Agricultural Waste Management Systems

Level 2

Tables and Charts

Nutrients	Primarily nitrogen, phosphorus and potassium; however, some of the trace elements are important to animal health and show up in agricultural wastes.
Oxygen-demanding material or organic matter	As micro-organisms consume the organic matter, they also consume free oxygen.
Pathogens	Disease causing organisms inhabit the intestines of warm blooded animals and can have a long survival period in the water column. E. Coli is one of several indicators used to show the presence of bacteria in the water.
Solids	Suspended sediments and dissolved material comprise a large portion of the water pollution from agricultural wastes.
Total Dissolved Solids (TDS)	Dissolved solids or salts in animal manures are particularly important where wastes are utilized in arid or semi-arid climates. The accumulation of salts in the soil profile can lead to seed germination problems and reduced yields.
Agrichemicals and other organic and inorganic material	While agrichemicals are not normally associated with waste management for livestock operations, they constitute a major portion of the water quality problem associated with agriculture.
Heat	Elevated water temperature in streams can be caused by lack of stream side shading or by water releases from water storage or detention ponds.

Table 1. Criteria Constituents

Selected Primary and Secondary Drinking Water Standards as Specified by the EPA

Constituent	**Maximum Allowed**
Primary Standards	
Inorganic chemicals	
Nitrate-nitrogen	10 mg/L
Selenium	0.045 mg/L *
Synthetic organic chemicals	
Lindane	0.0002 mg/L *
Toxaphane	0.00 *
Alachlor	0.00 *
Aldicarb	0.009 mg/L *
Carbofuran	0.036 mg/L *
Total coliform bacteria	
Total coliform no more than one coliform-positive sample/month for systems that analyze fewer than 40 samples/month, and no more than 5% of samples positive if system analyzes more than 40 samples/month.	
Fecal coliform bacteria	0.00 *
Secondary Standards	
Color	15 units
Foaming agents	0.5 mg/L
Odor numbers	3 threshold odor
Total dissolved solids	500 mg/L

* EPA values under 1966 Safe Drinking Water Act Amendments.

Table 2. Domestic water supply standards

Maximum Allowable Concentrations of Selected Constituents in Raw Water Supplies for Industrial Use (mg/L).					
Constituent	**Petroleum**	**Chemical**	**Paper**	**Textile**	**Cooling Water**
Ammonia	40	---	---	---	---
Nitrate	8	---	---	---	30
Dissolved solids	3,500	2,500	1,000	150	1,000
Suspended solids	5,000	10,000	---	1,000	5,000
Color	25	500	360	---	---

Table 3. Industrial water supply standard

Recommended Limits of Concentration of Some Potentially Toxic Substances in Drinking Water for Livestock (Based on Carson 1981)		
Substance	**Safe Upper Limit of Concentration (mg/L) USEPA***	**Safe Upper Limit of Concentration (mg/L) NAS****
Aluminum	5.0	
Arsenic	0.02 (0.06)	0.2
Barlum	(1.0)	***
Beryillum	No limit	
Boron	5.0	
Cadmium	0.05 (0.01)	0.05
Chromium	1.0 (0.5)	1.0
Cobalt	1.0	1.0
Copper	0.5 (1.0)	0.5
Fluoride	2.0	2.0
Iron	No limit (0.3)	***
Lead	0.1 (0.06)	0.1
Manganese	No limit (0.05)	***
Mercury	0.001 (0.000144)	0.01
Molybdenum	No limit	***
Nickel	(0.6)	1.0
Nitrate -N	100 (10.0)	100.0
Nitrite -N		10.0
Selenium	0.05 (0.01)	
Vanadium	0.1	0.1
Zinc	25.0 (5.0)	25.0

* U.S. Environmental Protection Agency
(standards for human drinking water are shown in parentheses)
** National Academy of Sciences
*** Not established/no limit. Experimental data available are not sufficient to make definite recommendations.

