United States Department of Agriculture

Natural Resources Conservation Service

Northeast NTC
160 East 7th Street
Chester, PA 19013

August 25, 1995

SUBJECT: ESP - ENVIRONMENTAL QUALITY TECHNICAL NOTE NO. N5 - SILAGE LEACHATE AND WATER QUALITY

ATTENTION: State Water Quality Coordinators/Specialists, State Agronomists, State Conservation Engineers, and State Resource Conservationists

Purpose: To transmit Environmental Quality Technical Note No. N 5, entitled, Silage Leachate and Water Quality.

Effective Date: When received.

Filing Instructions: File the enclosure with the NNTC-ESP Environmental Quality Technical Notes. Also, file this Technical Note with the Agricultural Waste Management Field Handbook.

If there are any questions and/or comments, please feel free to contact Jim Cropper or Carl DuPoldt.

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It is the responsibility of any silo user to prevent water pollution. Silage leachate in tanks and storage structures, especially if mixed with manure, can be hazardous to humans and animals (Graves, et 1993). Designers, installers, and operators must be cognizant of the dangers of silage leachate and take proper precautions to protect people and livestock that may be near or come in contact with silage leachate.

Suggested References

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Razl, Ivan, Bellman, H.E. and Turnbull, J.E., "Evaluation of sealers and mortars for protection of concrete silos", Canadian Society of Agricultural Engineering, Volume 30, January, 1988, pp 179-183.

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d. *Neutralization* - Researchers have investigated several common materials that can be used for neutralization. These include, rock and ground limestone, quick lime, hydrated lime and caustic soda. Hydrated lime is the best neutralizing agent for farm use. It must be thoroughly mixed with silage leachate for 30 minutes. As a "rule of thumb", approximately 22 pounds (10 kg) of hydrated lime is required to neutralize 260 gallons (1000 liters) of silage leachate. (typically pH ranges between 6 to 8) leachate at the following ratios:

1 part slurry manure to 1-3 parts silage leachate; When agitating mixtures of other agricultural waste and silage leachate care should be taken to minimize the effects of hazardous gases, such as hydrogen sulfide, particularly in confined spaces.

E-4. *Land Application* Recommendations:

This is perhaps the most practical method of disposal for silage leachate. However, care must be taken to prevent plant die-off and burning of vegetation. Some recommendations for land application based on [research include: (Stewart, 1979)

- Apply undiluted leachate only to the field from which the crop was harvested or grazed;
- Apply to hayland or cropland after harvesting or before green-up at agronomic rates. The application rates must not exceed 9000 gallons per acre (0.21 gallons per square foot) of undiluted silage leachate;
- Apply only neutralized silage leachate on actively growing crops at agronomic rates not to exceed 9000 gallons per acre (0.21 gallons per square foot);
- Never apply leachate during hot, dry weather when it may dry quickly on the plant foliage and burn it;
- Always apply leachate uniformly over the whole field;
- Repeated applications should be made at intervals of not less than three weeks. This will allow time for the vegetation and the soil microbes to assimilate the diluted leachate (on some crops, longer intervals may be necessary);
- If excess runoff is likely from land application provide a buffer of at least 100 feet between the stream banks, ditches or rivers, wells, sinkholes, or other locations that have the potential for contamination of either surface water or groundwater;
- Never apply leachate to areas with cracks in the soils, sinkholes, exposed bedrock or where there is a danger of direct discharge into groundwater;
- Never apply silage leachate on frozen ground, severely compact soil, waterlogged soil, or steeply sloping ground (greater than 25%);

E-5. Livestock Feeding Recommendations:

If this practice is considered, the first concern should be the health of the livestock. A veterinary specialist should be consulted prior to implementation of this silage leachate management methodology. In most cases, this may not be a viable consideration, unless fed as fresh leachate (less than 4 days old).

Conclusions:

In summary, the prevention of silage leachate formation through proper forage harvesting and ensiling techniques is the first line of defense. This will minimize or eliminate silage leachate production.

Proper collection, storage and treatment and/or disposal/land application of silage leachate are mitigative measures, and may be an essential component of an agricultural waste management system where leachate is produced. Routine maintenance of silage structures is also essential to preclude pollution of surface water and groundwater resources.

