Ammonium, Nitrate, and Total Nitrogen in the Soil Water of Feedlot and Field Soil Profiles

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A level feedlot, located in an area consisting of Wann silt loam changing with depth to sand, appears to contribute no more \( \text{NO}_3^- \) nitrogen, \( \text{NH}_4^+ \) nitrogen, and total nitrogen to the shallow water table beneath it than an adjacent cropped field. Soil water samples collected at 46, 76, and 107 cm beneath the feedlot surface generally showed \( \text{NO}_3^- \) nitrogen concentrations of less than 1 \( \mu \text{g} / \text{ml} \). During the summer months, soil water \( \text{NO}_3^- \) nitrogen increased at the 15-cm depth, indicating that nitrification took place at the feedlot surface. However, the low soil water \( \text{NO}_3^- \) nitrogen values below 15 cm indicate that denitrification takes place beneath the surface.

The possible movement of nitrogen-containing compounds from feedlot surfaces to groundwater is of serious concern to scientists and laymen alike. This concern is justified when one considers that in Nebraska alone about 3.5 million beef animals are fed annually with about 1.2 million on feed at a given time (8). These numbers are significant, inasmuch as a steer will excrete 0.18 kg of N per day (11), which amounts to approximately 216,000 kg of N deposited on Nebraska feedlots each day. Many of these feedlots are located on permeable soils over shallow water tables. The large quantities of N excreted on feedlots could provide a groundwater pollution hazard. However, to date, the effect of feedlots on groundwater quality is controversial.

Several studies have been conducted on the quality of groundwater beneath land subjected to diversified uses. In Colorado, Stewart et al. (10) found high \( \text{NO}_3^- \) nitrogen levels beneath some corrals and heavily fertilized, irrigated crops. However, they found almost no \( \text{NO}_3^- \) nitrogen beneath other corrals. They felt the low \( \text{NO}_3^- \) nitrogen values were due to denitrification beneath these corrals. In another study, Smith (9) attributed high \( \text{NO}_3^- \) nitrogen levels in some Missouri aquifers to livestock feedlots. In contrast, Mielke et al. (7) found a level feedlot contributed limited \( \text{NO}_3^- \) nitrogen to the groundwater beneath it. This feedlot was located on a coarse-textured soil with a high water table. These studies seem to show that feedlots may or may not allow \( \text{NO}_3^- \) nitrogen to move downward into the groundwater.

Investigations are required to determine why some feedlots may contaminate the groundwater while others do not. If feedlot management schemes are available or can be devised to prevent contamination, research needs to delineate them.

This study was conducted to measure \( \text{NH}_4^+ \) nitrogen, \( \text{NO}_3^- \) nitrogen, and total N compounds present in the soil water from the surface to groundwater in a feedlot and a cropped field.

MATERIALS AND METHODS

The level, beef feedlot studied by Mielke et al. (7) was used as the research site. The feedlot has a permeable soil, in its natural state, over an aquifer that fluctuates between 76 and 305 cm beneath the surface during the year. The water table is lowest at the end of the irrigation season and highest in the spring. The feedlot soil profile consists of a Wann silt loam becoming sandy at 91 cm and changing to sand and gravel at lower levels. The feedlot is stocked at a normal rate of about 1 animal/37 m², and no manure has been removed for the past 15 years. The manure has been mounded the last 2 years. Mounding is practiced as a method of on-site manure disposal, animal comfort, and a feedlot drainage aid. When the feedlot was scraped for mounding, care was exercised to leave a shallow layer of manure on the surface. Mielke et al. (7) found the infiltration rate was slow in the feedlot as a result of a dense layer that formed at the feedlot

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soil surface-manure interface. The thin manure cover was left to preserve the layer. Two caissons were installed in the feedlot, and one was placed in an adjacent cropped field (Fig. 1). The caissons served to protect soil water samplers (in duplicate in caisson) installed in the respective soil profiles at increments of depth (4). The soil water samplers consisted of porous ceramic cups in the soil profile to which vacuum was applied to obtain liquid samples. Samples were collected at 2-week intervals, or as weather permitted, between April 1970 and April 1971.

A Technicon AutoAnalyzer was used to analyze for NO$_3^-$ nitrogen by the hydrazine reduction method of Kamphake et al. (5); NH$_4^+$ nitrogen was determined by the indophenol method of Bolleter et al. (1). Nitrogen was measured by the microkjeldahl method described by Bremner (2).

RESULTS

Average monthly soil water NO$_3^-$ nitrogen levels were low in the feedlot except for the 15-cm samples in late summer and fall (Table 1). The 15-cm soil water NO$_3^-$ nitrogen increased from July through November. Probably this change can be attributed to nitrification near the feedlot surface. Soil water samples were not obtained at the 15-cm level in December and January because the feedlot surface was frozen. The other missing monthly samples were due to the soil being too dry for a suction sample to be obtained.

