NEW JERSEY
FARM-A-SYST
A FARMSTEAD WATER QUALITY ASSESSMENT SYSTEM

9 Fact Sheet: Reducing the Risk of Groundwater Contamination by Improving Silage Storage

1. Silage - makeup, moisture, and leachate

Silage is more than a nutrient-rich foodstuff: It is also a pollutant! The silage-making and -storing process can result in liquid effluents, or leachate, gases, malodors, undesirable microorganisms, and waste or spoiled silage. Most owners, managers, and designers of silage-processing and -storing systems do not usually consider the potential harmful effects that silage can have on the environment. The most common problems are with groundwater and surface water contamination. These problems can occur when silage leachate forms in too wet silage or precipitation flows through silage and dissolves the nutrients and other chemicals found in silage (Graves, et al, 1993).

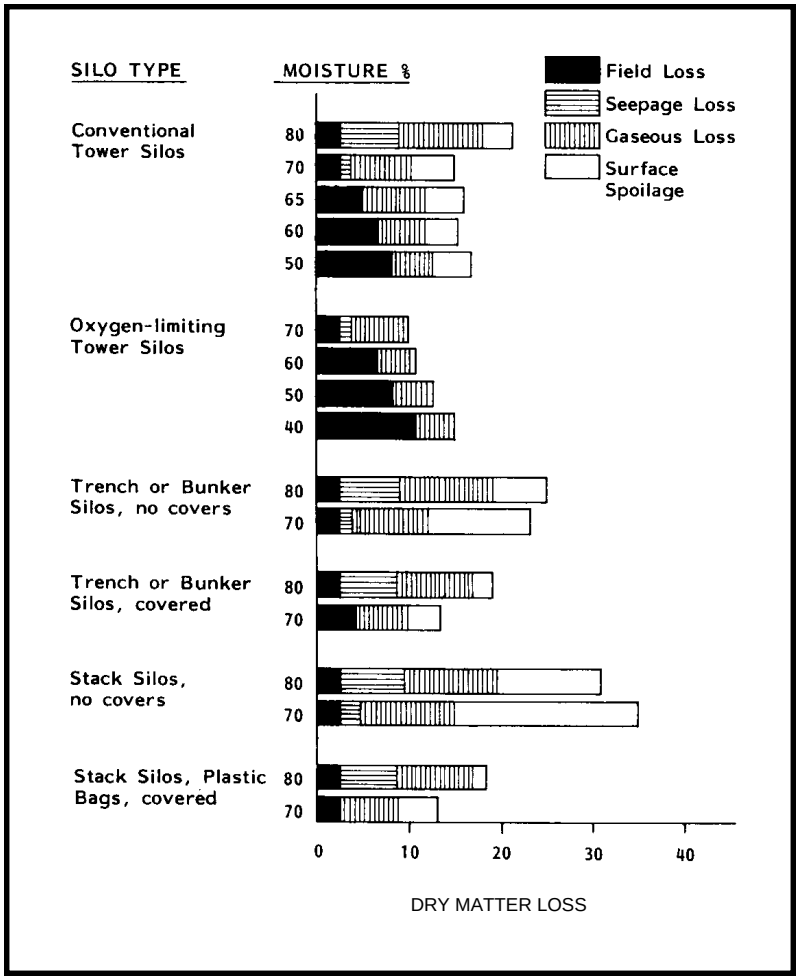

Figure 1: Chart of silage moisture content.
Source: Beef Housing and Equipment Handbook, MWPS-6, Fourth Edition, 1987, Midwest Plan Service, Ames, Iowa.

Silage can be made from corn, sorghum, legumes, grasses, other whole plant forages and canning company wastes, such as from sweet corn processing. Approximately two-thirds of the cropland in the northeast United States is devoted to forage production as hay or silage. (Pitt, 1990)

Fresh forage contains approximately eighty percent moisture. Soluble sugars are dissolved in the forage liquid, and this liquid provides the ideal medium for the growth of yeasts, molds and bacteria as well as for the rapid activity of plant enzymes.

