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Hydrogen Sulfide Concentration in Vicinity of Beef Cattle Feedlots

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Summary

A field survey of Total Reduced Sulfur (TRS) concentrations in the vicinity of beef cattle feedlots was conducted to compare field observations against current regulatory thresholds. It was observed that TRS levels in the vicinity of beef cattle feedlots are not likely to exceed current regulatory thresholds used by Nebraska. It was further noted concentration of TRS varies with air temperature and time of day. However, wet feedlot surface conditions had almost no impact upon observed TRS concentrations. Feedlots typically do not contribute significant hydrogen sulfide emissions and are unlikely to produce concentrations in excess of current Nebraska Department of Environmental Quality regulatory limits.

Introduction

In 1997, the Nebraska Department of Environmental Quality amended Title 129 Air Quality Regulations to establish a regulatory threshold for Total Reduced Sulfur (TRS) concentrations under ambient conditions. These thresholds are set at "10.0 parts per million (10.0 PPM) maximum 1 minute average concentration or 0.10 parts per million (0.10 PPM) maximum 30-minute rolling average."

TRS emissions, including hydrogen sulfide (H_2S), from livestock systems increasingly are being implicated with community health concerns. The Agency for Toxic Substances and Disease Registry, the federal agency charged with evaluating possible general public health risks form chemicals released at waste sites recently published recommended Minimal Risk Levels for H_2S. An intermediate (15 to 364 day exposure) and an acute (1 to 15 day exposure) inhalation minimum risk level is defined at 30 and 70 ppb daily average exposure, respectively (ATSDR, 1999).

This growing scrutiny prompted a field survey of TRS levels in the vicinity of typical feedlots in central Nebraska. The intent of this research was to:

1. Compare field observations from the vicinity of beef cattle feedlots against current regulatory thresholds for Nebraska (0.1 ppm TRS 1/2 hour average), Minnesota (0.03 ppm H_2S 1/2 hour average), and Iowa (proposed to be 0.07 ppm H_2S 1 hour average);
2. Identify environmental factors that influence TRS concentration.

Procedure

Two Jerome 631-S analyzers with memory were used to survey TRS concentrations at 15-minute intervals approximately 1 meter from the ground surface. To evaluate field observations, Nebraska's 10.0 ppm maximum, 1-minute average concentration and 0.10 ppm maximum, 30-minute rolling average were used to evaluate regulatory compliance. An on-site meteorological weather station (MicroMet Station) was used to collect wind speed, wind direction, air temperature barometric pressure, and relative humidity at 15-minute intervals.

Surveys were conducted on three feedlots for one-week periods under spring, summer and fall conditions during 2000. A perimeter survey was conducted at 0.2-mile intervals on all four township mile lines surrounding the feedlot. Within the feedlot, data were collected at the center point within the feedlot among the animal pens, at the downwind edge of the feedlot, and at the downwind edge of the runoff holding pond. Typically, one Jerome meter was located at the center of the feedlot for the entire week and the second meter was moved among the three locations for two- to three-day intervals.

A second survey was conducted in 2001 to identify environmental factors that increased the emission of TRS. Two 9-week surveys were conducted during the spring (April 4 through June 9) and summer (July 9 through September 12) of 2001 at a single location at the center of one feedlot with one Jerome meter. During the sampling period, on-site weather data were collected at 15-minute intervals and were matched with TRS observations collected at similar time intervals.

Table 1. Summary of TRS[a] observations within three Nebraska feedlots.

	Feedlot #1			Feedlot #2			Feedlot #3					
	Spr	Sum 2000	Fall[c]	Spr	Sum 2000	Fall	Spr	Sum 2000	Fall	Spr 2001	Sum 2001	Total
Center of Feedlot												
TRS > 1.0 (single observ.)	0	0	0	0	0	0	0	0	0	0	0	0
TRS > 0.1 PPM												
Single observations:	7	3	0	17	3	10	1	13	3	3	3	63
Running Average:	6	0	0	17	1	2	0	8	3	0	0	37
3 consecutive observations[b]:	0	0	0	2	0	0	0	0	0	0	0	2
Average TRS concentration[a]	0.010	0.012	0.001	0.028	0.037	0.009	0.006	0.014	0.002	0.006	0.008	
Number of observations	902	320	190	904	683	640	1249	558	854	5803	6115	18,218
Feedlot Edge												
TRS > 1.0 (single observ.)	0	0	0	0	0		0	0				0
TRS > 0.1 PPM												
Single observations:	9	1	0	1	0		0	4				15
Running Average:	9	0	0	0	0		0	6				15
3 consecutive observations[b]:	0	0	0	0	0		0	0.008				0
Average TRS concentration[a]	0.013	0.009	0.005	0.007	0.006		0.008	0				
Number of observations	251	343	496	184	176		118	180				1748
Holding Pond Edge												
TRS > 1.0 (single observ.)	1	0		0	1	0	0	0				2
TRS > 0.1 PPM												
Single observations:	2	2		1	4	0	1	3				13
Running Average:	6	3		0	9	0	3	0				21
3 consecutive observations[b]:	0	0		0	0	0	0	0				0
Average TRS concentration[a]	0.001	0.009		0.009	0.006	0.002	0.012	0.0008				
Number of observations	228	255		355	283	353	283	185				1942

[a]TRS is reported as parts per million H_2S equivalent .
[b]Three consecutive observations at 15-minute intervals would approximate situations where TRS levels exceeded the 0.1 PPM 30-minute average regulatory threshold for Nebraska.
[c]Most observations occurred after a six-inch blowing snow.

