Dairy Feedlot Contributions to Groundwater Contamination

A Preliminary Study in New Mexico

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Abstract

Feedlot milk production has increased dramatically in New Mexico in the past decade, along with the potential for groundwater contamination from animal wastes. State statutes require animal feedlots to maintain groundwater-monitoring wells and report water quality analyses quarterly to the New Mexico Water Quality Control Commission. This preliminary study analyzed six years of groundwater quality data from seven dairy feedlots and found elevated levels of nitrate, ammonia, chloride, total Kjeldahl nitrogen, and total dissolved solids. Samples were obtained from groundwater-monitoring wells located around dairy wastewater lagoons that were lined with clay, concrete, or synthetic membranes. Mean nitrate concentrations were significantly higher in groundwater samples taken in the vicinity of lagoons with clay liners. Lagoons with synthetic liners produced the lowest mean groundwater concentrations of ammonia and nitrate. Mean concentrations for all contaminants tended to increase as the size of dairy herds increased. Nitrate was the only groundwater contaminant measured that showed a consistently increasing trend from 1992 to 1997.

Editor's note:

This paper is the second in a two-part series about the environmental health impact that dairies have on local communities. Part I, published in the July/August 1999 issue of the Journal, *focused on health concerns resulting from groundwater contamination, odor, flies, and dust. Part II addresses the specific problem of groundwater contamination from nearby dairy feedlots and wastewater lagoons.*

Introduction

New Mexico ranks 12th in the nation in amount of milk produced. Growth of this industry has been phenomenal in the last decade—especially in New Mexico. In 1970, milk production in New Mexico totaled 304 million pounds; by 1995 it had increased to 3,623 million pounds (1).

Concern is growing about contamination from dairy feedlots as an environmental point-source pollutant in groundwater. Large dairy herds concentrate organic waste in a relatively small land area. Wastewater from the dairy milking center, including wastes from the milking parlor and wash pens (urine, manure, feed solids, hoof dirt) and from the milk house (bulk tank rinse water and cleaning detergents) can be a threat both to groundwater and to surface water (2). The water use of a 100-cow free-stall operation can range from 100 to 1,000 gallons per day. Wastewater is typically collected in a settling lagoon until conditions are suitable for land application or until the liquid evaporates. Lagoons usually are lined with clay, concrete, or a synthetic material; in some cases they are unlined. The collection of wastewater in a lagoon provides an opportunity to apply best management practices to address environmental contamination.

Many of southern New Mexico's milking operations are located in an established dairy center, called "the dairy belt," which runs along the Rio Grande River to the north and south of the City of Las Cruces in Dona Ana County. The threat of contamination in this dairy belt is significant because the depth to groundwater in the aquifer of the Rio Grande Valley is unusually shallow, ranging from 5 to 25 feet; the alluvial materials are generally permeable and allow relatively rapid movement of contaminants from the surface to the

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TABLE 1

Summary of Contaminant Concentrations for all Dairies and All Wells

Contaminant	Mean Value (mg/L)	Range (mg/L)	Standard (mg/L)
Ammonia	.44	0.01 to 1.44	0.2*
Chloride	975	65 to 2,820	250**
Nitrate	17.8	0.10 to 179	10†
Total dissolved solids	3,170	672 to 6,944	500**
Total Kjeldahl nitrogen	1.7	0.07 to 16.8	—

*New Mexico Water Quality Standard (6)
**National Secondary Drinking Water Regulation (5)
†National Primary Drinking Water Regulation (5)

underlying aquifer; and the shallow groundwater serves as a domestic water source (3).

Pursuant to Section 3-104 of the New Mexico Water Quality Control Commission (WQCC) Regulations, all dairies in New Mexico are required to apply for and maintain a groundwater discharge permit for discharge of wastewater generated from milk production activities (4). Wastewater must be handled in accordance with the approved permit, which specifies either that wastewater is to remain on site, or that it may be discharged onto neighboring agricultural lands. Discharge to an existing waterway is not permitted. So that the threat dairy cow feedlots pose to the groundwater can be understood and measured, all dairies in New Mexico are required to establish and maintain monitoring wells around their wastewater lagoons. In addition, feedlot dairies must collect water samples from each monitoring well on a quarterly basis and submit the samples to an independent laboratory for analysis of nitrate, ammonia, total Kjeldahl nitrogen (TKN), chloride, and total dissolved solids (TDS).

The purpose of this preliminary study is twofold:

1. to report on the analysis of groundwater samples that have been collected from dairy feedlot monitoring wells in southern New Mexico and
2. to assess the relative impacts herd sizes and lagoon linings have on groundwater contaminant levels.