The fundamental strategy in making silage is to exclude oxygen and reduce the pH rapidly through bacterial fermentation. On ensiling, the sugars present in the plant sap are transformed by bacterial action to form organic acids. These acids are essential for the proper preservation of the silage. During the silage making process, concentrated leachates can form. The prevention of silage leachate formation through proper forage harvesting and ensiling techniques is essential. If prevention techniques fail, these leachates need to be properly managed to preclude degradation of the water quality.

When moisture content is in excess of 70% or when rainfall infiltrates a silage pile, leachate is produced. Acids and sugars in the leachate are corrosive to exposed concrete and metal surfaces and can kill vegetation. The corrosiveness is due to the presence of organic acids, primarily lactic and acetic, found in the silage leachate.

Silage leachate can be generated with any of the following types of farm storage facilities:

Conventional tower silos
Oxygen limiting tower silos
Trench or bunker silos
Stack silos
Plastic wrapped or bagged large round bales
Plastic bag silos

Leachate represents a significant surface water and groundwater quality problem due to its high biochemical oxygen demand. The organic strength of silage leachate is on the order of 200 times stronger than raw domestic sewage (Bloxham, 1992).

In groundwater, silage leachate can cause severe public health related problems. In some cases, silage leachate may enter the groundwater through sink holes, cracked well casings, or fractures in the bedrock. When this occurs, the groundwater can be degraded for a long period of time due to the lack of natural aeration. Groundwater contaminated with silage leachates has a disagreeable odor and shows increased levels of acidity, ammonia, nitrates, iron and manganese.

There is potential for silage leachate to enter surface waters. Once released, it can use up vast amounts of dissolved oxygen. For example, as little as one gallon of silage leachate can lower the oxygen content of 10,000 gallons of river water below the level required for the survival of fish. If the silage leachate enters surface waters during periods when the flow is low and

water temperatures are warm, the oxygen depletion is further aggravated, since the dilution potential is extremely limited.

In order to mitigate the pollution risk of silage leachate entering surface waters, adequate forage harvest techniques, control and storage should be provided. The USDA Natural Resources Conservation Service recommends a minimum cubic foot (7.48 gallons) of leachate storage capacity for each ton of material placed in storage if and when containment becomes necessary. Silage leachate production varies based on crop, moisture content, silo type and silo cover. It is extremely important to harvest the forage to be ensiled at the proper maturity and moisture content to reduce or eliminate silage leachate formation.

2. Silage Leachate Considerations

If the dry matter content of the forage placed in the silo is maintained above 30 percent (%) for bunker or trenches, 40 percent (%) for haylage and 35 percent (%) for towers, then the silage leachate production will be substantially reduced, if not eliminated.

The following recommended guidelines will prevent the production of excess quantities of silage leachate:

✓ **Recommended proper growth stages for harvesting forage:**

Crop	Recommended Proper Growth Stages for Harvesting Forage
Corn	Early dent to 2/3 milk line stage of kernel maturity
Sorghum	Medium to hard dough stage of kernel maturity
Alfalfa (Est.), first cut	Mid-bud to early bloom
Alfalfa (Est.), later cuts	Late bud to early bloom
Alfalfa (New)	Early bloom
Red Clover, first cut	1/4 to 1/2 bloom
Red Clover, later cuts	1/4 bloom
Perennial grasses, first cut	Heads emerging from boot stage
Perennial grasses, later cuts	5 to 6 weeks after last harvest
Small grain	Early head emergence
Sorghum - sudan, hybrid multiple cuts	Height of 3 to 5 feet, before boot
Sorghum - sudan, hybrid, one cut system	Boot to early bloom
Grass - legume mixture	Based on legume maturity

✓ **Recommended moisture level for placement of forage into silos:**

Wilted Hay Crops- Conventional tower silo, 60 to 65 percent moisture. Oxygen-limiting, 40 to 55 percent moisture. Trench, bunker, or stack, 65 to 70 percent to ensure adequate packing. Round bale or bagged, 40 to 60 percent mois ture.

