Nitrogen Enrichment of Surface Water by Absorption of Ammonia Volatilized from Cattle Feedlots

Abstract. *Apparatus designed to measure absorption of ammonia from the air by aqueous surfaces was installed near several cattle feedlots and in appropriate control areas. Ammonia absorption rates measured near feedlots were as much as 20 times greater than near the control. Their magnitudes indicate that absorption of ammonia volatilized from cattle feedlots contributes significantly to the nitrogen enrichment of surface water in the vicinity of feedlots.*

Concern over the nitrogen pollution hazard created by large livestock feeding operations has focused on the nitrogen in runoff and the nitrate in deep percolation from cattle feedlots (*1*). The third mode of nitrogen loss from feedlots—volatilization of nitrogenous gases, primarily ammonia, into the atmosphere—has been ignored as a contributor to soil and water pollution. Direct absorption of atmospheric ammonia by lakes and streams could contribute to their eutrophication, thereby reducing their value for recreational and domestic uses. Ammonia absorption by cultivated soils could increase their fertility and reduce their requirement for nitrogen fertilizer.

The odor of ammonia is common around feedlots and other areas where livestock and poultry are confined. Laboratory studies indicate that as much as 90 percent of the nitrogen in urine excreted in cattle feedyards may escape into the air as ammonia (*2*). We found that a significant amount of ammonia volatilized from the surface of cattle feedlots is absorbed from the air by water surfaces in the vicinity of the feedlot. The magnitude of nitrogen enrichment of lakes via this pathway can be large as compared to other sources of nitrogen pollution. Based on our measurements, Seeley Lake, about 2 km from a feedlot consisting of 90,000 units in northeastern Colorado, absorbs enough ammonia from the air in 1 year to raise its nitrogen concentration by 0.6 mg/liter. Sawyer *et al.* (*3*) have suggested that 0.3 mg per liter of inorganic nitrogen is the critical concentration beyond which algal bloom can normally be expected in a lake. The total nitrogen concentration of Seeley Lake averaged about 2 mg/liter during the period of measurement, while inorganic nitrogen ranged from 0.2 to 0.4 mg/liter.

The objective of our research was to determine the rate at which ammonia is absorbed directly from the air by aqueous surfaces under different conditions of temperature and climate at various distances and directions from feedlots. Simultaneously, the amounts of ammonia in rain and snow were measured.

To estimate the rate of absorption of atmospheric ammonia by aqueous surfaces under various existing field conditions, specially constructed traps were built that contained an absorbing surface of dilute acid of 240 cm^2. The absorbing surface was protected from rain by a sheet-metal roof and from birds and insects by enclosing the trap in wire-mesh screen. Dilute acid (approximately $0.01N$ H_2SO_4) was used instead of water to increase the ammonia-retention capacity of the traps and to minimize biological transformation of absorbed ammonia to organic nitrogen compounds or to nitrate. Dilute acid absorbs ammonia at about double the rate of demineralized water as will be discussed later.

An ammonia trap and a rain gauge were installed at each of five sites near feedlots and in two control areas, all in northeastern Colorado. The amount of ammonia collected by the traps was measured at weekly intervals from 27 July 1968 through 27 February 1969. Ammonia analysis was accomplished by steam distillation with magnesium oxide according to the method of Bremner and Keeney (*4*).

A brief description of the seven experimental sites, including the location of the traps with respect to nearby feedlots, is given in Table 1. Site 1 served as the control for the study; it is well isolated from the nearby influence of feedlots, cities, and irrigated fields, all of which were considered possible sources of ammonia. Since all sites near feedlots were also near cities and in irrigated areas where the use of high rates of ammoniacal fertilizers is common, we felt that a second control was necessary to measure the possible influence of these two factors on the amount of ammonia trapped. Site 2 was chosen for this purpose; although it is not entirely removed from all feedlot operations, it meets this criterion as well as any site in the experimental area that is also in an irrigated area near a city. Sites 3 and 4 were chosen so that we could evaluate the influence of average-sized feedlots on the amount of ammonia absorbed, and sites 5, 6, and 7 were chosen to measure ammonia absorption at various distances and directions from a very large feedlot.

