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Wastewater Volume and Nitrogen Concentrations in Willamette Valley, Oregon Dairy Ponds

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WASTEWATER VOLUME AND NITROGEN CONCENTRATIONS in Willamette Valley, Oregon Dairy Storage Ponds

by Mike Gangwer, OSU Extension Service,
and Monte Graham, Soil Conservation Service

INTRODUCTION

During the past 10 years, the most common animal storage system built on Willamette Valley dairy sites includes an earthen storage pond. This publication is written for dairy producers who have one of these animal storage ponds or are considering constructing one.

These ponds are constructed to store animal wastewater discharges from the dairy facility. Typical storage ponds are designed for at least 180 days of storage. When practical, clean lot and roof runoff is directed away from the pond with gutters or curbing. Sprinkler wash systems are discouraged because they increase the volume of wastewater and result in a larger pond. Most new storage systems have a liquid/solid separator, which removes the larger particles from the liquid waste, thereby reducing the organic loading rate to the storage pond.

In response to increasing concern about water quality, dairy producers are learning new techniques for properly handling the wastewater from these ponds. These include applying wastewater during periods of the year when the soil is not hydraulically saturated and at rates and volumes that do not create runoff, as well as matching the nutrients in the wastewater to agronomic uptake rates of the crop.

All animal storage systems, regardless of size, components, and design, require day-to-day management and maintenance to function properly.

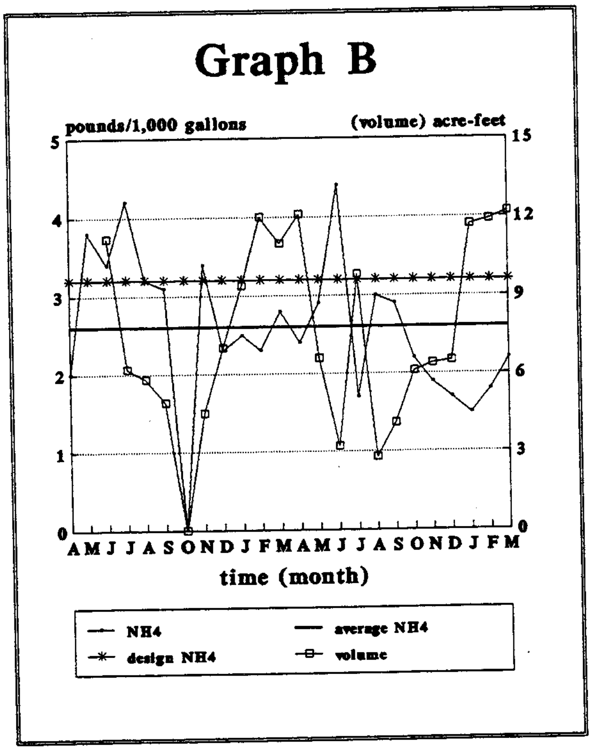
These animal storage systems are ultimately paid for by the income from the sale of milk. The management and maintenance of these systems are costs of production, and are listed as costs of managing manure on the dairy facility. In part, these animal storage systems are paid for by recycling manure nutrients, which are taken up by the crop. Because plants show no preference as to the source of inorganic nutrients they may be supplied by either inorganic commercial fertilizer or animal manures. The application of animal manure (nutrients) at agronomic rates is important because animal manures supply nutrients to the soil and reduce the demand for inorganic commercial fertilizer.

As growing crops withdraw nutrients from the soil, the dairy operator withdraws nutrients from the storage pond and applies them to the soil to satisfy the needs of the crop. The animal storage pond, therefore, is merely a storage container for nutrients. To be sure crops receive the proper nutrients, the dairy operator must determine the amount of nutrients contained in the animal storage pond.

PROJECT PURPOSE AND GOALS

1. Determine the NH_4 (ammonium) concentration of wastewater in the pond on a monthly basis. Ammonium is an inorganic form of nitrogen.
2. Determine the volumes of wastewater in the pond at the time of sampling.
3. Determine the Total Kjeldahl Nitrogen (TKN) concentration in the wastewater. TKN is the total amount of ammonium and organic nitrogen in a sample.