- Size the tank to hold the maximum leachate volume plus rainfall. A "rule of thumb" estimate is to allow two (2) day's leachate and all rainfall less than or equal to 0.25 inches per hour during the storage, which determines the leachate volume (rainfall intensities greater than 0.25 inches per hour will dilute the leachate). However, consideration should be given to discharging to a vegetated filter area.

- Level control alarms with both audible and visible signals should be installed on all leachate collection tanks;

- Such alarms should be actuated when the collection tank is at 75% of storage capacity;

- Tank designs should be such as to withstand the surrounding soil pressures and water table conditions

- Tanks should be designed as watertight structures;

- Tanks should be acid resistant, such as, plastic-coated concrete, etc.;

- Tanks should be protected from flotation;

- Covered tanks should be adequately vented to preclude the build-up of harmful gases (mainly hydrogen sulfide);

- Tank fencing should be provided, if the tank is not covered;

- Provision should be made for placement of appropriate warning signs;

- Locate as far as practical from critical water resources, wells, sinkholes or other potential paths to the groundwater;

- Divert precipitation away from silos and silage handling areas;

- Divert high seasonal groundwater flows away from the silage stack or provide an impervious floor;

- And, equipment such as pumps and controls should be constructed of materials that resist attack from corrosion.

E-3. <u>Leachate Treatment Methods:</u>

The following methods have been employed to manage silage leachate prior to land application. These include:

a. *Storage* - The acids in silage leachate gradually oxidize if the leachate is stored for a long time. Prolonged storage also helps to reduce some of the high biochemical oxygen demand characteristic of silage leachate. (typically longer than 10 days)

b. *Aeration* - Aerating the leachate for about one week oxidizes the organic acids present. The aeration time needed can be further reduced by first diluting the leachate with clean water.

c. Dilution - Dilution with clean water at a rate of 1:1 has been found to be effective in most cases. This will also help reduce some of the biochemical oxygen demand of the silage leachate. A 1:1 dilution ratio may not always be effective.

Under certain instances, laboratory analyses and pilot scale studies may be needed to confirm the need for a higher dilution ratio. (typically BOD concentrations ranging between 300 and 600 mg/l)

The diluting with other agricultural wastes involves the collecting of leachate into existing waste storage tanks. The immediate effect of mixing silage leachate with other agricultural wastes is to lower the pH and soluble total nitrogen ratio of the waste. Research has shown that it takes from 10 to 12 weeks for the waste to return to its original composition. A "rule of thumb" is to mix slurry manure with silage

Corn or Sorghum -

Conventional tower, 63 to 68 or Sorghum 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.

c. 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;

d. 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;

e. 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;

f. Bacterial contamination can be minimized by good sanitation of the silo and adjacent areas;

g. Eliminate groundwater or surface water sources that can infiltrate the silage pile;

h. Consider adding absorbent materials, such as alfalfa cubes, chopped dry hay or beet pulp to help use up the excess moisture in the silage that is ensiled wetter than desirable.

E-2. Leachate Collection Recommendations:

Leachate collection and disposal around stack silos and above ground bunker silos can be accomplished through conveying the liquid into a waste storage pond [Practice Standard (425)] or a waste storage structure [Practice Standard (313)]. Consider installation of a pond liner depending on subsurface conditions to preclude groundwater contamination with silage leachate, if not already sealed.

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;

The structures are usually constructed using pre-cast or cast-in-place concrete tanks. Non-metallic perforated subsurface drainage piping around the base of the silo can be used to collect any seepage from the silo.

The outlet pipe to the collection facility must be non-metallic, watertight pipe and directed to a waste storage pond for later land application in a manner that will not degrade surface or ground water. A unique feature for silage leachate collection tanks (a separate tank for leachate) is that they be both watertight and corrosion resistant.

The following leachate collection tank (not the waste storage tank) recommendations are presented for consideration:

In the event that a collection tank is needed for the storage of silage leachate, the following recommendations should be considered:

- Below ground transfer piping to the tank should be of durable, non-metallic watertight construction, for example, schedule 40 PVC pipe or other similar material.

- Silage acids can cause severe silo deterioration when leachate occurs. Leachate can be reduced or eliminated by harvesting forages at the correct moisture content.