Table 4. Limits of Concentration

Desired and Potential Problem Levels of Pollutants in Livestock Water Supplies *		
Substances	**Substances**	**Problem Range**
Total bacteria/100 ml	<200	>1,000,000
Fecal coliform/100 ml	<1	>1 for young animals >10 for older animals
Fecal strep/100 ml	<1	>3 for young animals >30 for older animals
pH	6.8-7.5	<5.5 or >8.5
Dissolved solids (mg/L)	<500	>3,000
Total alkalinity (mg/L)	<400	>5,000
Sulfate (mg/L)	<250	>2,000
Phosphate (mg/L)	<1	**
Turbidity (Jackson units)	<30	**

* Based on research literature and field experience in Northeastern United States
** Not established
Table 5. Problem levels of pollutants

Module 1c

Properties and physiological effects of the most important gases produced from animal wastes in an anaerobic environment				
Gas	Lighter than air	Odor	Class	Comments
Ammonia	Yes	Sharp/ Pungent	Irritant	Irritation of eyes and throat at low concentrations. Asphyxiating - could be fatal at high concentrations with 30- 40-min exposure.
Carbon dioxide	No	None	Asphyxiant	<20,000 ppm = safe level; increased breathing, drowsiness, and headaches as concentration increases; could be fatal at 300,000 ppm for 30 min.
Hydrogen sulfide	No	Rotten eggs	Poison/ Asphyxiant	Headaches, dizziness at 200 ppm for 60 min. Nausea, excitement, insomnia at 500 ppm for 30 min. Unconsciousness, death at 1,000 ppm.
Methane	Yes	None	Flammable	Nontoxic; headaches at 500,000 ppm.

Module 2

Example Animal Unit Computations

For some livestock, an animal unit might be only a fraction of an individual animal's weight.

For example, a 1400 pound Holstein cow would be 1.4, 1000 pound animal units.

$$\frac{\text{1400 pounds per cow}}{\text{1000 pounds per animal unit}} = 1.4 \text{ 1000 lb animal units}$$

For other livestock, a specie individual may only be a fraction of a 1000 pound animal unit. For example, it would take 250, 4 pound chickens to make one 1000 pound animal unit.

$$\frac{\text{250 chickens x 4 pounds per chicken}}{\text{1000 pounds per animal unit}} = 1.0 \text{ 1000 lb animal unit}$$

Table 4-1 Definitions and Descriptions of Waste Characterization Terms					
Term	**Abbrev-iation**	**Units of measure**	**Definition**	**Method of measurement**	**Remarks**
PHYSICAL PROPERTIES					
Weight	**Wt**	**lb**	**Quantity or mass**	**Scale or balance**	
Volume	Vol	Ft^3;gal	Space occupied in cubic units	Place in or compare to container of known volume; calculate from dimensions of containment facility.	
Moisture content	MC	%	That part of a waste material removed by evaporation and oven drying at 217°F (103°C).	Evaporate free water on steam table and dry in oven at 217°F for 24 hours or until constant weight.	Moisture content (%)plus total solids(%) equals 100%.
Total solids	TS	% %w.b.; %d.w	Residue remaining after water is removed from waste material by evaporation; dry matter.	Evaporate free water on steam table and dry in oven at 217°F for 24 hours or until constant weight.	Total of volatile and fixed solids; total of suspended & dissolved solids.
Volatile solids	VS; TVS	% %w.b.; %d.w	That part of total solids driven off as volatile (combustible) gases when heated to 1112°F (600°C) organic matter.	Place total solids residue in furnace at 1112°F for at least 1 hr	Volatile solids determined from difference of total and fixed solids.
Fixed solids	FS; TFS	% %w.b.; %d.w	That part of total solids remaining after volatile gases driven off at 1112°F (600°C); ash.	Determine weight (mass) of residue after volatile solids have been removed as combustible gases when heated at 1112°F for at least 1 hr.	Fixed solids equal total solids minus volatile solids.
Dissolved solids	DS; TDS	% %w.b.; %d.w	That part of total solids passing through the filter in a filtration procedure.	Pass a measured quantity of waste material through 0.45 micron filter using appropriate procedure; evaporate filtrate and dry residue to constant weight at 217°F.	Total dissolved solids (TDS) may be further analyzed for volatile solids and fixed dissolved solids parts.
Suspended solids	SS; TSS	% %w.b.; %d.w	That part of total solids removed by a filtration procedure.	May be determined by difference between total solids and	Total suspended solids may be further analyzed for volatile and fixed suspended solids parts.