Waste Storage Pond B



In pond B, there is an inverse relationship between pond volume and NH_4 concentration. Note that when the NH_4 concentration is relatively high, the pond volume is relatively low. This is due to dilution of additional water into the storage pond, lowering the NH_4 concentration.

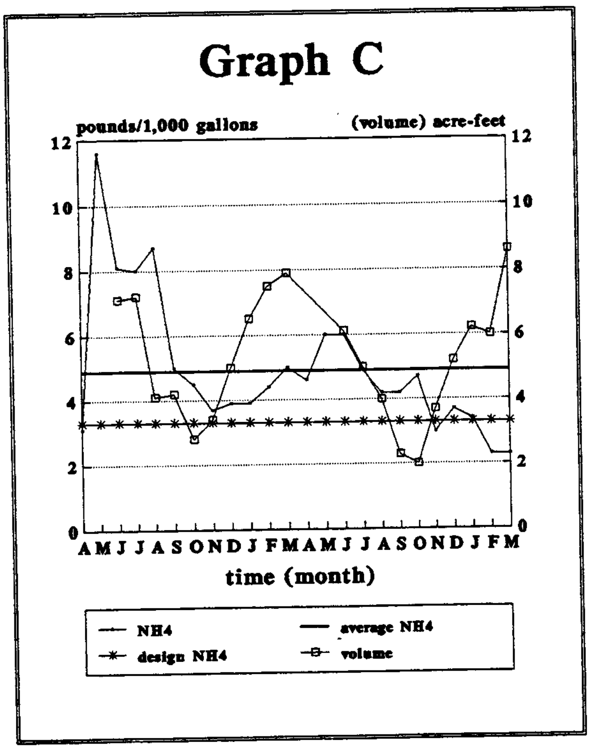
Also, notice that the pond volumes are low during the fall months in preparation for winter storage, indicating good management by the dairy owner. Pond volumes increase during the winter months, as rainwater enters the pond.

During the sampling month of October 1991, the pond was empty.

The design NH_4 is 3.0 pounds/1,000 gallons of wastewater, and the average NH_4 concentration is 2.6 pounds/1,000 gallons of wastewater.

The application rate of one acre-inch of wastewater is 70.6 pounds of NH_4, using the average NH_4 concentration.

Waste Storage Pond C



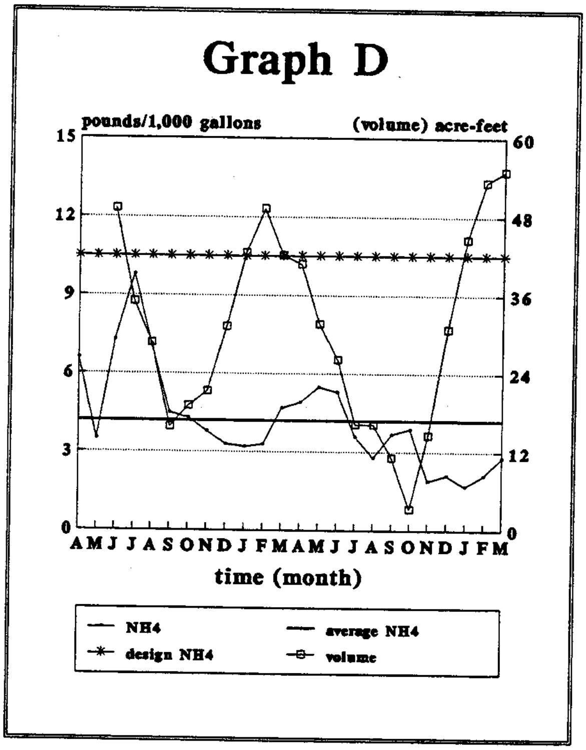
In pond C, measured NH_4 concentrations were higher in the summer months, compared to the winter months, indicating increased biologic activity during the summer months.

Pond volumes of wastewater showed good management by the dairy owner, in that during the fall months, volumes were the lowest in preparation for the demand for winter storage space.

Note that the inverse relationship exists in this pond between NH_4 concentration and wastewater volume. When NH_4 concentration is relatively high, wastewater volume is low. This indicates the impact of dilution of rainwater during the winter months, lowering the concentration of NH_4.

The design NH_4 is 3.2 pounds/1,000 gallons; the average NH_4 concentration is 4.9 pounds/1,000 gallons. The application rate of one acre-inch of wastewater is 133 pounds of NH_4.