Soil water NO$_3^-$ nitrogen values in the field varied, but usually were highest in May and June following fertilization and then declined rapidly. Because the field soil was quite dry at the 122- and 152-cm depths during and immediately following the growing crop, only scattered samples were obtained in this period, and these data were not felt to be representative.

The feedlot NH$_4^+$ nitrogen was high in the soil water samples obtained at the 15-cm depth but declined markedly to low levels at 76 and 107 cm (Table 2). The declining trends found with NH$_4^+$ nitrogen were similar to those found for NO$_3^-$ nitrogen. Ammonia values were generally very low in the field soil water samples.

The total N in the feedlot soil water samples (Table 3) was high at the 15-cm depth, but at 46 cm and lower appeared comparable to, or less than, the field values. The highest value obtained from samples taken at 107 cm was 14 µg of total N/ml. Obviously, limited amounts of N-containing compounds were present in the feedlot soil profile. The field total-N samples followed the trends obtained for NO$_3^-$ nitrogen and NH$_4^+$ nitrogen.

Table 4 shows a comparison of average yearly concentrations of the nitrogen compounds beneath a feedlot and a cropped field. The feedlot NO$_3^-$ nitrogen values at 46 cm and below appeared lower than those obtained from the cropped fields. The NH$_4^+$ nitrogen samples from the feedlot and field were similar at 76 cm and below. At these depths, total-N values seem to be higher in the field than in the feedlot. However, the total-N values include the NO$_3^-$ nitrogen values, which were higher in the cropped field. If the NO$_3^-$ nitrogen values are subtracted, the total-N values from 76 cm and below in the feedlot and the cropped field would be comparable.

DISCUSSION

Soil water samples indicate this feedlot contributes low amounts of NO$_3^-$ nitrogen, NH$_4^+$ nitrogen, and soluble N-containing compounds to the groundwater. Samples from the feedlot obtained at the 15-cm depth were high in these compounds; however, at the 76-cm depth the levels appeared as low as, or lower than, comparable field samples.

There was evidence that nitrification took place in the feedlot because NO$_3^-$ nitrogen at the 15-cm depth increased during the summer with no increase at lower depths at any time. In another study, Elliott and McCalla (3) found that reducing conditions existed beneath this feedlot. That report, coupled with the data of Mielke et al. (7) and the information in this paper showing that NO$_3^-$ nitrogen declined rapidly beneath the 45-cm depth, indicates denitrification probably takes place in this
TABLE 1. Average monthly concentrations of NO$_3^-$ nitrogen found in the soil solution samples in a soil profile beneath a feedlot and a cropped field

| Depth (cm) | Feedlot | Field |
|-----------|---------|-------|
|           | Apr     | May   | June  | July  | Aug   | Sept  | Oct   | Nov   | Dec   | Jan   | Feb   | Mar   | Apr   |
| 15        | 0       | 0     | 0.3   | 2.7   | 25.4  | 45.4  | 45.4  | 101.3 | 0.4   | 0.1   |       |       |       |
| 46        | 0       | 0     | 0     | 0     | 0.3   | 0.1   | 0.1   | 0     | 0.5   | 0.5   | 0     | 0     | 1.6   |
| 76        | 0       | 0     | 0.3   | 1.7   | 0.2   | 0.1   | 0.1   | 0     | 0     | 0.1   | 0     | 0     | 0.1   |
| 107       | 0       | 0     | 1.1   | 2.8   | 0.1   | 0.1   | 0.1   | 0     | 0     | 0     | 0.3   | 0     | 0     |
| 30        | 4       | 56.1  | 0     | 2.1   | 0.8   | 0.9   | 2.7   | 4.4   | 11.3  | 9.3   | 17.4  |       |       |
| 61        | 2.2     | 44.4  | 0     | 0.8   | 0.8   | 1.1   | 1.6   | 2.8   | 3.5   | 9.7   | 10.2  | 16.5  |       |
| 91        | 1.8     | 24    | 31.9  | 18.5  | 0.5   | 0.5   | 1.1   | 2.4   | 1.5   | 3.2   | 0.3   | 9.7   | 19.2  |

* Each value represents the average of four to six samples.