Weekly rates of ammonia nitrogen absorption measured at five of the seven experimental sites are plotted in Fig. 1, and the mean rates at all sites are given in column 3 of Table 1. Data from sites 4 and 5 are not included in Fig. 1 because they are not greatly different from the data plotted for sites 3 and 6, respectively. Although weekly rates of absorption of ammonia fluctuated widely, absorption at sites near feedlots was always substantially higher than at the control sites. The difference between sites 1 and 7 was on the average nearly 20-fold. The mean absorption rate at site 7 was 2.8 kg of ammonia nitrogen per hectare per week, and individual values ranged up to 5.7 kg (the ammonia was absorbed in a trap containing dilute acid). Increasing

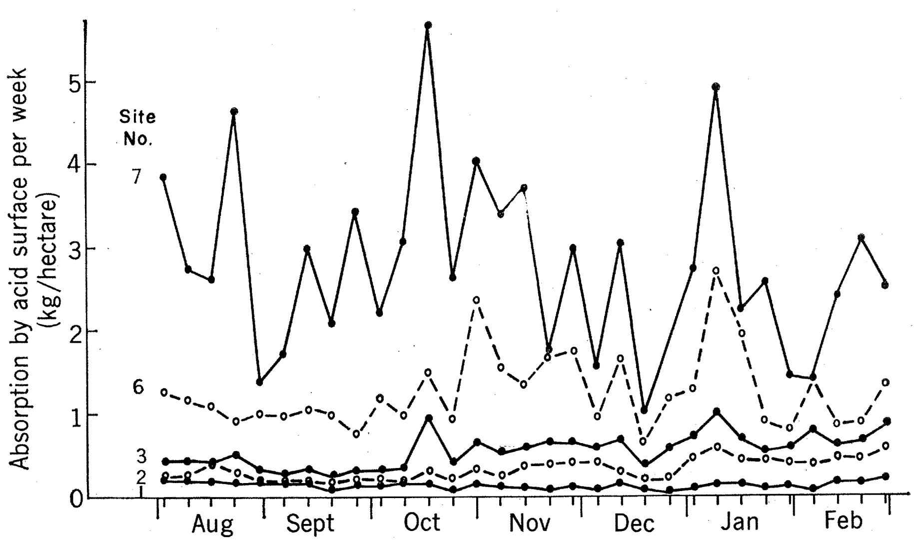

Fig. 1. Weekly absorption of ammonia nitrogen from the air by dilute acid traps placed at five of the seven experimental sites during the period 27 July 1968 to 27 February 1969.

Table 1. Descriptions of the seven experimental sites, weekly absorption (mean) of ammonia nitrogen by dilute acid traps during the period 27 July 1968 through 27 February 1969 (except sites 4 and 5, where measurement began 27 September 1968); estimated annual absorption of ammonia nitrogen by water surfaces; and ammonia nitrogen in precipitation during the period 21 September through 21 November 1968.

Site	Site description	Ammonia nitrogen (kg/ha)		
		Absorption		Precipitation
		Weekly	Annual	
1	No feedlots or irrigated fields within 3 km; no large feedlots or cities within 15 km	0.15	3.9	0.22
2	Only small (less than 200-unit) feedlots within 4 km, none closer than 0.8 km	.34	9.1	.29
3	About 0.2 km east of 800-unit feedlot and 0.6 km west northwest of another similar feedlot	.57	15	.32
4	On northeast shore of Clark Lake and 0.5 km southwest of 9,000-unit feedlot	.62	17	.29
5	On southeast shore of Seeley Lake and 2 km west northwest of 90,000-unit feedlot	1.3	34	.53
6	About 2 km east of 90,000-unit feedlot	1.3	34	.40
7	About 0.4 km west of 90,000-unit feedlot	2.8	73	.61

the distance from the same feedlot by five times (from 0.4 km west to 2 km east) decreased the mean ammonia absorption rate by only about one-half. Records of the U.S. Weather Bureau (*5*) show that the monthly resultant wind directions for 5 months of the 7-month absorption period were between 170° and 200°, which probably accounts for the similarity of absorption rates at the two sites. Apparently, a large feedlot can influence the ammonia absorption rate of an aqueous surface a considerable distance away from the feedlot.