Waste Storage Pond D



As with the previous two ponds (B and C), pond D shows two similar patterns.

The NH_4 concentration is inversely related to pond volumes, indicating the addition of rainwater that adds to the total pond volume.

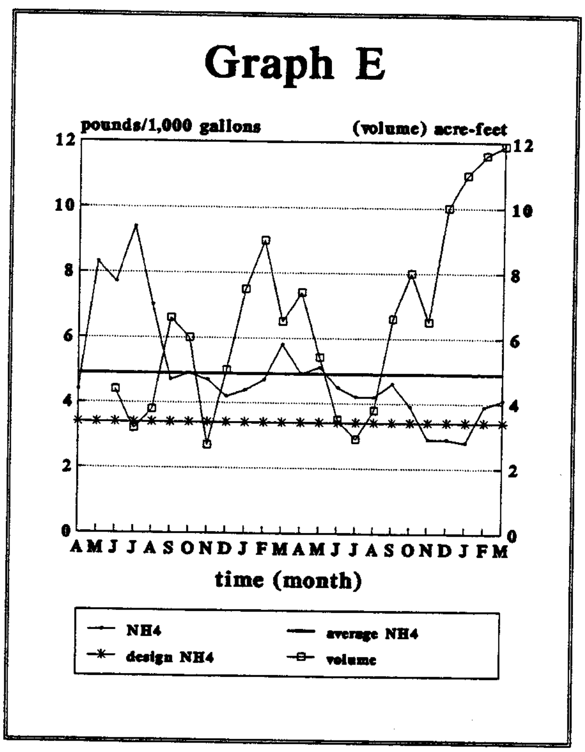
The pond volumes are lowest during the fall months, indicating that good management by the dairy owner is reducing wastewater volume in the pond in preparation for the winter storage period.

Notice the rapid increase in wastewater volumes during the months of October through February. The dairy owner reduces the wastewater volume during the spring and summer months, as crops are growing and soils are drier.

The design NH_4 is 10.5 pounds/1,000 gallons; the average NH_4 concentration is 4.2 pounds/1,000 gallons.

The application rate of one acre-inch of wastewater is 114 pounds of NH_4.

Waste Storage Pond E



In pond E, wastewater volumes indicate good management by the dairy owner, in that volumes are lowest in the fall in preparation for winter storage needs.

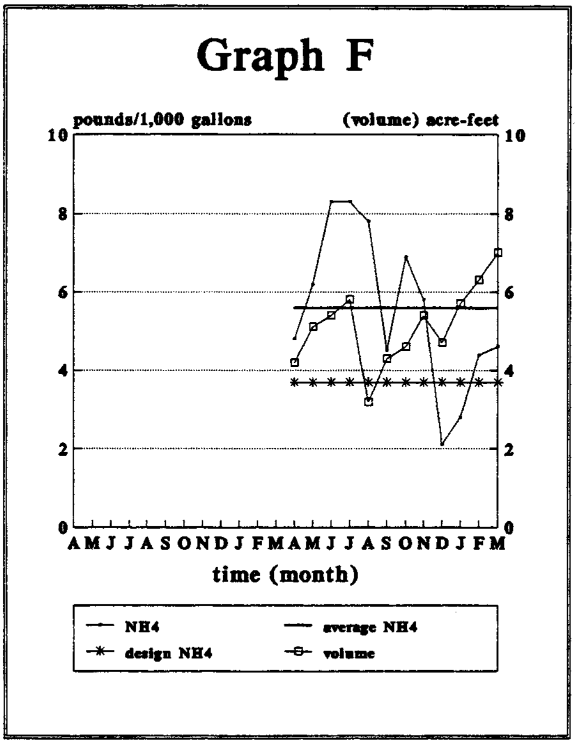
As with the previous pond (D), NH_4 concentrations were higher during the summer months of 1991 compared to 1992. Pond wastewater volumes remained very similar for both summers. No logical explanation for the changes in NH_4 concentration is given.

Pond volume did increase to its highest point during the late winter months of 1993, indicating the impact of additional rainwater entering the pond. The NH_4 concentration was lowest during this period, indicating dilution.