Table 2. Summary of daily TRS[1] level relative to rainfall events at feedlot #3 in 2001.

Day	Event 1		Event 2		Event 3		Event 4		Event 5		Event 6	
	April 7 - 16		May 1 - 10		May 17 - 26		May 27 - June 5		Aug. 11 - 20		Aug. 20 - 29	
	Rainfall (mm)	Average TRS (PPM)	Rainfall (mm)	Average TRS (PPM)	Rainfall (mm)	Average TRS (PPM)	Rainfall (mm)	Average TRS (PPM)	Rainfall (mm)	Average TRS (PPM)	Rainfall (mm)	Average TRS (PPM)
-3	0.4	0.004	0.8	0.007		0.008		0.008		0.007		0.008
-2	0.1	0.003	14.9	0.006		0.007		0.007		0.008		0.008
-1		0.004	5.2	0.006	1.2	0.007	9.6	0.006		0.007		0.007
0	16.0	0.002	72.9	0.004	17.7	0.007	40.4	0.007	26.0	0.009	20.0	0.007
1	5.8	0.003	9.1	0.007		0.007		0.007		0.008		0.007
2		0.003		0.007	0.7	0.007	0.1	0.006		0.005		0.006
3		0.002		0.004		0.006		0.006		0.007		0.006
4		0.003			0.2	0.005	17.9	0.007		0.006		0.007
5						0.007	2.2	0.003		0.005		0.007
6	0.2	0.007				0.008	1.2	0.006		0.008		0.006

[1]TRS concentrations are reported as an H_2S equivalent. See Procedure section.

Results

Perimeter Observations

To determine the impact of feedlot TRS emissions on the community, a survey of neighborhood concentrations was completed on the township mile lines surrounding the feedlot. The average TRS levels at these locations ranged from 0.002 to 0.006 PPM (parts per million by volume) for all three feedlots. The peak observation was 0.030 PPM, well below the regulatory thresholds for Nebraska. The 0.030 PPM reading was observed at a location about one mile from the feedlot and based upon other observations and readings at nearby

(Continued on next page)

locations, it appeared to be an isolated observation not related to the feedlot. Other higher than normal values were from locations directly next to the feedlot facilities. However, the perimeter observations provided no indications of TRS levels that might exceed regulatory thresholds.

About 3,700 observations were made at a location a few meters immediately downwind (based on prevailing winds) from the feedlot and holding pond (Table 1). Only two observations exceeded Nebraska's 10 ppm, 1-minute standard, both at the edge of the holding pond. The 30-minute running averages exceeded Nebraska's 0.1 ppm, 30-minute standard on 36 occasions (15 and 21 occurrences at the edge of the feedlot and holding pond, respectively). However, the calculated running average from this survey was based upon 3 data points and often heavily influenced by a large single observation. No situations were observed where three consecutive readings exceeded Nebraska's 0.1 ppm, 30-minute standard.

Based on observations at the edge of the feedlot and holding pond, few differences were observed among the three feedlots. Average TRS concentrations were similar with most averages being less than 0.01 ppm. Feedlot 1 experienced more single point observations above common regulatory thresholds at the feedlot edge location. Feedlot 2 experienced higher rates of observations above these thresholds at the holding pond edge. However, average TRS concentrations were similar among all three feedlots and all were low relative to regulatory thresholds and ATSDR defined minimum risk levels based upon inhalation.

Feedlot Center Observations

At the center of the feedlot, spikes in TRS concentration that may exceed a property line threshold were common, but sustained levels (30 minute periods) were not. More than 18,200 observations were made at the center of the feedlots. Sixty-three single point observations exceeded a 0.1 PPM level. However, even at the center of the feedlot sustained TRS levels exceeding the 0.1 ppm (2 occurrences or 0.01 % of observations).

Several environmental factors have the potential to impact TRS concentrations. TRS levels increased linearly with air temperature between 0 and 35°C (Figure 1). A 20°C rise in air temperature correlated to a doubling of observed TRS concentration. Increased soil temperatures should contribute to increased soil microbial activity and greater production of volatile sulfur compounds. Soil temperature, not measured in this experiment, would be expected to track changes in air temperature.