Ammonia absorption rates at sites 3 and 4 near smaller feedlots were lower than those measured at sites 5, 6, and 7, but were still about four times greater than the control, indicating that even smaller feedlots may release sufficient ammonia to have a substantial influence on the water quality of nearby lakes. The ammonia absorption rates at sites 1 and 2 differed little until early in November, when several small feedlot operators in the vicinity of site 2 began using feedlots that had been empty during the summer months. A close comparison of the data obtained at sites 1 and 2 reveals the sensitivity of the dilute acid traps for detecting ammonia in the air and also lends support to the contention that cattle feedlots are the primary source of atmospheric ammonia in the experimental area.

There was no apparent seasonal influence on the amount of ammonia trapped at any of the sites, even though both feedlot surfaces and absorbing acid solutions were completely frozen during some of the winter absorption periods. We believe that the wide fluctuations in weekly ammonia absorption rates are a function of the moisture status of the feedlot surface acting as the ammonia source. Maximum absorption peaks coincided with periods when feedlot surfaces were undergoing rapid drying, and conversely, minimums generally occurred during periods of precipitation or low evaporation.

To aid in interpreting the meaning of our data in terms of rates of ammonia absorption by actual lake surfaces, larger ammonia traps, filled with tap water and completely open to the atmosphere, were installed on the lakes at sites 4 and 5. The larger traps were designed to simulate an actual lake surface as closely as possible and consisted of plastic containers (114 cm in diameter) with circular baffles, floated on wooden rafts in the centers of the two lakes. During three weekly absorption periods, when the ammonia absorption rates of the small dilute acid traps at the two sites ranged from 0.47 to 2.0 kg of ammonia nitrogen per hectare per week, absorption rates by the corresponding lake traps were 0.49 ± 0.04 times as great. This difference in absorption rates is entirely accounted for by the difference in *p*H of the absorbing solutions. When identical small traps, one filled with dilute acid and the other with demineralized water, were placed side by side at site 7, the regression of the absorption rate by water on the absorption rate by acid was $y = 0.51x + 0.17$, and the mean ratio of absorption by water to that by dilute acid was 0.59 ± 0.03.

The conclusion is that, if the values in Fig. 1 and the means in the first data column in Table 1 are divided by 2, they are good estimates of the amounts of ammonia that would have been absorbed by actual lake surfaces at the same sites under the same conditions. This knowledge, along with the observation that there was no apparent seasonal influence on rates of ammonia absorption, was used in estimating annual rates of ammonia nitrogen absorption by water surfaces at each of the seven experimental sites (Table 1). The estimate for site 5 was used to calculate the ammonia absorption value given in the introduction to this report.

Ammonia contained in precipitation at each of the experimental sites during the period 21 September through 21 November 1968 is recorded in the last column in Table 1. At site 1, 22 mm of precipitation was recorded and at the other sites, between 30 and 36 mm. About half was rain, and the rest was snow. Although there was a tendency for the ammonia content of precipitation to increase with proximity to large feedlots, in no case was the amount of ammonia washed from the atmosphere by precipitation very large. The highest value for a single storm was 0.23 kg of ammonia nitrogen per hectare, contained in 14 mm of snow at site 7 on 13 November. Apparently, the amount of ammonia brought down by precipitation is insignificant compared to the amount absorbed directly from the air by aqueous surfaces in the vicinity of cattle feedlots.

Our data upset the prevailing concept that only runoff and deep percolation from cattle feedlots require control to prevent nitrogen enrichment of the surrounding environment. Although control of runoff into streams to prevent pollution by sediment, phosphorus, and organic wastes justifies adequate and often expensive design of feedlot installations, nitrogen pollution can still occur.

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References and Notes

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6. Research was conducted in cooperation with Colorado Agriculture Experiment Station. This report is Scientific Journal Series No. 1439.

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