Design NH_4 is 3.4 pounds/1,000 gallons; the average NH_4 concentration is 4.9 pounds/1,000 gallons.

The application rate of one acre-inch of wastewater is 133 pounds NH_4.

Waste Storage Pond F



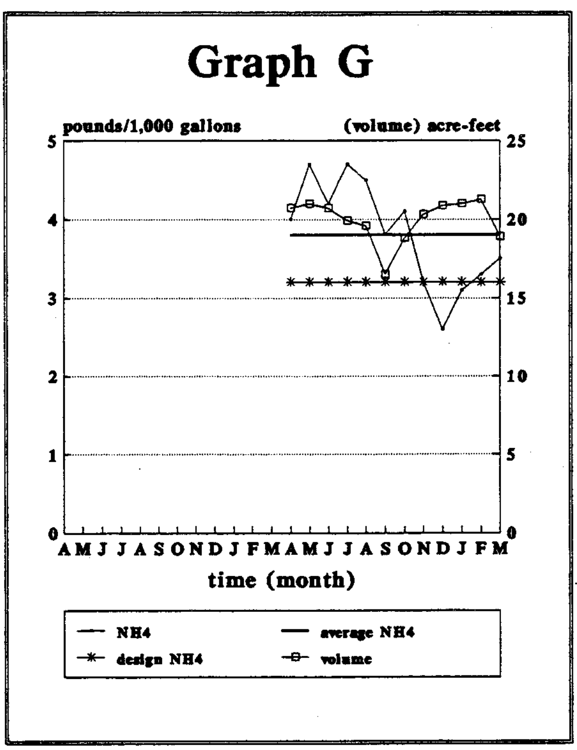
In pond F, NH_4 concentrations were highest during the summer months, indicating increased biologic activity during warmer temperatures.

Pond volumes were at their lowest in August, reflecting a spring and early summer pumpdown, then began increasing during the fall and winter months. The highest volume recorded was in March, as the impact of winter rain contributed to the total volume of the pond.

Design NH_4 is 3.7 pounds/1,000 gallons: average NH_4 concentration is 5.6 pounds/1,000 gallons.

The application rate of one acre-inch of wastewater is 152 pounds of NH_4.

Waste Storage Pond G



Pond G volumes were relatively stable throughout the year, except for September and October. The lower volume for these two months indicates good management by the dairy owner in preparing for winter rainfall by increasing the space available.

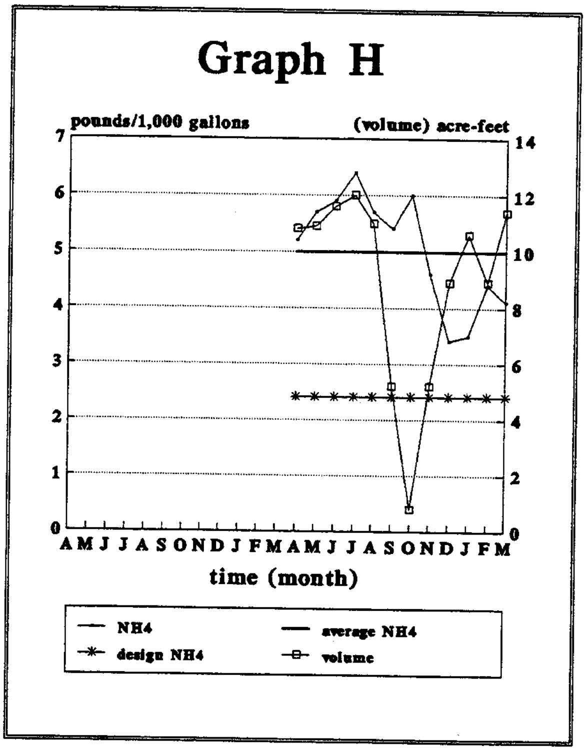
Note the decrease in pond volume during March 1992. The dairy owner began pumping after the winter storage period.

NH_4 concentrations were lower in the winter months, due to dilution of wastewater volume by rainwater, and the decrease in biologic activity by bacteria in the pond.

Design NH_4 is 3.2 pounds/1,000 gallons; average NH_4 concentration is 3.8 pounds/1,000 gallons.

The application rate of one acre-inch of wastewater is 103.2 pounds of NH_4.