Term	Abbrev-iation	Units of measure	Definition	Method of measurement	Remarks
CHEMICAL PROPERTIES					
Ammoniacal nitrogen		mg/L	Both NH_3 and NH_4 nitrogen compounds	Common laboratory procedure uses digestion, oxidation, and reduction to convert all or selected nitrogen forms to ammonium that is released and measured as ammonia.	Volatile and mobile nutrients; may be a limiting nutrient in land spreading of wastes and in eutrophication.
(total ammonia)		µg/L			
Ammonia nitrogen	NH_3-N	mg/L µg/L	A gaseous form of am moniacal nitrogen.		
Ammonium nitrogen	NH_4-N	mg/L µg/L	The positively ionized (cation) form of ammoniacal nitrogen.		Can become attached to the soil or used by plants or microbes.
Total kjeldahl nitrogen	TKN	mg/L µg/L	The sum of organic nitrogen and ammoniacal nitrogen.		
Nitrate nitrogen	NO_3-N	mg/L µg/L	The negatively ionized (anion) form of nitrogen that is highly mobile.		Nitrogen in this form can be lost by denitrfication, percolation, runoff, and plant microbial utilization.
Total nitrogen	TN N	%; lb	The summation of nitrogen from all the various nitrogen compounds listed above.		Macro-nutrient for plants.
Phosphorus	P	%; lb	Acid-forming element that combines readily with oxygen to form the oxide P2O5. As a plant nutrient, it promotes rapid growth, hastens maturity, and stimulates flower, seed, and fruit production.	Laboratory procedure uses digestion and/or reduction to convert phosphorus to a colored complex; result measured by spectrophotometer	Critical in water pollution control; may be a limiting nutrient in eutrophication an in spreading of wastes.
Potassium	K	%; lb	As a plant nutrient, available potassium stimulates the growth of strong stems, imparts resistance to disease, increases the yield of tubers and seed, and isnecessary to form starch, sugar, and oil and transfer them through plants.	Laboratory digestion procedure followed by flame photometric analysis to determine elemental concentration.	
5-day Bio- chemical Oxygen Demand	BOD_5	lb of O_2	That quantity of oxygen needed to satisfy biochemi-cal oxidation of organic matter in waste sample in 5 days at 68°F (20°C).	Extensive laboratory procedure of incubating waste sample in oxygenated water for 5 days and measuring amount of dissolved oxygen consumed.	Standard test for measuring pollution potential of waste materials that could be discharged to surface water.
Chemical Oxygen Demand	COD	lb of O_2	Measure of oxygen consuming capacity of organic and some inorganic components of waste materials	Relatively rapid laboratory procedure using chemical oxidants and heat to fully oxidize organic components of waste.	Estimate of total oxygen that could be consumed in oxidation of waste material

Table 4-2
Factors for Determining Nutrient Equivalency

Multiply	By	To Get
NH3	0.842	N
NH4	0.778	N
NO3	0.226	N
N	1.216	NH3
N	1.285	NH4
N	4.425	NO3
PO4	0.326	P
P2O5	0.437	P
P	3.067	PO4
P	2.288	P2O5
K2O	0.830	K
K	1.205	K2O
ppm	0.842	lb/1000 gal

Table 4-3
Unit Weights of Common Bedding Materials

Material	Loose lb/ft^3	Chopped lb/ft^3
Legume Hay	4.25	6.25
Nonlegume hay	4.00	6.0
Straw	2.50	7.0
Wood Shavings	9.00	
Sawdust	12.00	
Soil	75.00	
Sand	105.00	
Ground Limestone	95.00	

Table 4-4
Daily Bedding Requirements for Dairy Cattle

	Stanchion	Free Stall	Loose Housing
Loose Hay or straw	5.4		9.3
Chopped hay or straw	5.7	2.7	11.0
Shavings or sawdust		3.1	
Sand, soil, or limestone		1.5	