- Old concrete silos showing signs of deterioration (i.e. pitting, spalling concrete, etc.) should be smoothed with an appropriate coating that is resistant to silage leachate corrosion damage.

- Glass-fused steel tower silos should be inspected for fractures or chipping of the glass coating and deterioration of construction joints and fasteners. All damage should be repaired as quickly as possible to forestall excessive corrosion and possible failure.

- Raw linseed oil can be brushed or sprayed on smooth silo walls to form a water-repellent coating. Do not use raw linseed oil on rough, pitted walls. If raw linseed oil is used on rough surfaces, the coating will not be uniform. There will be areas that are not coated and subject to rapid corrosion. Do not use boiled linseed oil since it may contain toxic additives.

- Plastic wrapped bales or silo bags must be protected from punctures, rips, and burrowing animals. They should be placed on a firm, smooth surface free of projections such as sticks, pointed rocks or gravel, stiff stubble, or brush.

E. Leachate Management Considerations:

E-1. Leachate Reduction through Harvest Management Methods:

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 in towers) and 35 percent (%) (for corn silage in towers), then the silage leachate production will be substantially reduced, if not eliminated.

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.

The following recommended guidelines will prevent the production of excess quantities of silage leachate: (Isher, 1991, Heath, 1985, and Jensen, 1989)

a. 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 (Established) first cut - Mid-bud to early bloom.

Alfalfa (Established) later cuts - Late bud to early bloom.

Alfalfa (New), first cut - 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 as previously described.

b. Recommended moisture level for placement of forage into silos: (Isher, 1991)

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 moisture.

D-3. Concrete Protection:

Concrete deteriorates when exposed to silage leachate. This problem is particularly serious where greater compaction pressures cause saturation in the lower portions of a tower silo. One way to provide protection is through the application of protective barrier coatings, including organic resin coatings such as epoxies, polystyrenes and polyurethanes.

However, these protective barriers are costly, impermeable to moisture movement and sensitive to the substrate moisture both during and after the application. Razl, Bellman and Turnbull, 1988, performed research and made a comparison of silage leachate on concrete and various protective barriers. Their summary is presented below:

Untreated Concrete

Initial absorption followed by continuous deterioration at almost a constant rate.

Polystyrene Resin

Initial absorption of acids followed by deterioration of the sealer on the high spots of surface roughness.

Epoxy Resin

Initial absorption of acids followed by blistering of the sealer.

Acrylic Water-Borne Resin

Initial absorption of acids followed by debonding of the sealer without blistering.

Acrylic Solvent-Borne Resin

Only initial acid absorption observed.

Silicate Sealer

Limited effect, similar performance as untreated concrete only slightly delayed.

Latex Modified Mortar

Small absorption of acids , followed by a much slower surface deterioration rate (sandy surface) than untreated concrete.

Latex and Condensed Silica Fume Additives

Small absorption of acids, followed by only negligible deterioration.

Based on the foregoing summary, the following can be concluded:

1. Thin polymer-based sealers provide very limited protection to concrete against attack by silage leachates. An exception is an acrylic solvent-borne sealer that showed superior durability in laboratory tests and good performance up to two (2) years in a farm silo.

2. Properly formulated Portland cement-based mortar coatings, especially those with the latex and condensed silica fume additives, showed superior protection for two (2) years against silage leachate attack, at a reasonable cost. Long term protection of these coatings is still being evaluated.

3. An alternative may include the incorporation of microsilica in the concrete mix as a partial substitute for cement will provide long term protection.

D-4. Silo Maintenance:

All silos must be maintained in order to prevent the loss of leachate. Some recommendations for maintenance are as follows: (Heath, Barnes, Metcalf, 1991 and Pitt, 1990)

- The inside surfaces of tower silos should be free of cracks, holes and other surface defects. In addition, the surfaces should be smooth. Silo doors should be airtight. If not, they should be replaced or repaired.

- Placement of a non-porous collection receptacle at the logical outlet point in the catchment tarp.

- The storage area should be cleared of debris or crop stubble that can pierce the bale wrapper.

- The silage leachate collected in the collection receptacle should be properly diluted or neutralized and land applied at agronomic rates (rates that are within crop tolerances and do not exceed soil loading thresholds). See Section E-3 for dilution or neutralization techniques.