Corn or Sorghum- Conventional tower, 63 to 68 percent moisture. oxygen-limiting, 55 to 60 percent moisture for mechanical reasons. Trench,bunker, or stack, 65 to 70 percent to ensure adequate packing. Baled (wrapped or bagged), 65-70 percent moisture.

Note: Drying-type moisture testers or microwave oven weighing and drying procedure should be used to determine forage moisture levels before and during the harvest of forage silages.

✓ Use the proper cut setting on the forage chopper. Set shear-plate for a 3/8 to 3/4 inch theoretical cut. Keep knives well sharpened. Keep 15 to 20 percent of the forage particles at 1.0 to 1.5 inches. Do not use re-cutters or screens unless moisture levels are below those recommended;

✓ Use and maintain a silo that excludes both air and water and has no holes or cracks that allow leachate to leave the facility unless diverted to a collection channel or pipe;

✓ Fill the silo rapidly, pack thoroughly, and distribute evenly. Use a wetter material on top to facilitate packing. Bunker, trench, and stack silos require packing with heavy machinery on a continuous basis while filling. Pack periodically for two to three days after final fill;

✓ Seal the top of the silo with an air tight material such as 6 mil black plastic. If exposed to wind, weight it down in numerous places to prevent any lifting of the plastic;

✓ Bacterial contamination can be minimized by good sanitation of the silo and adjacent areas and ensiling forages with dry matter content greater than 30 percent;

✓ Design the leachate collection system and install a cover to minimize the entry of clean rain water from the top of the cover into the leachate collection system.

3. Silo location

In order to preclude groundwater contamination, silos should be located as far away from wells as practical. Typical isolation distances range from 50 to 250 feet and preferable down slope of a private rural well depending on geology, soil type, well type and silo type. In highly permeable soils and fractured bedrock longer horizontal isolation distances should be considered. With silos that are tightly sealed, a reduction in the horizontal isolation distances may be considered.

In the case of community wells, larger isolation distances should be considered due to the degree of risk involved. These distances can be as high as

1000 feet or more and located preferable down gradient from a community well.

In some cases, vertical separation distances and maximum slopes for ensilage locations are considered. Some general "rules of thumb" are as follows:

- ✓ Locate the silage pile at least five feet above the seasonal high ground water table;
- ✓ Locate the silage pile on slopes less than two percent (two feet of fall in 100 feet);
- ✓ Divert stormwater around the silage pile to prevent stormwater mixing with silage leachate.

4. Silage storage

Most harvested grasses, legumes or grass-legume mixtures are characterized as low-moisture haylage. Permit the plant material to wilt to the proper moisture content prior to chopping to ensure optimum ensiling. Corn and sorghum silage, for example, are direct cut and ensiled at the moisture content found in the standing forage. Compaction with machinery is necessary in order to reduce oxidation of the silage. This silage must be wetter to compact well.

Direct cut grass silage stored in tower silos has been reported to produce significant amounts of silage leachates due to compression of the silage. However, most grass, legumes and grass-legumes ensiled in the United States are wilted first and made as haylage. This virtually eliminates silage leachate.

Typically, silage that is stored in horizontal silos has a higher moisture content. Trench or stack silos with earthen floors pose the greatest threat to the groundwater resource. Particularly in areas where ensiling has taken place in the same area for many years, the soil in that area cannot act as an effective biological filter since there has been a toxic build-up from the silage leachate.

5. Silo design and construction

Silo construction for most agricultural uses is not regulated in New Jersey. Most silos being built today have interiors made of concrete or, in the case of oxygen-limiting silos, a glass-like coating over steel. Silage stored in glass-lined silos typically has a lower moisture content and poses a low risk of groundwater contamination. It is possible, though, for some liquid to leak out.

