,30] may eventually renew attention on sulfur dynamics in cattle feeding. In addition, the re-listing of H_2S as a "hazardous air pollutant" is always a possibility given the ongoing pressure on EPA from environmental advocacy groups.[11]

Greenhouse Gases (GHG)

It appears that the public emphasis on greenhouse gas (GHG) emissions from livestock production is here to stay, especially with respect to bovines. A great deal of research is underway to develop a process-based understanding of how the major GHGs – carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (NO_2) – are produced and emitted throughout the life cycle of beef and dairy production. As with NH_3 and H_2S, to some extent the emissions of CO_2 and CH_4 to the atmosphere represent a waste of valuable, metabolic potential energy and nutrition for the livestock. Consequently, the primary focus for reducing those emissions is and must be the animal diets themselves, along with any animal- or facility-management tactics that increase the animals' feed conversion and reduce maintenance requirements.

The literature on bovine GHG emissions is vast and growing rapidly as a result of the burgeoning research portfolios at the federal, state, and even international levels. During the summer of 2014, USDA released a massive guidance document co-authored by a multi-state team of animal scientists, soil chemists, agronomists, and engineers.[12] The authors surveyed the literature, broadly construed, and identified the best available process-based and empirical models for calculating GHG emissions at the "entity" scale (meaning, for all practical purposes, the farm scale). Farm-scale resolution, coupled with (a) ever-improving grasp of the emissions processes, (b) how those processes are controlled and throttled, and (c) how spatially and temporally varying climatic regimes influence those process behaviors, promises a long-term increase in the reliability and credibility of larger-scale emissions inventories and source-apportionment ledgers used to meet various regulatory and economic objectives.

Particulate Matter (PM)

Emissions of fugitive dust from open-lot cattle-feeding and dairy operations remain a vexing problem, not because we have no idea how to control them, but because controlling them can be an expensive proposition.[2,8,9,21] These livestock-derived emissions tend to be a local to regional concern rather than a national one, although some forms of soil-derived particulate matter can circulate the globe and exert significant ecological stress.[13] The primary regulatory venue for livestock dust is still nuisance litigation, although State Implementation Plans for agricultural dust increasingly prescribe abatement measures for cattle feedyards and dairies among the larger category of agricultural PM emissions.[1] Low confidence in the quality and reliability of emission estimates developed for PM from open-lot livestock facilities in the United States led EPA to withdraw its guidance document for the states in the late 1990s.

The dominant conceptual model of fugitive PM emissions from these 2 livestock categories describes the emission process as driven primarily by hoof action on dry, unconsolidated manure on the corral surface, with wind scouring a distant second.[3] The main control measures follow logically from that model: active water application via sprinkler systems or water trucks,[6] surface treatments to absorb shear energy from animal hooves,[15,24] and strategic management of manure-harvesting operations.[4] Several cattle feedyards in the Plains and West have experimented with passive moisture application through stocking density manipulation; the first systematic, peer-reviewed, commercial-scale evaluation of that strategy is scheduled for publication in the fall of 2014.[10]

Endnotes

[a]The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, a. k. a., "Superfund;" PL 96-510, 1980).

[b]The Emergency Planning and Community Right-to-Know Act (EPCRA; PL 99-499, 1986).

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