Note: All entries are lb/d/1000#

Table 4-5
Dairy Waste Characterization – As Excreted *

Component	Units	Cow Lactating	Cow Dry	Heifer
Weight	lb/d/1000#	80.00	82.00	85.00
Volume	ft^3/d/1000#	1.30	1.30	1.30
Moisture	%	87.50	88.40	89.30
TS	% w.b.	12.50	11.60	10.70
	lb/d/1000#	10.00	9.50	9.14
VS	lb/d/1000#	8.50	8.10	7.77
FS	lb/d/1000#	1.50	1.40	1.37
COD	lb/d/1000#	8.90	8.50	8.38
BOD_6	lb/d/1000#	1.60	1.20	1.30
N	lb/d/1000#	0.45	0.36	0.31
P	lb/d/1000#	0.07	0.05	0.04
K	lb/d/1000#	0.26	0.23	0.24
TDS	lb/d/1000#	0.85		
C:N ratio	lb/d/1000#	10	13	14

*Increase solids and nutrients by 4% for each 1% feed waste more than 5%.

Table 4-6
Dairy Waste Characterization - Milking Center*

Component	Units	MH	MH+MP	MH+MP+HA	
				**	***
Volume	ft^3/d/1000#	0.22	0.60	1.40	1.60
Moisture	%	99.72	99.40	99.70	98.50
TS	% w.b.	0.28	0.60	0.30	1.50
VS	Lb/1000 gal	12.90	35.00	18.30	99.96
FS	Lb/1000 gal	10.60	15.00	6.70	24.99
COD	Lb/1000 gal	25.30	41.70		
BOD			8.37		
N	Lb/1000 gal	0.72	1.67	1.00	7.50
P	Lb/1000 gal	0.58	0.83	0.23	0.83
K	Lb/1000 gal	1.50	2.50	0.57	3.33
C:N ratio	Lb/1000 gal	10	12	10	7

*MH – Milk House MP – Milking Parlor HA – Holding Area
**Holding area scraped and flushed – manure excluded
***Holding area scraped and flushed – manure included

Table 4 -7
Dairy Waste Characterization - Lagoon

Component	Units	Anaerobic Supernatant	Anaerobic Sludge	Aerobic Supernatant
Moisture	%	99.75	90.00	99.95
TS	% w.b.	0.25	10.00	0.05
VS	lb/1000 gal	9.16	383.18	1.67
FS	lb/1000 gal	11.66	449.82	2.50
COD	lb/1000 gal	12.50	433.16	1.25
BOD_6	lb/1000 gal	2.92		0.29
N	lb/1000 gal	1.67	20.83	0.17
NH_4 – N	lb/1000 gal	1.00	4.17	0.10
P	lb/1000 gal	0.48	9.16	0.08
K	lb/1000 gal	4.17	12.50	
C: N ratio	lb/1000 gal	3	10	

*Milk house and milking parlor wastes only

Table 4-8
Beef Waste Characterization – As Excreted

Component	Units	Feeder, yearling			
		750 to 1,100		450 – 750 lb	Cow
		High forage diet	High energy diet		
Weight	lb/d/1000#	59.10	51.20	58.20	63.00
Volume	ft^2/d/1000#	0.95	0.82	0.93	1.00
Moisture	%	88.40	88.40	87.00	88.40
TS	% w.b.	11.60	11.60	13.00	11.60
	lb/d/1000#	6.78	5.91	7.54	7.30
VS	lb/d/1000#	6.04	5.44	6.41	6.20
FS	lb/d/1000#	0.74	0.47	1.13	1.10
COD	lb/d/1000#	6.11	5.61	6.00	6.00
BOD_6	lb/d/1000#	1.36	1.36	1.30	1.20
N	lb/d/1000#	.031	.030	.030	.033
P	lb/d/1000#	0.11	0.094	0.10	0.12
K	lb/d/1000#	0.24	0.21	0.20	0.26
C: N ratio	lb/d/1000#	11	10	12	10

*Average daily production for weight range noted. Increase solids and nutrients by 4% for each 1% feedwaste more than 5%

Table 4-9
Beef Waste Characterization – Feedlot Manure

Component	Units	Unsurfaced Lot	Surfaced Lot	
			High forage diet	high energy diet
Weight	lb/d/1000#	17.50	11.70	5.30
Moisture	%	45.00	53.30	52.10
TS	% w.b.	55.00	46.70	47.90
	lb/d/1000#	9.60	5.50	2.50
VS	lb/d/1000#	4.80	3.85	1.75
FS	lb/d/1000#	4.80	1.65	.075
N	lb/d/1000#	0.21		
P	lb/d/1000#	0.14		
K	lb/d/1000#	0.03		
C: N Ratio	lb/d/1000#	13		

*Dry climate (annual rainfall less than 15 inches);annual manure removal.
** Dry climate; semi – annual manure removal.

