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Methane emissions from southern High Plains dairy wastewater lagoons in the summer

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ABSTRACT

Methane is a greenhouse gas with a global warming potential 25-fold that of CO_2, and animal agriculture is recognized as a source of CH_4 to the atmosphere. Dairy farms on the southern High Plains of New Mexico and Texas (USA) are typically open lot, and sources of CH_4 are enteric emissions from cattle and wastewater lagoons. Uncovered anaerobic lagoons are identified by the US Environmental Protection Agency as a source of CH_4 in dairy manure management systems. Our objective was to quantify summer CH_4 emissions from wastewater lagoons of a commercial dairy farm in eastern New Mexico. Research was conducted during 8 days in August (2009) at a 3500 cow open lot dairy farm with flush alleys. Methane concentration over three lagoons (total area of 1.8 ha) was measured using open path laser spectroscopy. Background CH_4 concentration was measured using a back-flush gas chromatography system with flame ionization. Wind and turbulence data were measured using a three-axis sonic anemometer. Emissions were estimated using an inverse dispersion model. Methane concentrations in the air over the lagoons ranged from 3 to 12 ppm, and averaged 5.6 ppm, with a background CH_4 concentration of 1.83 ppm. Methane flux density (*i.e.*, emission rate/unit area) ranged from 165 to 1184 $\mu g/m^2/s$, with a mean daily CH_4 flux density of 402 kg/ha/d. Methane emission rate averaged 0.211 kg/head/d. Uncovered anaerobic lagoons were a source of CH_4 emitted from this southern High Plains dairy farm, and lagoons could be a control point for emission reductions.

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1. Introduction

Methane is second to CO_2 in atmospheric radiative forcing (*i.e.*, effect on the earth's radiation balance), providing about 20% of the positive radiative forcing of long lived greenhouse gases (IPCC, 2007). Though present in the atmosphere at a relatively low concentration (~1.8 ppm), its global warming potential is 25 times that of CO_2 over 100 years. Methane

Abbreviations: BLS, backward Lagrangian stochastic; CO_2e, carbon dioxide equivalent; CP, crude protein; DIM, days in milk; DM, dry matter; DOY, day of year; GHG, greenhouse gas; MMS, manure management system.

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Table 1
Cattle population and composition of key feed ration components.

Cow type	Population (head)	DM intake (kg/hd/d)	Crude protein (g/kg)	Neutral detergent fiber (g/kg)	Acid detergent fiber (g/kg)	Fat (g/kg)
Milking	2541	25.1	174.5	347.4	211.9	47.0
Fresh	261	21.5	167.3	384.3	232.5	39.0
Dry (close-up)	168	13.4	151.7	418.8	311.4	21.0
Dry (far-off)	522	13.5	135.8	357.2	226.2	30.0

concentration increased from its pre-industrial concentration of 0.7 ppm to 1.7 ppm by the early 1990s. Beginning in the mid-1980s, the rate of increase of atmospheric CH_4 decreased to near zero during 2000–2006 (Steele et al., 1992; Bousquet et al., 2006). However since 2007 this trend has reversed and CH_4 concentration has increased about 7 ppb/year (Rigby et al., 2008).

Methane comprised 9.6% of US CO_2 equivalent (CO_2e) greenhouse gas (GHG) emissions in 2007 (EIA, 2008). Major sources of CH_4 emitted to the atmosphere in the US GHG inventory include fossil fuel energy production systems (39%), landfills (24%), enteric fermentation by ruminant livestock (20%) and animal waste (9%). USDA (2008) estimated that dairy cattle were responsible for 20% of the 259 Tg of livestock CO_2e emissions in 2005, second to beef cattle (65%). Dairy cattle emitted 25% of enteric CH_4 emissions, and 46% of CH_4 from managed livestock waste (USDA, 2008).

The US Environmental Protection Agency (EPA, 2009) ruled that livestock facilities with manure management systems (MMS) that emit more than 25,000 t CO_2e/year were required to report CH_4 and N_2O emissions. Manure management systems include uncovered anaerobic lagoons, liquid/slurry systems, solid manure storage and dry lots. The threshold for dairies to report is an average annual animal population of 3200. Although the MMS portion of the mandatory GHG reporting rule is not currently in force because US Federal Congress prohibited expenditure of funds to implement it, accurate and comprehensive data on GHG emissions from dairy farms are needed for potential regulatory demands and for national and international GHG inventories.

Our objective was to quantify CH_4 emissions during summer from an uncovered anaerobic wastewater lagoon at a commercial dairy farm typical of those in operation on the southern High Plains of New Mexico and Texas (USA).

2. Materials and methods

2.1. Research site and dairy management

The research was conducted from 8 August 2009 to 15 August 2009 at a commercial dairy farm located in Curry County, New Mexico (USA), which was judged to be typical of dairy farms in eastern New Mexico and western Texas (Fig. 1). Cows were housed in open lot soil/manure surfaced corrals (from 82 to 96 m × 225 m), with a total area of 22.5 ha. A 7 m × 192 m sun shade was provided in each corral. Feed lanes were surfaced with concrete, and flushed on an irregular schedule with lagoon waste water to remove accumulated manure. Flushed effluent entered a 700 m canal that flowed into a sump pit. From there effluent was pumped to a solids separator before it entered the lagoon system.

The lagoon system consisted of 4 lagoons. During the study, the first 3 lagoons (1.8 ha surface area) contained effluent and the fourth was dry. A pump that operated intermittently near the inlet of the first lagoon pumped solids back to the separator. The first lagoon (east) was connected to the second (west) by a 2 m wide surface channel, while the third lagoon (south) only received effluent that overflowed from the first lagoon. Water from the first lagoon was periodically pumped to the north end of the dry lot and recycled as flush water. Information from dairy management and random soundings indicated that water depth was generally 1–2 m and bottom sludge depth was 0.25–0.5 m.

The dairy was only populated with lactating and dry cows, ~3500, with 73% being in lactation (average 150 days in milk (DIM)), 7% fresh (average 20 DIM) and 20% dry (Table 1). Dry matter (DM) intake averaged 25.1 and 21.5 kg/head/d and crude protein (CP) was 167.3 and 174.5 g/kg (DM basis) for milking and fresh cows, respectively. The DM intake was 13.4 and 13.5 kg/head/d, and CP was 151.7 and 135.8 g/kg for close up and far off dry cows, respectively. During the study period, milk production averaged 29.2 kg/head/d.

2.2. Micrometeorological measurements and flux quantification

Methane concentration at the lagoons was measured using an open path tuned diode laser (Gasfinder 2.0, Boreal Laser, Inc., Spruce Grove, AB, Canada) deployed at a height of 1.65 m. Prevailing wind direction was southerly, so the laser path was positioned either along the north side of the lagoons (day of year (DOY) 219–223, path length 233 m) or diagonally from northeast to southwest across the lagoons (DOY 224–227, path length 239 m; Fig. 1). The laser path was changed during the morning of DOY 224 to include easterly winds. The laser measured CH_4 concentration every 35 s. The open path laser was calibrated using standard gas concentrations in the laboratory after completion of the study and a calibration factor of 1.26 used to adjust measured concentrations, which were then averaged into 15 min mean concentrations. Background CH_4 concentration was measured at a location 75 m south of the southwest corner of the open lot corrals and 680 m west of the lagoons using a back-flush gas chromatography system with flame ionization detector (Model 55I, Thermo Scientific,