With horizontal trench silos that are excavated into the ground, the groundwater may be at risk to contamination. This, silage usually has a sufficient moisture content, to produce leachate since the material must be sufficiently wet to exclude oxygen through mechanical compaction. This is particularly true in coarse textured soils, sites that are close to the high seasonal water table, karst sites, or sites with fractured bedrock near the surface. To reduce groundwater pollution potential, an impervious liner should be considered depending on subsurface conditions.

Any infiltration into a silage stack can also contribute to leachate production. This infiltration can be from surface runoff, direct rainfall or groundwater seeps into the silage pile.

Silo caps or covers are essential in that they preserve the quality of the silage as well as minimize leachate production from direct rainfall infiltration. Under some site conditions diversion of stormwater runoff or groundwater interceptor drains around trench or stack silos is essential to protect groundwater and the surface water from leachate contamination.

It is more cost-effective to cover the silage stack than to leave it uncovered. The cost of site remediation and lost feed value is far in excess of providing a cover for the silage pile.

With covered silage, the dry matter loss is on the order of 20-30 % lower than for uncovered silage. With good management, storage losses are 13-15% of the original dry matter. With poor management, storage losses are 30-40% of the original dry matter. (Holmes, 1992)

D-2. 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 preferably 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 from wells and the use of sealed silo types should only be considered. With silos that are tightly sealed, a reduction in the horizontal isolation distances may be considered. State health department regulations may contain additional requirements or isolation distances.

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 preferably down gradient from a community well.

For stacked ensilage locations, consider vertical separation distances and maximum slopes for placement. The following general "rules of thumb" should be considered:

- Locate the silage stack at least five feet above the seasonal high ground water table;

- Locate the silage stack on slopes less than two percent (two feet of fall in 100 feet);

- Divert stormwater around the silage stack to prevent stormwater mixing with silage leachate.

Amino acids are minor components of silage leachate. They are the building blocks of protein. Most of the five day biochemical oxygen demand (BOD_5) in silage leachate is generated from metabolites of sugars such as acetic acid, succinic acid, propionic acid, lactic acid, butyric acid, and ammonia amines.

B. Water Quality Impacts:

Silage leachate can impact the dissolved oxygen content of surface water. 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. (less than 5.0 milligrams per liter dissolved oxygen). 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 and bacteria respiration rates are higher.

Silage leachate is an extremely strong organic waste. Reported biochemical oxygen demand (BOD) values range from 12,000 to 90,000 parts per million (ppm) or milligrams per liter (mg/l). The sugars and other compounds in silage leachate are decomposed rapidly when released into surface waters, using up large amounts of dissolved oxygen in the process.

When allowed to infiltrate into the soil in large quantities, silage leachate can deplete oxygen in the soil. The high oxygen demand, high reducing potential, and low pH of the leachate in contact with the soil and/or bedrock can cause iron, manganese and other minerals to become soluble and leach into the groundwater. These minerals and leachate have the potential to contaminate water supplies.

Most silage leachate is produced in the fall during corn silage harvest when flow rates in rivers and streams are at seasonal lows and water temperatures are at seasonal highs. The sudden release of silage leachate into surface water under these conditions can have a devastating effect on aquatic life.

For surface water bodies and streams with low flow rates, discharge of silage leachate can result in the destruction of aquatic life. Small feeder streams, wetlands, and ponds are particularly vulnerable to this type of pollution. Heavy growths of grey or white biomass mats which can tolerate anaerobic conditions are indicators of pollution from high strength organic wastes such as silage leachate.

It is important that farmers be aware of the nature and extent of the damage that can be caused by silage leachate entering groundwater or surface water.

Farmers need to plan and install practices to prevent the release of this contaminant.

In order to reduce the pollution risk of silage leachate entering surface waters and groundwaters, harvest at optimal moisture content or install leachate control and storage practices. The Agricultural Waste Management Field Handbook recommends a minimum of one 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. Reference should be made to the section entitled, E-1 Leachate Reduction through Harvest Management Methods.

C. Microbial and Other Health Risks

C-1. Listeria monocytogenes:

Listeria monocytogenes bacteria cause listeriosis, a disease dangerous to both animals and humans. In animals, listeriosis causes encephalitis (inflammation of the brain tissue). Silage has been strongly implicated as a source of listeriosis in farm animals. In order to grow in silage, listeria requires oxygen and a pH of 5.5. Small pockets of silage at high pH may contain listeria.