Methods

This study analyzed the results of 313 groundwater samples collected from 26 monitoring wells around seven wastewater lagoons on seven dairies located in southern New Mexico over a six-year period. Water samples were analyzed for nitrate, ammonia, TKN, chloride, and TDS. All data in this study were obtained from the Groundwater Quality Bureau, of the New Mexico Environment Department. Water samples from each dairy previously had been submitted to independent laboratories for analysis of ammonia, nitrate, TKN, chloride, and TDS. Each dairy then reported these data to the state of New Mexico to comply with groundwater discharge permitting requirements. Data were extracted from these reports and entered into SPSS® Version 8.0 for Windows for statistical analysis. Figure 1 indicates the layout of a typical dairy in southern New Mexico, including the relative location of monitoring wells around wastewater lagoons.

Results

As indicated in Table 1, all mean contaminant levels exceeded water quality standards for nitrate, ammonia, chloride, and TDS at all dairies and all wells (5,6). When organic nitrogen and ammonia nitrogen forms are found together, they are measured as Kjeldahl nitrogen. Free ammonia represents the first product of decomposition of organic matter; thus, appreciable concentrations of free ammonia

FIGURE 1

Schematic of Typical Dairy

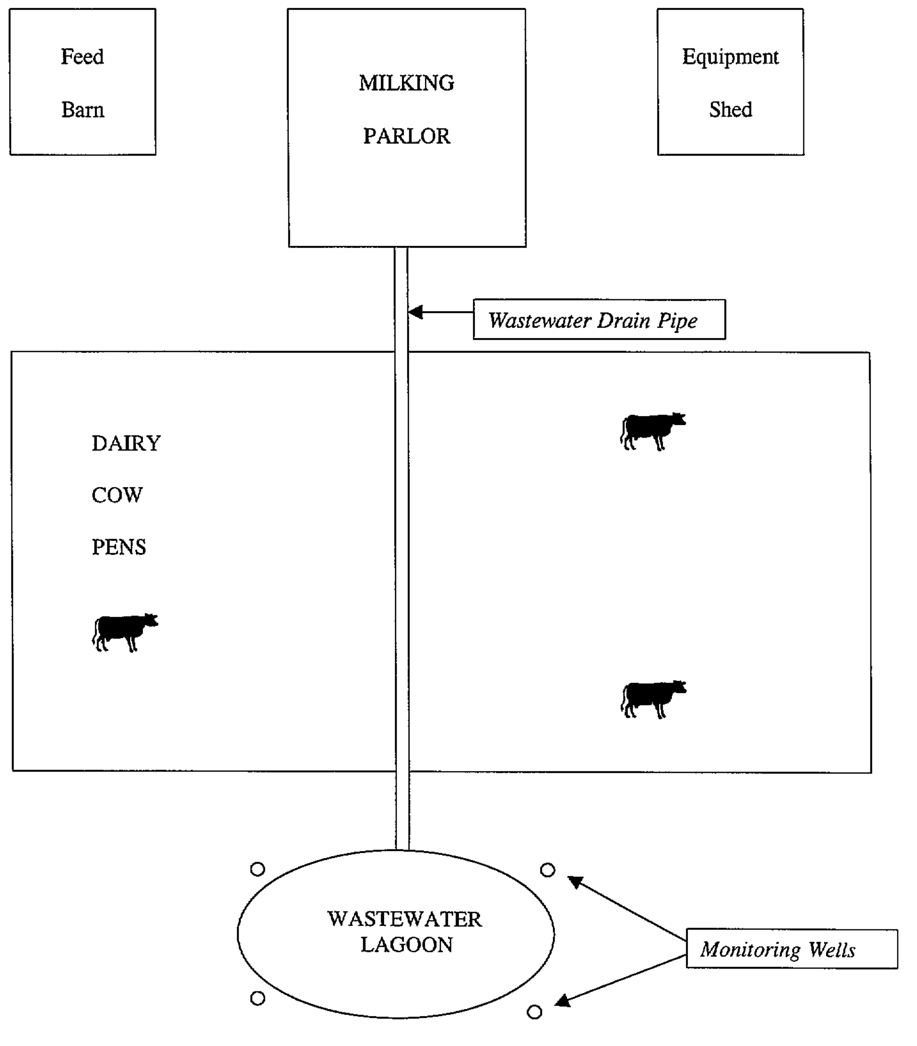

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TABLE 2

Mean Contaminant Levels by Type of Lagoon Lining and ANOVA Results

Lining Types	Nitrate	Ammonia	TKN	Chloride	TDS
Clay	28.7*	.49	1.78	1046	3319
Cement	14.7	.58	1.43	916	3119
Synthetic	7.2	.24*	2.13*	944	3037
F-tests	25.0	8.2	4,405	1.78	1.42
p-values	.0000	.0000	.0130	.1710	.2440

**Tukey honestly significant difference (HSD) post hoc significant at alpha = .05*

usually indicate "fresh pollution" of sanitary significance. The following values may be of general significance in appraising free ammonia content in groundwater:

- low—0.015 to 0.03 mg/L,
- moderate—0.03 to 0.10 mg/L, and
- high—0.10 mg/L or greater.