Silo bags generally store silage of higher moisture content. Liquid can pool in the bag and leak out when it is opened.

Horizontal trench silos excavated into the ground may affect groundwater, especially in coarse soils and sites close to the water table. Properly compacted clay soils and concrete floors can limit leachate seepage.

The type of silo on your farm often has less effect on its potential to contaminate groundwater than the condition of the silo. For example, an old wooden silo with an earthen floor poses a higher risk than a concrete horizontal silo with a concrete floor (see Figure 2). Older structures can be relined to make them relatively watertight.

Silo caps or covers keep rain water from entering the silage, preserving a quality silage, but alsoreducing the potential for producing leachate. Horizontal silos am covered with a plastic sheet. Tires are used to keep the cover in place.

It is important to divert clean water away from new and existing silage storage structures. For both vertical and horizontal silos, diverting clean water away from silage can protect both groundwater and surface water.

6. Leachate collection and disposal

Leachate can be collected from tower and horizontal silos by channeling the liquid into a water retention structure, usually a pond lined with concrete, clay or plastic. Drain tiles

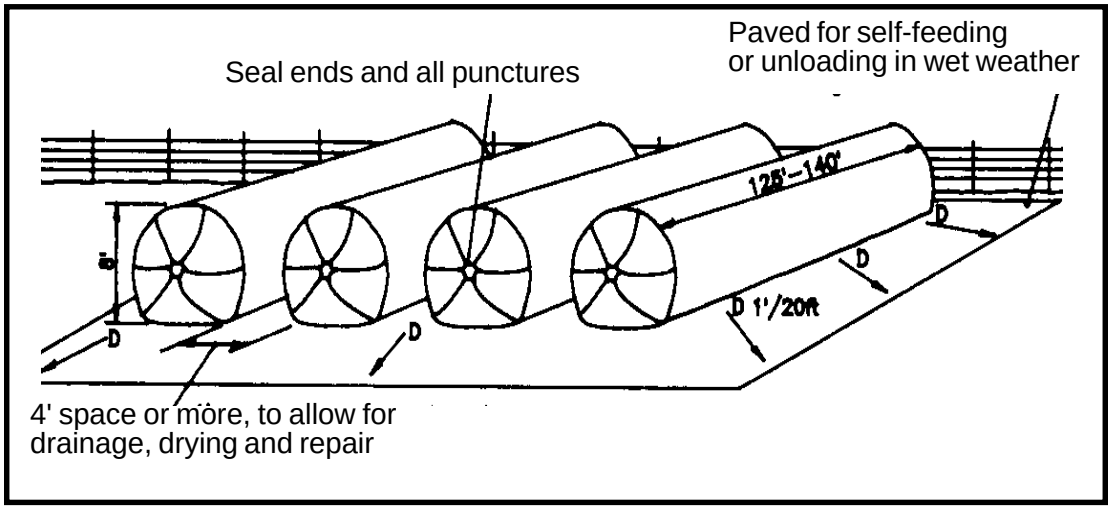

Figure 2: Horizontal silo. *Source: Beef Housing and Equipment Handbook, MWPS-6, Fourth Edition, 1987, Midwest Plan Service, Ames, Iowa.*

around tower silos can be used to collect any seepage from the silo. Horizontal silos use channels to direct seepage into a collection area. Contact your county Extension office or NRCS for assistance with design.

The most cost-effective disposal method is land spreading. Nitrogen in leachate has significant fertilizer value if applied during spring or early summer.

Because of its high organic content, leachate can burn grasses and remove oxygen from the soil. Farmers who consider land spreading should consult a soil specialist to determine how much leachate can be safely spread on each field.

CONTACTS AND REFERENCES

Who to call about...

General Contacts

See introductory sheet

Silo design and construction

Your Soil Conservation District office.

Silo construction guidelines

Available for tower silos from the International Silo Association, 8725 Rosehill, Suite 210, Lenexa, Kansas 66215, (913) 599-1919.

What to read about...