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A-3. Characteristics of High Quality Silage:

Practices which exclude oxygen from the silage maximize feed recovery from silos. Oxygen diffusion from the atmosphere is minimized by tightly packing the silage during filling and by covering the top surface with a durable material.(Holmes, 1992).

Some characteristics of high quality silage, enhanced by covering, are: (Heath, et al 1991)

- pH less than or equal to 4.2 for high moisture silages and pH of approximately 4.5 for wilted silages. pH is not as critical for low moisture silages.
- 5-10% lactic acid on a dry basis in high moisture silages.
- Absence of caramelized or "tobacco-like" odors and a brown or black color as found in burnt forage..
- Freedom from molds and objectionable odors, such as, those from butyric acid and mustiness which form in heated silage.
- Firm texture with no sliminess.

Refer to Table 5 for dry matter and moisture percentages that are conducive to forming different silage end products.

A-4. Chemical and Physical Characteristics of Silage Leachate:

Although generated in small quantities compared to other types of agricultural wastes, silage leachate represents a pollution potential of equal or greater magnitude (See Table 6). Silage leachate is 95% water. The solids portion is composed of soluble, highly digestible nutrients (Graves, et al, 1993). Some of the characteristics of silage leachate revealed by literature searches, are as follows:

o pH	3.6 to 5.5
o Ammonium Content	less than or equal to 10% of the initial silage concentration
o Phosphorus	approx. 558 mg/l
o Calcium	approx. 1200 mg/l
o Magnesium	approx. 220 mg/l
o Sodium	approx. 340 mg/l
o Phosphate Levels	(as P_2O_5) 0.02 to 0.3% of the initial silage concentration
o Potassium	approx. 3400 mg/l
o Potash (as K_2O)	0.3 to 0.7% of the silage concentration
o Amino Acids	approx. 1900 mg/l potentially wide variation
o Total Dissolved Solids	High (usually in excess of 1000 mg/l)
o Organic Acids Present	Usually Lactic, Acetic, Butyric Succinic and Propionic
o Organic Nitrogen	approx. 3700 mg/l
o Ammonia-Nitrogen	approx. 700 mg/l
o Biochemical Oxygen Demand (Five Day)	12,000 to 90,000 mg/l

Table 6 - Estimated Silage Storage Losses

Silo Type	Moisture (0%)	Dry Matter Loss (%)			
		FL	SL	GL	SS
Conventional Tower	80	3.0	5.5	9.0	2.5
	70	2.0	2.0	4.0	6.0
	65	5.5	0.0	3.0	7.5
	60	7.0	0.0	5.0	3.0
	50	8.0	0.0	4.0	4.0
Oxygen Limiting Tower	70	2.5	1.0	6.5	0.0
	60	7.5	0.0	3.5	0.0
	50	8.0	0.0	4.5	0.0
	40	10.0	0.0	5.0	0.0
Trench or Bunker (No Covers)	80	3.0	6.5	8.5	6.0
	70	3.0	1.5	7.0	11.0
Trench or Bunker (Covers)	80	3.0	7.0	7.5	1.5
	70	5.0	0.0	6.0	3.0
Stack (No Covers)	80	3.0	6.0	10.0	11.0
	70	3.0	2.0	10.0	18.0
Stack or Plastic Bags (Covered)	80	3.0	6.0	7.5	1.5
	70	3.0	0.0	6.0	4.0

Source: Agricultural Canada, Best Management Practices - Water Management", page 41.

Figure 2

Dry Matter Losses during Harvest as Dependent on Hay Crop Silage Moisture Content at Harvest (Source: R.E. Pitt, Cornell University, Ithaca, NY, (NRAES-5))