In the treatment of drinking water, the goal is a concentration less than 0.1 mg/L; however, less than 0.5 mg/L is acceptable (7).

One-way analysis of variance (ANOVA) was performed for each contaminant by type of lagoon lining. Nitrate levels were significantly higher for clay linings. Ammonia levels were significantly lower for synthetic linings, but TKN was significantly higher for synthetic linings. No significant effect was found for chloride and TDS concentrations (Table 2).

One-way ANOVA was performed for each contaminant by the number of cows at each dairy. Nitrate, ammonia, chloride, and TDS levels varied significantly by feedlot size, with smaller contaminant concentrations usually exhibited at smaller dairy herd sizes. TKN did not vary significantly by dairy herd size (Table 3).

No trends in contaminant concentrations were evident for depth of monitoring well or depth to water. Nitrate was the only groundwater contaminant that exhibited an increasing trend over the sampling period (1992 to 1997), as illustrated in Figure 2. Concentrations of the other contaminants showed no meaningful trends over time, remaining relatively stable. No significant correlation was found among contaminant concentrations, except for chloride and TDS ($r = 0.89$, $p = .000$).

Discussion

Despite significant progress in reducing water pollution, serious water quality problems persist throughout the country (8). Animal feeding operations (AFOs) can pose a number of risks to water quality and public health, mainly because of the amount of animal manure and wastewater they generate (8). Manure and wastewater from animal feeding operations have the potential to contribute pollutants such as nutrients (e.g., nitrogen, phosphorus), sediment, pathogens, heavy metals, hormones, antibiotics, and ammonia to the environment. Excess nutrients in water can result in or contribute to eutrophication and anoxia (i.e., low levels of dissolved oxygen); in combination with other circumstances, excess nutrients have been associated with outbreaks of microbes such as *Pfiesteria piscicida* (8).

Approximately 450,000 agricultural operations nationwide confine animals (9). U.S. Department of Agriculture (USDA) data indicate that the vast majority of farms with livestock are small. About 85 percent of these farms have fewer than 250 animal units (AUs) (10). An AU is equal to roughly one beef cow; therefore, 1,000 AUs is equal to 1,000 beef cows or an equivalent number of other animals. In 1992, about 6,600 farms had more than 1,000 AUs and were considered to be large operations (8).

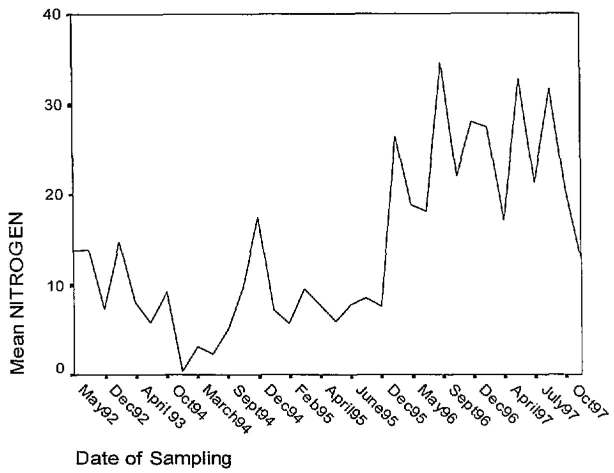
The goal of USDA and United States Environmental Protection Agency (U.S. EPA) is for AFO owners and operators to minimize water pollution from confinement facilities by means of land application of manure. To accomplish this goal, a unified strategy has been established as a national performance expectation: All animal feeding operations should develop and implement technically sound and economically feasible comprehensive nutrient management plans (CNMPs) to minimize impacts on water quality and public health (8).

USDA and U.S. EPA agree that the following minimum components should be included in a CNMP:

- feed management,
- manure handling and storage,
- diversion of clean water,
- prevention of waste containment leakage,
- provide adequate storage of dry manure,
- manure treatment,
- management of dead animals,
- land application of manure,
- nutrient balance,
- timing and methods of application,
- land management, and
- adequate record keeping (8).