Waste Storage Pond H



In pond H, the pattern of summer and fall pumpdown is shown, indicating good management by the dairy owner. Notice the significant pumpdown during October 1992. Wastewater volume increases rapidly until February, and some pumping in February and March reduces the volume of the pond.

NH_4 concentrations are lower during the winter months, which is an indication of increased total wastewater volume due to rainfall, and decreased biologic activity during cooler temperatures.

Design NH_4 is 2.4 pounds/1,000 gallons; average NH_4 concentration is 5 pounds/1,000 gallons.

An application rate of one acre-inch of wastewater is 135.8 pounds of NH_4.

SUMMARY TABLE

In Table 2, a summary of these eight systems is provided. Animal Units (AU) are converted to 1,000 pound units, assuming a 1400-pound cow, milking and dry, and an average heifer weight of 800 pounds.

Pounds of NH_4 in the animal storage pond are calculated by multiplying the average wastewater volume and the average NH_4 concentration.

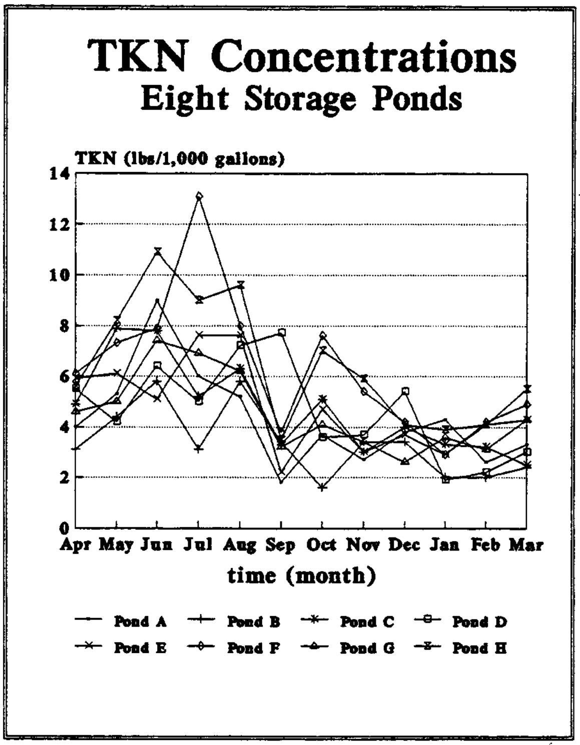
Animal Units per acre-foot are calculated by dividing the Animal Units by the average volume of wastewater in the animal storage pond. This measure describes the number of animals for the average pond volume throughout the year.

Pounds of NH_4 per Animal Unit are calculated by dividing the average total pounds of NH_4 in the waste storage pond by the number of Animal Units. This measure indicates the average pounds of NH_4 in the storage pond for each Animal Unit.

POND	Animal Units	Average lbs NH4	Average Wastewater AF	Total Pounds NH4	Animal Units per acre-foot	Pounds NH4 Animal Unit
A	268	2.6	7.5	6,357	36	23.7
B	272	4.9	5.2	8,306	52	30.5
C	474	4.4	4.0	5,738	119	12.1
D	2,435	4.2	30.8	42,171	79	17.3
E	528	4.9	6.5	10,383	81	19.7
F	688	5.6	5.1	9,310	135	13.5
G	470	3.8	20.0	24,776	24	52.7
H	565	5.0	8.9	14,507	63	25.7

TOTAL KJELDAHL NITROGEN

The graph below illustrates the monthly concentrations of TKN/1,000 gallons of wastewater for the eight ponds in the project. Samples were submitted to a private laboratory in Oregon for analysis.



The summer months contain a higher concentration of TKN than the winter months. This may be due to the increased biologic activity of the pond, as bacteria are breaking down or digesting organic material that has settled near the bottom of the pond. As this organic layer is digested, some organic matter rises into the liquid, thus increasing the concentration of the wastewater.

Also, one by-product of this organic digestion is NH_4, which is included in the measurement of TKN concentration. Thus a higher TKN concentration during the warmer summer months is explained by the increased physical movement of organic material from the organic layer near the bottom of the pond, and a higher NH_4 concentration as organic material is digested by bacteria.