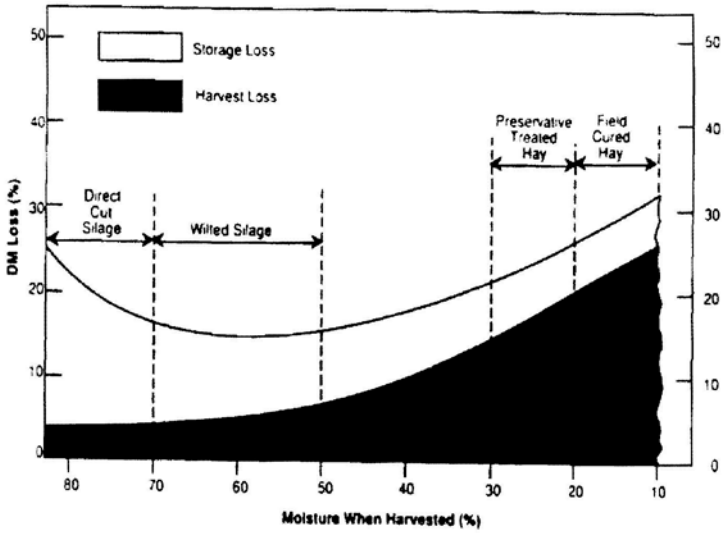


Table 5

Optimum Percent Dry Matter and Percent Moisture Ranges by Silo Type

Forage/Silage Components Produced	Burnt Forage		Heated Silage		Optimum *		Leachate Flow	
	% DM	% M	% DM	% M	% DM	% M	% DM	% M
	80-60	20-40	60-50	40-50	50-30	50-70	30-10	70-90

* Optimum for Silage % DM (Percent Dry Matter); % M (Percent Moisture)
Source: R.E. Pitt, Cornell University Ithaca, NY (NRAES-5)

Table 3 -
Maximum Allowable Moisture Content of Hay Crop Silages to Prevent Effluent Flow from Tower Silos

Silo Height (Feet)	Silo Diameter (Feet) 10	12	14	16	18	20	22	24	26	28	30
	Percent (%) Moisture										
20	78	77	76	75	75	74	74	74	74	74	73
24	77	75	75	74	73	73	72	72	72	72	71
28	76	74	73	72	72	71	71	70	70	70	69
32	75	73	72	71	71	70	69	69	69	68	68
36	74	73	71	70	70	69	68	68	67	67	66
40	74	72	71	69	68	68	67	66	66	65	65
44		71	70	68	67	67	66	65	64	64	63
48		71	69	68	67	66	65	64	63	63	62
52			69	67	66	65	64	63	62	62	61
56			68	66	65	64	63	62	61	61	60
60			68	66	65	63	62	61	60	60	59
64					64	62	61	60	59	59	58
68					63	62	61	60	58	58	57
72								59	58	57	56
76								58	57	56	55
80								57	56	55	54

(Source: R.E. Pitt, Cornell University, Ithaca, NY (NRAES-5)

Table 4

Minimum Dry Matter Content to Prevent Silage Leachate from Tower Silos

Silo Height (Feet)	Silo Diameter (Feet) 10	16	20	24	30
	Percent (%) Dry Matter				
20	22	25	26	26	26
30	24	28	29	30	31
40	26	31	32	34	35
50		32	34	36	38
60		34	37	39	40
70				41	43
80				43	46

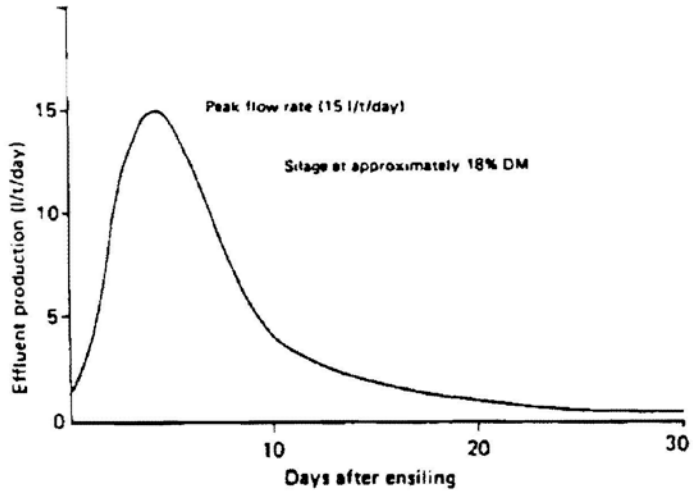
(Source: R.E. Pitt, Cornell University, Ithaca, NY (NRAES-5))

Figures 2 and Table 5 further illustrate the need to closely monitor the moisture of silage. Figure 2 compares losses due to storage and harvest among forage crop preservation methods. An increase in dry matter loss when hay crop forages are direct cut ensiled, is due primarily to leachate formation and drainage from the stack. Comparing the Figure 2 and Table 5, note that wilted hay crop silage has the optimum silage making moisture range.