FIGURE 2

Trend in Mean Nitrate Concentrations by Sampling Date



In southern New Mexico, discharge options for milking-center wastewater include sprinkler application and slow surface irrigation on neighboring agricultural fields. To maximize nitrogen uptake, the effluent is usually applied to a cropping system that involves both cool and warm season crops. New Mexico regulations limit the amount of nitrogen that may be applied to crops. The maximum is 200 pounds of nitrogen per acre per year or the amount that the crop will take up plus 25 percent, whichever is greater. Forage crops grown year round and harvested regu-

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TABLE 3

Mean Contaminant Levels by Number of Cows and ANOVA Results

Number of Cows	Nitrate	Ammonia	TKN	Chloride	TDS
1,000	11.2	.46	1.55	598*	2,217*
1,200	15.2	.73	1.77	1,266	4,097
1,500	7.8	.17*	1.98	1,118	3,487
2,100	49.4*	.52	1.44	1,206	3,837
3,600	25.1	.52	1.51	1,133	3,393
F-tests	32.1	6.7	.93	27.3	35.2
p-values	.0000	.0000	.4480	.0000	.0000

**Tukey HSD post-hoc significant at alpha = .05.*

larly may take up more than 200 pounds of nitrogen per acre. Applying milking-center wastes to fields at rates that do not exceed crop needs for nitrogen is least problematic for groundwater contamination from effluent or from solid manure. Phosphorous may accumulate to levels that will harm crops, but in New Mexico's typically phosphorous-deficient soils, high phosphorus levels usually are not a problem (2).

New Mexico farmers are working with state agencies to develop guidelines that allow each dairy farmer to submit a single discharge plan. This effort is new, and guidelines are not yet finalized. The single discharge plan must comply with the technical discharge plan requirements of New Mexico Water Quality Control Commission Regulations (WQCC), requirements of the National Pollutant Discharge Elimination System general permit for Concentrated Animal Feeding Operations (CAFO), the New Mexico Environment Department (NMED) Policy for Storage and Disposal of Dairy Wastes, and the Water Quality Act (11).

Conclusions

Analysis of data from this study yielded the conclusions listed below. It is important to emphasize that these are preliminary conclusions based on a fairly small study (313 groundwater samples collected from 26 monitoring wells around seven wastewater lagoons on seven dairies over a six-year period).

1. Mean contaminant concentrations exceeded groundwater quality standards for nitrate, ammonia, chloride, and TDS at all dairies and all wells.
2. Mean nitrate levels were significantly the highest for clay-lined lagoons. Mean TKN, chloride, and TDS levels were slightly higher for clay linings than for cement or synthetic linings. These results suggest that among the three types of linings, clay linings are the least effective at reducing groundwater contamination.
3. Mean ammonia levels were significantly the lowest for synthetic linings. Nitrate and TDS levels were slightly lower than for cement and clay lagoon liners. These results suggest that among the three types of linings, synthetic linings are the most effective at reducing groundwater contamination.
4. Nitrate, ammonia, chloride, and TDS levels varied significantly by feedlot size, with smaller contaminant concentrations exhibited for smaller dairy herd sizes. TKN showed no significant variation by dairy herd size.
5. Mean nitrate concentrations increased during the sampling period; all other contaminant concentrations remained relatively stable.

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REFERENCES

1. Office of the Director/Secretary (1995), *New Mexico Agricultural Statistics*, Santa Fe, N.M.: U.S. Department of Agriculture.
2. Ruynon, C. (1998), "Farm*A*Syst [Farmstead Assessment System] Fact Sheet #10," <http://www.cahe.nmsu.edu/pubs/farmasyst/>.
3. Environmental Improvement Division (1984), *Seepage Rates and Ground Water Quality Impacts from Manure-Lined Dairy Waste Lagoons,* Santa Fe, N.M.: New Mexico Ground Water and Hazardous Waste Bureau.
4. *New Mexico Water Quality Control Commission Regulations* (1996), Santa Fe, N.M.: New Mexico Water Quality Control Commission.
5. U.S. Environmental Protection Agency (1998), *Current Drinking Water Standards,* www.epa.gov/OGWDW/wot/appa.html.
6. U.S. Environmental Protection Agency (1988), *State Water Quality Standards Summary: New Mexico,* Available from National Technical Information Service, Springfield, Virginia, NTIS order number PB89-141998.
7. Salvato, J.A. (1992), *Environmental Engineering and Sanitation*, 4th ed., New York: John-Wiley and Sons, Inc.
8. U.S. Department of Agriculture and U.S. Environmental Protection Agency (1998), *Draft Unified National Strategy for Animal Feeding Operations*, <http://www.epa.gov/cleanwater/afo/>.
9. *Animal Agriculture: Information on Waste Management and Water Quality Issues* (June 1995), Washington, D.C.: General Accounting Office.
10. *Farm Costs and Returns Survey* (1992), Washington, D.C.: U.S. Department of Agriculture
11. *Questions and Answers About CAFO Regulations* (1997), Santa Fe, N.M.: New Mexico Environment Department.

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