Table 4 -10
Beef Waste Characterization – Feedlot Runoff Pond

Component	Units	Runoff Pond	
		Supernatant	Sludge
Moisture	%	99.70	82.80
TS	% w.b.	0.30	17.20
VS	lb/d/1000 gal	7.50	644.83
FS	lb/d/1000 gal	17.50	788.12
COD	lb/d/1000 gal	11.67	644.83
N	lb/d/1000 gal	1.67	51.66
NH_4-N	lb/d/1000 gal	1.50	
P	lb/d/1000 gal		
K	lb/d/1000 gal	7.50	14.17

Note: See table 4-10a, Agricultural Waste Management Field Handbook, for nitrogen content of cattle feedlot runoff.

Table 4 – 11
Swine Waste Characterization – As Excreted*

Component	Units	Grower 40-220 lb	Replacement gilt	Sow Gestation	Sow Lactation	Boar	Nursing pig 0-40 lb.
Weight	lb/d/1000#	63.40	32.80	27.70	60.00	20.50	106.00
Volume	ft_3/d/1000#	1.00	0.53	0.44	0.96	0.33	1.70
Moisture	%	90.00	90.00	90.80	90.00	90.70	90.00
TS	% w.b.	10.00	10.00	9.20	10.00	9.30	10.00
	lb/d/1000#	6.34	3.28	2.50	6.00	1.90	10.60
VS	lb/d/1000#	5.40	2.92	2.13	5.40	1.70	8.80
PS	lb/d/1000#	0.94	0.36	0.37	0.60	0.30	1.80
COD	lb/d/1000#	6.06	3.12	2.37	5.73	1.37	9.80
BOD_6	lb/d/1000#	2.08	1.08	0.83	2.00	0.65	3.40
N	lb/d/1000#	0.42	0.24	0.19	0.47	0.15	0.60
P	lb/d/1000#	0.16	0.08	0.06	0.15	0.05	0.25
K	lb/d/1000#	0.22	0.13	0.12	0.30	0.10	0.35
TDS	lb/d/1000#	1.29					
C: N Ratio	lb/d/1000#	7	7	6	6	6	8

*Average daily production for weight range noted. Increase solids and nutrients by 4% for each 1% feed waste more than 5%.

Table 4 -12
Swine Waste Characterization – Storage Tanks under Slats

Component	Units	Farrow	Nursery	Grow/Finish	Breeding gestation
Moisture	%	96.50	96.00	91.00	97.00
TS	% w.b.	3.50	4.00	9.00	3.00
VS	lb/1000 gal	189.85	233.27	562.35	149.96
FS	lb/1000 gal	101.64	99.97	187.45	99.97
N	lb/1000 gal	29.16	40.00	52.48	25.00
NH_4-N	lb/1000 gal	23.32	33.32		
P	lb/1000 gal	15.00	13.32	22.50	10.00
K	lb/1000 gal	23.32	13.32	18.33	17.50
C: N ratio	lb/1000 gal	4	3	6	3

Table 4-13
Swine Waste Characterization – Anaerobic Lagoon; Feedlot Runoff

Component	Units	Anaerobic Lagoon		Feedlot Runoff	
		Supernatant	Sludge	Runoff/water	Settling basin sludge
Moisture	%	99.75	92.40	98.50	88.8
TS	% w.b.	0.25	7.60	1.50	11.2
VS	lb/1000 gal	10.00	379.89		90.7 **
FS	lb/1000 gal	10.83	253.27		21.3**
COD	lb/1000 gal	10.00	538.18		
BOD_6	lb/1000 gal	3.33			
N	lb/1000 gal	2.91	25.00	2.00**	5.6**
NH_4-N	lb/1000 gal	1.83	6.33	1.20**	4.5**
P	lb/1000 gal	0.63	22.50	0.38**	2.2**
K	lb/1000 gal	3.16	63.31	1.10**	10.0**
C:N ratio	lb/1000 gal	2	8		