TABLE 2. Monthly averages of NH$_4^+$ nitrogen detected in soil solution samples from beneath a feedlot and a cropped field

| Depth (cm) | Feedlot | Field |
|-----------|---------|-------|
|           | Apr     | May   | June  | July  | Aug   | Sept  | Oct   | Nov   | Dec   | Jan   | Feb   | Mar   | Apr   |
| 15        | 32.7    | 205.9 | 349.1 | 462.5 | 817.8 | 593.1 | 662.5 | 530.4 | 586.2 | 613.6 |       |       |       |
| 46        | 1.3     | 23.5  | 36.3  | 28.7  | 48.1  | 34.9  | 28.0  | 25.8  | 3.60  | 27.1  | 34.9  | 51.9  |       |
| 76        | 0       | 2     | 6.0   | 2.9   | 7.4   | 2.2   | 1.7   | 1.7   | 0.7   | 0.5   | 1.2   | 1.3   |       |
| 107       | 0       | 0     | 0.3   | 3.6   | 0.6   | 1.6   | 0.9   | 0.8   | 1.1   | 1.1   | 0.9   | 0.4   |       |
| 30        | 37.1    | 16.5  | 2.8   | 0.5   | 0.9   | 1.3   | 6.0   | 0     | 0     | 0     | 0.1   |       |       |
| 61        | 0.2     | 0     | 0     | 0     | 0     | 0.2   | 0.5   | 1.5   | 0.9   | 0.2   | 0.2   | 0.2   |       |
| 91        | 0.2     | 0.8   | 4.3   | 0     | 1.0   | 1.1   | 0.5   | 0.3   | 1.0   | 0.2   | 0.2   | 0.1   |       |

* Each value represents the average of four to six samples.

TABLE 3. Total nitrogen in soil solution samples taken from beneath a feedlot and a cropped field

| Depth (cm) | Feedlot | Field |
|-----------|---------|-------|
|           | Apr     | May   | June  | July  | Aug   | Sept  | Oct   | Nov   | Dec   | Jan   |       |       |
| 15        | 51.1    | 506.2 | 551.9 | 655.7 | 697.0 | 1,078.0 | 803.7 | 758.0 | 681.3 | 490.0 |       |       |
| 46        | 1.8     | 36.1  | 38.1  | 44.5  | 52.8  | 38.6  | 47.3  | 7.8   | 11.5  | 1.5   |       |       |
| 76        | 0.4     | 13.7  | 8.4   | 12.0  | 12.5  | 7.8   | 11.5  | 9.0   | 9.0   | 1.5   |       |       |
| 107       | 0.1     | 11.3  | 9.9   | 7.6   | 7.4   | 6.6   | 4.6   | 4.0   | 1.6   | 7.8   |       |       |
| 30        | 26.6    | 71.6  | 31.7  | 33.8  | 8.6   | 4.5   | 9.4   | 5.2   | 11.3  |       |       |       |
| 61        | 2.8     | 52.4  | 4.5   | 21.5  | 4.4   | 2.6   | 39.2  | 3.3   | 8.4   |       |       |       |
| 91        | 3.2     | 26.1  | 37.4  | 20.1  | 13.4  | 8.2   | 2.6   | 8.0   | 2.0   | 3.5   |       |       |

* Each value represents the average of four to six samples.

The presence of CH$_4$ (3) and soluble-N compounds indicates that organic matter, which is a requirement for denitrification, is present in the soil profile. Denitrification would account for the fact NO$_3^-$ nitrogen was generally low in the feedlot.

The infiltration rate in this feedlot is low because a dense layer forms at the soil-manure interface (7). However, the samplers at 15 cm are just beneath this dense layer, and these samples did show elevated levels of NO$_3^-$ nitrogen, NH$_4^+$ nitrogen, and total N. Therefore, it is assumed some materials pass through the dense layer. Because soil water NO$_3^-$ nitrogen increased during the summer, it must be assumed nitrification took place in the feedlot and NO$_3^-$ nitrogen did get below the dense layer. In view of the fact low NO$_3^-$ nitrogen was found below this depth, it would seem reasonable to postulate denitrification occurred. It
may be argued that soil water $\text{NO}_3^-$ nitrogen content will fluctuate widely depending on soil moisture. This is true to a point; however, the sampling method will collect a sample only when suction is 0.7 bar, or less. Consequently, this effect would not be great enough to affect seriously the trend of the results.

The literature shows some feedlots may contaminate groundwater, and this particular feedlot would seem a likely candidate. The feedlot has not been cleaned for 15 years and is situated on an originally permeable soil, and the water table fluctuates between 76 and 305 cm from the feedlot surface (7). However, the data presented here and elsewhere (7) show this feedlot does not contaminate the groundwater. Possibly, the answer lies in management. This feedlot is used continuously throughout the year. The surface of the feedlot, when the manure pack is intact, has a low infiltration rate (7). Therefore, it seems that if a feedlot is kept well stocked and the manure pack-soil interface is not disturbed, only limited organic matter and $\text{NO}_3^-$ nitrogen will reach the underground water supply (6). Also, the feedlot soil profile should remain anaerobic.

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