Figure 1 -

Silage Leachate Production over the Life of the Silage Stack

(To obtain gallons from liters multiply by 0.2642)



TYPICAL PATTERN OF EFFLUENT FLOW

SOURCE: ADAS, BOOKLET, NUMBER 24

Technical Information

A. General Information:

A-1. Storage Methods:

Most ensiled grasses, legumes or grass-legume mixtures are harvested as low-moisture haylage. This plant material is wilted to the optimal moisture content prior to chopping to ensure quality ensilage with minimal leachate formation. Corn and sorghum silage are direct cut and ensiled at the moisture content found in the standing forage. The key here is to cut these two forage types at the proper maturity to meet optimum moisture content.

Direct cut grass silage stored in tower silos has been reported to produce significant amounts of silage leachate due to compression of the silage. However, most grasses, 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 than tower silos to ensure sufficient packing by machinery.

Table 1 -

Silage End Products Produced at Different Ranges of Percent Dry Matter and Percent Moisture

Type of Silo	Horizontal Silos	Tower Silos		
	% DM	% M	% DM	% M
	45-35	55-65	50-35	50-65

%DM (Dry Matter); %M (Moisture)

Source: R.E. Pitt, Cornell University, Ithaca, NY (NRAES-5)

Compaction with machinery is necessary in order to reduce oxidation of the silage. Trench or stack silos with earthen floors pose the greatest threat to groundwater and surface water resources.

A-2. Silage Moisture Content:

The amount of leachate produced varies with the material stored, its moisture and nitrogen content, and its handling and storage conditions. Of these, moisture content is the most critical.

The dry matter content of the plant material ensiled is perhaps the greatest single factor in determining the amount of silage leachate. Some comparisons between dry matter percentage and leachate produced in bunker silos are presented in Table 2. Tables 3 and 4 give the percent moisture and the percent dry matter figures respectively for grass ensilage that can be stored in tower silos without leachate flow.

During the fermentation process, at least 50% of the silage leachate is generated within the first week. In the next two weeks, an additional 25% is generated. Therefore, 75% of the silage leachate can be generated within three weeks after ensiling. Silage leachate can continue to be generated for a period up to eight weeks after ensiling (Stewart, et al, 1974). Figure 1 shows the pattern of silage leachate generation over time.

However, in cases where rainfall, groundwater or stormwater are not excluded, silage leachate generation can continue for the entire biological life of the silage stack.

Table 2 -

Leachate Produced from Grass Crops Ensiled in Bunker Silos

Dry Matter Content of Grass Ensiled (%)	Leachate Produced (gallons of silage)
< 15	100 to 50
15 to 20	50 to 30
20 to 25	30 to 5
> 25	virtually nil

Source: Stewart, T.A. et al (1974)

Introduction

Silage is more than a nutrient-rich livestock feed. Improperly handled, it may also produce 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 leachate can have on the environment. The most common problems with silage leachate are contamination of groundwater and surface water. Leachate problems can occur when forage is harvested containing a dry matter content less than 30 percent or when precipitation flows through silage and transports the nutrients and other chemicals found in silage (Graves, et al, 1993).

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. If excess moisture is present during the silage making process, concentrated leachates can form. The prevention of silage leachate formation through proper forage harvesting and ensiling techniques is preferable. If prevention techniques are rendered impractical due to wet weather harvesting conditions, silage leachates formed under these wet weather conditions need to be properly managed to preclude contamination of water resources.

Acids and sugars in the leachate are corrosive to exposed concrete and metal surfaces and can kill vegetation. This corrosiveness is due to the presence of organic acids, primarily lactic and acetic, found in the silage leachate.

Leachate is produced when an excess amount of moisture is present during anaerobic fermentation. Silage leachate is either clear or straw colored. Leachate is called by other names, such as silage juice, silo juice or silage effluent.