*Semi-humid climate (approx. 30” annual rainfall: annual sludge removal
**lb/d/1000#

Table 4-14
Poultry Waste Characterization – As Excreted*

Component	Units	Layer	Pullet	Broiler	Turkey	Duck
Weight	lb/d/1000#	60.50	45.60	80.00	43.60	
Volume	ft_3/d/1000#	0.93	0.73	1.26	0.69	
Moisture	%	75.00	75.00	75.00	75.00	
TS	% w.b.	25.00	25.00	25.00	25.00	
	lb/d/1000#	15.10	11.40	20.00	10.90	12.0
VS	lb/d/1000#	10.80	9.70	15.00	9.70	
FS	lb/d/1000#	4.30	1.70	5.00	1.25	5.0
COD	lb/d/1000#	13.70	12.20	19.00	12.30	9.5
BOD_6	lb/d/1000#	3.70	3.30	5.10	3.30	2.5
N	lb/d/1000#	0.83	0.62	1.10	0.74	0.7
P	lb/d/1000#	0.31	0.24	0.34	0.28	0.3
K	lb/d/1000#	0.34	0.26	0.46	0.28	0.5
TDS				2.89		
C: N ratio	lb/d/1000#	7	9	8	7	6

*Increase solids and nutrients by 4% for each 1% feed waste more than 5%.

Table 4-15
Poultry Waste Characterization - Litter

Component	Units	Layer High-rise *	Broiler	Turkey	Broiler breeder **	Duck
Weight	lb/d/1000#	24.00	35.00	24.30		
Moisture	%	50.00	24.00	34.00	34.00	11.20
TS	% w.b.	50.00	76.00	66.00	66.00	88.80
	lb/d/1000#					
VS	lb/d/1000#		21.40			
FS	lb/d/1000#		5.10			
N	lb/d/1000#	0.425	0.68	0.88	1.06	2.31
NH_4 –N	lb/d/1000#			0.01		
P	lb/d/1000#	0.275	0.34	0.40	1.32	
K	lb/d/1000#	0.30	0.40	0.45	1.19	
C: N Ratio		9				

*No bedding or litter material added to waste
**All values % w.b.

Table 4-16
Poultry Waste Characterization – Anaerobic Lagoon

Component	Units	Layer Supernatant	Layer Sludge	Pullet Supernatant	Pullet Sludge
Moisture	%	99.50	86.90	99.70	92.60
TS	% w.b.	0.50	13.10	0.30	7.40
VS	lb/1000 gal	18.33	404.06	10.83	314.09
FS	lb/1000 gal	23.32	687.32	14.17	302.42
N	lb/1000 gal	6.25	32.50	3.00	24.17
NH_4 – N	lb/1000 gal	4.58	7.66	2.24	4.91
P	lb/1000 gal	0.83	45.82	0.75	27.49
K	lb/1000 gal	8.33	6.00	7.00	6.17
C: N ratio		2	7	2	7

Table 4-18
Lamb Waste Characterization – As Excreted *

Component	Unit	Lamb
Weight	lb/d/1000#	40.00
Volume	ft_3/d/1000#	0.63
Moisture	%	75.00
TS	% w.b.	25.00
	lb/d/1000#	10.00
VS	lb/d/1000#	8.30
FS	lb/d/1000#	1.76
COD	lb/d/1000#	11.00
BOD_6	lb/d/1000#	1.00
N	lb/d/1000#	0.45
P	lb/d/1000#	0.07
K	lb/d/1000#	0.30
C: N ratio		10

*Increase solids and nutrients by 4% each
1% feed waste more than 5%

Table 4-19
Horse Waste Characterization – As Excreted*

Component	Unit	Horse
Weight	lb/d/1000#	50.00
Volume	ft_3/d/1000#	0.80
Moisture	%	78.00
TS	% w.b.	22.00
	lb/d/1000#	11.00
VS	lb/d/1000#	9.35
FS	lb/d/1000#	1.65
N	lb/d/1000#	0.28
P	lb/d/1000#	0.05
K	lb/d/1000#	0.19
C:N ratio		19