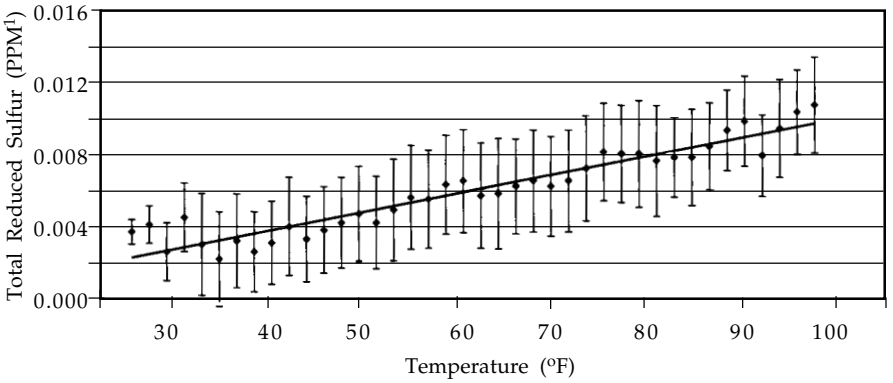

Figure 1. Average TRS concentration (± one standard deviation) vs. Air Temprature for Feedlot #3 during Spring 2001.

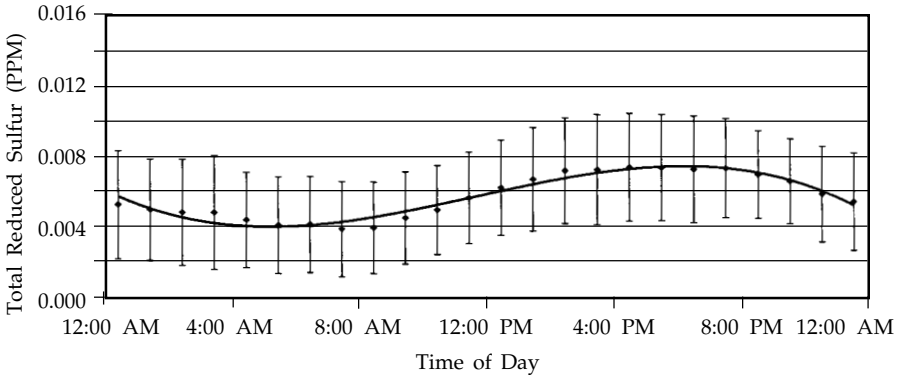

Figure 2. Average TRS concentration (reported as an H_2S equivalent) vs. time of day for feedlot #3 during Spring 2001.

A strong diurnal pattern was observed for TRS concentration (Figure 2). Peak concentrations were observed during mid-afternoon and the lowest concentrations occurred during early morning hours. Afternoon concentrations were approximately twice those observed during the early morning. Several factors will impact daily TRS concentrations.

Soil temperature and animal activity may provide the most plausible explanation of this diurnal pattern. Soil surface temperature, which impacts microbial action and TRS production, would increase during daylight and decline during the night similar to the pattern observed for TRS. Animal activity would tend to increase during the morning hours as a result of feeding practices and during late afternoon and evening

hours as temperatures cool. The late afternoon TRS peak is at a similar time as the late afternoon peak in animal activity. Peaks in animal activity commonly are correlated with feedlot dust emissions (Auverman, 2001). Thus, soil temperature and animal activity are potential factors contributing to the observed diurnal TRS levels at the feedlot's center.

It was anticipated that feedlot surface moisture level would influence TRS concentration. Wet feedlot conditions, conducive to bacterial activity, and anaerobic conditions should result in greater TRS production. Feedlot surface conditions in Nebraska vary dramatically based upon weather conditions. The extended sampling during the spring and summer of 2001 was conducted in hopes of capturing the effects of volatile sulfur production under muddy feedlot surface conditions.

Six rainfall events occurred during the spring and summer 2001 sampling periods. TRS levels between 3 days before and 6 days after significant (>15mm) rainfall events are summarized in Table 2. For much of the early spring 2001, wet feedlot conditions were common. Summer feedlot surface conditions were typically very dry with short wet periods following a rainfall event. The TRS concentration for the days following rainfall events did not rise above the levels observed before or on the day of rainfall events (see Table 2). No increase in TRS levels could be attributed to wet feedlot conditions.

Based upon the observations made in this survey of Total Reduced Sulfur (TRS) concentrations (expressed as a hydrogen sulfide equivalent) in the vicinity of cattle finishing feedlots, the following conclusions were drawn:

- Sustained levels of TRS at the township mile lines and prevailing downwind edge of the feedlot and holding pond above the regulatory thresholds for Nebraska, Iowa (proposed) and Minnesota, were extremely rare. TRS concentration in the vicinity of beef cattle feedlots are unlikely to exceed common regulatory thresholds or health risk levels identified by ATSDR.
- TRS levels increase linearly with increasing air temperature. It is anticipated that warming of feedlot surface is partially responsible for the increased production of TRS.
- A diurnal pattern was observed for TRS concentrations with peak levels occurring in mid-afternoon. This pattern is also likely attributable to varying feedlot surface temperature and possibly animal activity.
- TRS level was not influenced by rainfall events or wind speed. Transiently wet feedlot surface conditions do not appear to increase TRS emissions.

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