Publications are available from sources listed at the end of the reference section. (Refer to number in parentheses after each publication.)

Health effects of nitrates

Nitrate, Groundwater and Livestock Health. University of Wisconsin-Extension Bulletin G3217. (1)

Nitrate in Dairy Cattle. Rutgers Cooperative Extension Fact Sheet 118. (2)

Design criteria and general information

Dairy Housing and Equipment Handbook. Midwest Plan Service. MWPS-7. (3)

Farm and Home Concrete Handbook. Midwest Plan Service. MWPS-35. (3)

Silo Capacity Reference Chart. NJ Dairyman. L547. (2)

Publications available from...

1. Agricultural Bulletin, Room 245, 30 N. Murray Street, Madison, Wisconsin 53715, (608) 262-3346. There may be charges for publications, postage and sales tax.

2. Your county office of Rutgers Cooperative Extension (found in the blue pages of your phone book) or the Publications-Distribution Center, Cook College - Rutgers University, New Brunswick, NJ 08903, (732) 932-9762.

3. The Midwest Plan Service Secretary, Agricultural Engineering Department, 460 Henry Mall, University of Wisconsin, Madison, Wisconsin 53706, (608) 262-3310.

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The New Jersey Farmstead Assessment System is a cooperative project of the USDA Natural Resources Conservation Service, Rutgers Cooperative Extension, and New Jersey Department of Environmental Protection.

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#9 Worksheet: Assessing the Risk of Groundwater Contamination from
Silage Storage

Why should I be concerned?

Silage is an essential feed for livestock-based agriculture. When properly harvested and stored, silage poses little or no pollution threat, but improper handling can lead to a significant flow of silage juices (or leachate) from the silo. Leachate is an organic liquid that results from pressure in the silo or from extra water entering the silo. It is usually a problem only when silage is fresh, or just after storage. This loss of leachate represents a major loss of nutrient value from the silage. Canning company wastes, which are often used for silage, frequently contain excess moisture, which increases the potential for leachate to cause groundwater contamination.

Silage liquid is often highly acidic and can be corrosive to concrete and steel. If it enters a stream, its high organic content feeds bacteria that rob the water of oxygen. Groundwater contaminated with silage juices has a disagreeable odor and shows increased levels of acidity, ammonia, nitrates and iron.

Along with the pollutants found in silage leachate, an even greater potential threat is that the low pH created by the presence of acids in silage leachate can free up and release naturally occurring metals in the soil and aquifer, which can increase their concentrations in groundwater. Leachate from 300 tons of high-moisture silage has been compared to the sewage generated daily by a city of 80,000 people.

Nitrate is the most important potential contaminant to consider. Levels of 20-40 milligrams per liter (mg/l; equivalent to parts per million in water measure) can cause livestock problems, especially if feed contains more than 1,000 ppm nitrate-nitrogen. Water with levels over 100 mg/l nitrate-nitrogen should not be used for livestock. Water with over 10 mg/l nitrate-nitrogen should not be used for infants under 6 months of age.

The goal of Farm•A•Syst is to help you protect the groundwater that supplies your drinking water.

How will this worksheet help me protect my drinking water?

- It will take you step by step through your silage storage practices.
- It will rank your activities according to how they might affect the groundwater that provides your drinking water supplies.
- It will provide you with easy-to-understand rankings that will help you analyze the "risk level" of your silage storage practices.
- It will help you determine which of your practices are reasonably safe and effective, and which practices might require modification to better protect your drinking water.

How do I complete the worksheet?

Follow the directions at the top of the chart on the next page. It should take you about 15-30 minutes to complete this worksheet and figure out your ranking.

Worksheet #9

Silage Storage: Assessing Drinking Water Contamination Risk

1. Use a pencil. You may want to make changes.
2. For each category listed on the left that is appropriate to your farmstead, read across to the right and circle the statement that **best** describes conditions on your farmstead. (Skip and leave blank any categories that don't apply to your farmstead.)
3. Then look above the description you circled to find your "rank number" (4, 3, 2 or 1) and enter that number in the blank under "your rank."
4. Directions on overall scoring appear at the end of the worksheet.
5. Allow about 15-30 minutes to complete the worksheet and figure out your risk ranking for silage storage practices.