*Increase solids and nutrients by 4% for each 1% feed waste more than 5%

Table 4-20
Rabbit Waste Characterization – As Excreted*

Component	Unit	Rabbit
VS	% d.b.	0.86
FS	% d.b.	0.14
COD	% d.b.	1.00
N	% d.b.	0.03
P	% d.b.	0.02
K	% d.b.	0.03
C: N ratio	% d.b.	16

*Increase solids and nutrients by 4% for each 1% feed waste more than 5%

Table 5-2
Agricultural Waste - Soil Permeability
Rate Limitations

Waste	**Limitations**		
	Slight*	**Moderate***	**Severe***
Solids	<2.0	2.0-6.0	.6.0
Liquid	0.2-2.0	0.06-2.0 or 2.0-6.0	<0.06 or >6.0

*Permeability rate = in/hr

Table 5-3
Soil characteristics and recommendations and limitations for land application of waste

Restricting feature (Soil characteristics)	**Site condition**	**Degree of limitation**	**(Limitation or hazard) Recommendations**	**Impact**
Excessive sodium (Sodium adsorption)	(SAR)	Slight	Apply waste.	None.
	< 4	Moderate	(Slight sodicity, choice of crops and germination restricted.) Apply high C:N, low sodium wastes. Rotate application fields and reduce rates for sodic wastes.	**High C:N & low sodium wastes:** Improve soil infiltration, permeability, and structure; reduce plant toxicity. **Sodic wastes:** May increase soil sodicity if applied at continuous high rates.
	> 13	Severe	(Sodicity, limited to sodium-tolerant grasses.) Apply high C:N, low sodium wastes. Rotate applications of sodium wastes. Rotate application fields and reduce rates for sodic wastes.	**High C:N & low sodium wastes:** Improve soil infiltration, permeability, and structure; reduce plant toxicity. **Sodic wastes:** May increase soil sodicity if applied at continuous high rates.

Table 6-6 Plant nutrient uptake by specified crop and removed in the harvest part of the crop										
Crop	**Typical yield/acre plant part**	**---------- Average concentration of nutrients (%) ----------**								
		N	**P**	**K**	**Ca**	**Mg**	**S**	**Cu**	**Mn**	**Zn**
Forage crops		**---------- % of the dry harvested material ----------**								
Tall fescue	3.5 tons	1.97	0.20	2.00	0.30	0.19				

Table 10D-1
Grouping of Soils According to Their Estimated Permeability

Group	Description
I	Soils that have less than 20% passing a No. 200 sieve and have a PI of less than 5
II	Soils that have 20% or more passing a No. 200 sieve and have a PI of less than or equal to 15. Also included in this group are soils with less than 20% passing the No. 200 sieve with fines having a PI of 5 or greater
III	Soils that have 20% or more passing a No. 200 sieve and have a PI of 16 to 30
IV	Soils that have 20% or more passing a No. 200 sieve and have a PI of more than 30

Note: PI =Plasticity Index

Table 10D-2
Unified Classification versus Soil Group for Permeability

Unified Classification[1]	Permeability group[2]			
	I	**II**	**III**	**IV**
CH	N	N	S	U
MH	N	S	U	S
CL	N	S	U	S
ML	N	U	S	N
CL-ML	N	A	N	N
GC	N	S	U	S
GM	S	U	S	S
GW	A	N	N	N
SM	S	U	S	S
SC	N	S	U	S
SW	A	N	N	N
SP	A	N	N	N
GP	A	N	N	N

Note 1: ASTM Method D-2488 has criteria for use of index test data to classify soils by the Unified Soil Classification System.
Note 2: A= Always in this permeability group (PG)
N =Never in this PG
S=Sometimes in this PG (< 10% of samples fall in this group)

U=Usually in this PG (> 90% of samples fall in this group)

Acceptable Settlement

The amount of settlement that is usually considered as acceptable is not very much. For example, the limits of settlement for structures with a spread footing[1] is one inch of total settlement and three-quarters of an inch for differential settlement. For mat foundations[1], the limit is two inches for total settlement and three-quarters of an inch for differential settlement.