TKN concentrations fell significantly in seven of the eight ponds during September. This may be explained by lower temperatures and dilution. As fall arrives, the biologic activity in the ponds is reduced because of lower temperatures. Increased amounts of rainfall also impact ponds, diluting the TKN concentration.

DISCUSSION AND CONCLUSIONS

In this two-year study of eight dairy storage ponds, ammonium and Total Kjeldahl Nitrogen concentrations in the pond wastewater were measured, along with pond wastewater volumes. We learned several things:

1. All dairy owners pumped out of their storage ponds during the spring and summer months. They accumulated liquid, and therefore nutrients, including nitrogen, during the winter months. All dairy owners pumped at certain times during the winter months. This is cause for concern, for two reasons.

First, if there is still capacity for wastewater in the storage pond, then pumping during the months in which crops are not growing is a waste of nutrients that could be stored for use during the spring and summer.

Second, if wastewater is applied to fields that are not able to absorb the volume into the soil profile, then the possibility of surface pollution of wastewater is increased. The goal of all dairy owners should be the storage of manure nutrients until these nutrients can be applied at agronomic rates to growing crops. The agronomic considerations of manure nutrient utilization are not within the scope of this publication.

2. Ammonium concentrations were variable between pond and time of year. If we learned just one thing with this study, it is the need for the dairy owner to take regular samples of wastewater to measure nutrient concentrations. The sample should be taken just prior to pumping so the correct nutrient application rates can be calculated.

3. Pond volumes were dependent upon the management of the system, which includes:
   a. Controlling rainfall on roof and concrete slabs that could drain into the pond
   b. Addition of irrigation water during the summer for surplus storage of water to ensure that crop irrigation requirements can be met
   c. Use of sprinkler pens, which can add additional water to the pond
   d. Use of wash hoses in the milking parlor

   We did not measure the water contribution to the storage pond of either c or d.

4. At certain times the pond was agitated just prior to sampling. Higher TKN concentrations are common in stirred ponds. When the organic material that has settled on the bottom of the pond is mixed with the liquid, the TKN concentration reflects the value of the organic nitrogen as well as the ammonium.

5. An inverse relationship exists between wastewater volume and NH_4 concentrations much of the time. As wastewater volume increases, the concentration of NH_4 decreases, due to additional water from rainfall.

6. The average NH_4 concentration for all ponds for all sampling periods is 4.4 pounds/1,000 gallons of wastewater, or 120 pounds per acre-inch (range = 2.6-5.6 pounds). The average TKN concentration for all ponds for all sampling periods is 4.9 pounds/1,000 gallons wastewater, or 133 pounds per acre-inch (range = 3.4-6.4 pounds). The maximum wastewater volume was measured in each pond; thus the dairy owners on all eight facilities had to manage a waste storage pond that was full. This alone indicates that regardless of size, these ponds do fill up, and the volume must be managed properly in order to utilize the nutrients at agronomic rates and to prevent the wastewater volume from polluting surface or groundwater.

DEFINITIONS AND UNITS

Below are some helpful definitions, units of measure and conversions used in this publication.

1. The typical expression of NH_4 in units, as listed in this publication, is pounds per 1,000 gallons of wastewater.
2. Pounds of NH_4/1,000 gallons, or any other manure nutrient in the wastewater solution, can be multiplied by 27.154 to determine pounds per acre-inch (27,154 gallons). Thus 4.4 pounds/1,000 gallons = 120 pounds per acre-inch = 1,440 pounds per acre-foot.
3. One acre-foot = 27,154 gallons/acre-inch multiplied by 12 inches/foot = 325,848 gallons.
4. One million gallons = 3.07 acre-feet. A storage pond with a capacity of 16.6 acre-feet will store 5.41 million gallons of wastewater.
5. Multiply pounds of NH_4 concentration by 0.778 to convert to nitrogen when comparing nitrogen units of inorganic commercial fertilizer. Thus 4.4 pounds NH_4/1,000 gallons wastewater contains 3.4 pounds of nitrogen/1,000 gallons of wastewater.
6. Divide pounds/1,000 gallons by 0.0083 to convert to parts per million (ppm). Thus 4.4 pounds NH_4/1,000 gallons wastewater = 530 parts per million NH_4.

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