	LOW RISK (rank 4)	LOW-MOD RISK (rank 3)	MOD-HIGH RISK (rank 2)	HIGH RISK (rank 1)	YOUR RANK
Silage moisture content*	Below 65%	Between 65% and 70%	Between 71% and 85%	Over 85%	___
Silage storage location	At least 100 feet downslope from well (silos, glass-lined feed storage, plastic tubes). At least 500 feet downslope (earthen trench). Water drains away from storage to field or pasture.	At least 50 feet downslope from well (silos, glass-lined feed storage, plastic tubes). At least 250 feet downslope (earthen trench). Water drains to field or pasture.	Within 100 feet upslope of well (silos, glass-lined feed storage, plastic tubes). Within 500 feet upslope (earthen trench). Water pools or stands near storage.	Within 50 feet of well (silos, glass-lined feed storage). Within 250 feet (earthen trench). Water pools on soil surface.	____
Silage storage floor or surface condition	Concrete or asphalt surface. No cracks.	Concrete or asphalt surface has some cracks.	Surface has some permeable soils (silt loam) and has some cracks.	Surface has permeable soil (sand), not compacted.	____
Silage storage cover condition	Cover tight fitting. No leaks.	Cover tight fitting. Minor leaks repaired.	Cover, but many large leaks not repaired.	No cover.	____
Silage storage lining	New or relined in last 5 years.	Relined 6 to 25 years ago.	Relined 26 to 40 years ago.	Relined more than 40 years ago.	____
Leachate collection system	Designed system in place and maintained.	Designed system in place but not maintained.	No system in place. Leachate moves to waterway.	No system in place. Leachate collects in low area.	____

*For this worksheet, categories on the left are listed in order with the most important factor for groundwater contamination listed first.

TOTAL ☐

Use this total to calculate risk ranking on back page of worksheet.

What do I do with these rankings?

Step 1: Begin by determining your overall silage storage risk ranking. Total the rankings for the categories you completed and divide by the number of categories you ranked:

_____ divided by _____ equals [ ]*
total of rankings; # of categories ranked; risk ranking

*Carry your answer out to one decimal place.

3.6–4=low risk, 2.6–3.5=low to moderate risk, 1.6–2.5=moderate to high risk, 1–1.5=high risk

This ranking gives you an idea of how your silage storage practices **as a whole** might be affecting your drinking water. This ranking should serve only as a **very general guide, not a precise diagnosis.** Because it represents an **averaging** of many individual rankings, it can mask any **individual** rankings (such as 1's or 2's) that should be of concern. (See Step 2.)

Enter your boxed silage storage risk ranking on page 1 of Worksheet #12. Later you will compare this risk ranking with other farmstead management rankings. Worksheet #11 will help you identify your farmstead's site conditions (soil type, soil depth and bedrock characteristics), and Worksheet #12 will show you how these site conditions affect your risk rankings.

Step 2: Look over your rankings for individual activities:

- **Low-risk** practices (4's): ideal; should be your goal despite cost and effort
- **Low-to-moderate-risk** practices (3's): provide reasonable groundwater protection
- **Moderate-to-high-risk** practices (2's): inadequate protection in many circumstances
- **High-risk** practices (1's): inadequate; pose a high risk of polluting groundwater

Regardless of your overall risk ranking, any individual rankings of "1" require immediate attention. Some concerns you can take care of right away; others could be major—or costly—projects, requiring planning and prioritizing before you take action.

Find any activities that you identified as 1's and list them under "High-Risk Activities" on pages 6-7 of Worksheet #12.

Step 3: Read Fact Sheet #9, *Improving Silage Storage,* and consider how you might modify your farmstead practices to better protect your drinking water.

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