Leachate represents a significant threat to surface water and groundwater quality due to its high biochemical oxygen demand (BOD), low pH, and high reducing potential. The organic strength of silage leachate is on the order of 200 times stronger than raw domestic sewage (Bloxham, 1992). When silage leachate enters surface waters it can reduce the dissolved oxygen level and in many cases it can cause fish kills, destroy benthic organisms, and result in the growth of dense mats of biomass (algae and fungus) in streams or ponds.

Silage leachate can contaminate private and public groundwater sources. In some cases, silage leachate may enter the groundwater through sinkholes, 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 an unpleasant odor and shows increased levels of acidity, ammonia, nitrates, iron and manganese.

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 (balage)
- Plastic bag silos

OUTLINE OF CONTENTS

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Conclusions

Suggested References

NNTC Tech Note 5 August, 1995.

Environmental Quality Technical Note No N _5_
Silage Leachate and Water Quality

GENERAL:

This technical note provides information on the recognition of the pollution potential of high moisture ensiled forages that produce silage leachate. It can be used as a guidance document when evaluating alternatives for preventing silage leachate or managing it if produced. This technical note can serve as supplemental guidance to Chapter 4, Section 651.0404 (C), Other Wastes, "Silage Leachate", of the Agricultural Waste Management Field Handbook, National Engineering, Handbook, issued April, 1992. It is also suggested that this Technical Note be filed with the Agricultural Waste Management Field Handbook(AWMFH).

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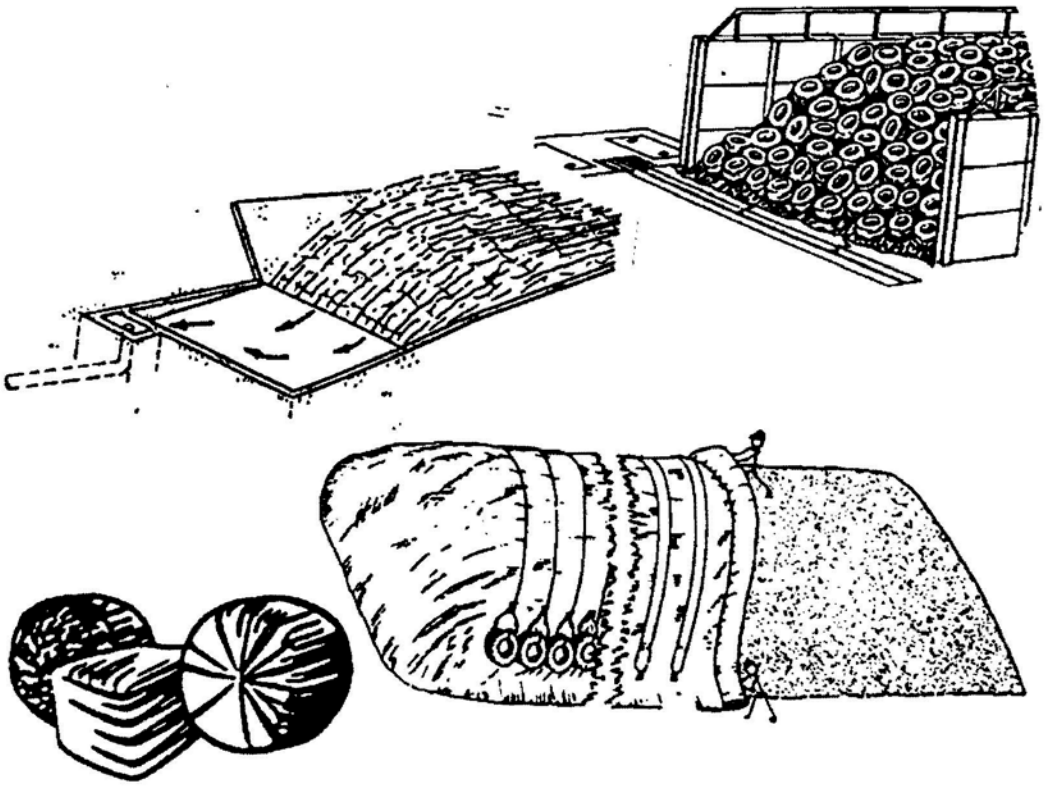
ENVIRONMENTAL QUALITY

TECHNICAL NOTE N5

SILAGE LEACHATE & WATER QUALITY



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