Foundation type	Total (inches)	Differential (inches)
Spread footing mat	1.00	0.75
	2.00	0.75

Note 1: All the load and weight of a structure must be supported by the soil. Since the allowable pressure on the soil is generally less than the structure imposes, it is necessary to spread the load over a larger area by using a foundation footing. The most common foundation is the spread footing -- a strip of concrete sufficiently wide to both carry the weight of the structure and to distribute the load over the soil. The mat (or raft) type of foundation is continuous under an entire structure.

Table 10-4
Sludge Accumulation Ratios (Barth: 1985)

Animal type	SAR
Poulty	
Layers	0.0295
Pullet	0.0455
Swine	0.0485
Dairy Cattle	0.0729

Table 10-7
Poultry Mortality Rates

Poultry type	Loss rate % (M)	Flock life (days) (T)	Cycles per year	Market weight (lb) (W)
Broiler Roaster	4.5-5.5	42-49	5.5-6.0	4.2
Females	3	42	4	4.0
Males	8	70	4	7.5
Laying hens	14	440	0.9	4.5
Breeding hens	10-12	440	0.9	7-8
Breeder males	20-25	300	1.1	10-12
Turkey females	5-6	95	3	14
Turkey males	9	112	3	24
Turkey feather prod.	12	126	2.5	30

Table 10-9
Operation Data for Solid/Liquid Separators

Waste type	Separator	- - TS concentration(%)			% Retained in separated solids				
		Raw waste	Separated		TS	VS	COD	N	P
			Liquids	Solids					
Dairy	Vibrating screen								
	16 mesh	5.8	5.2	12.1	56	-	-	-	-
	24 mesh	1.9	1.5	7.5	70	-	-	-	-
	Decanter centrifuge								
	16-30 gpm	6-8	4.9-6.5	13-33	35-40	-	-	-	-
	Static inclined screen								
	12 mesh	4.6	1.6	12.2	49	-	-	-	-
	32 mesh	2.8	1.1	6.0	68	-	-	-	-
Beef	Static inclined screen	4.4	3.8	13.3	15	-	-	-	-
	Vibrating screen	1-2	-	-	40-50	-	-	-	-
Swine	Decanter centrifuge								
	3 gpm	7.6	2.6	37	14	-	-	-	-
	Vibrating screen22 gpm/ft^2								
	18 mesh	4.6	3.6	10.6	35	39	39	22	26
	30 mesh	5.4	3.5	9.5	52	56	49	33	34

Table 10-10
Characteristics of Solid/Liquid Separators (Barker: 1986)

Characteristic	Decanter centrifuge	Vibrating screen	Stationary inclined screen
Typical screen opening	-	20 mesh	10-20 mesh
Maximum waste TS concentration	8%	5%	5%
Separated solids TS concentration	to 35%	to 15%	to 10%
TS reduction *	to 45%	to 30%	to 30%
COD reduction *	to 70%	to 25%	to 45%
N reduction *	to 20%	to 15%	to 30%
P reduction *	to 25%	-	-
Throughput (gpm)	to 30	to 300	to 1,000

* Removed in separated solids

Table 11-1
Friction Loss Ratio, Slurries versus Clean Water
(pipe, 6" to 10" diameter)

Velocity	---------- Percent Solids ----------					
Fps	**4**	**5**	**6**	**7**	**8**	**10**
1.0	1.1	1.5	2.1	2.9	4.0	5.3
1.5	1.0	1.2	1.5	2.1	2.5	4.0
2.0	1.0	1.0	1.0	1.6	1.9	3.3
2.5	1.0	1.0	1.0	1.3	1.6	2.9
3.0	1.0	1.0	1.0	1.2	1.5	2.7
3.5	1.0	1.0	1.0	1.1	1.3	2.5
4.0	1.0	1.0	1.0	1.0	1.0	2.4
4.5	1.0	1.0	1.0	1.0	1.0	2.3
5.0	1.0	1.0	1.0	1.0	1.0	2.2
5.5	1.0	1.0	1.0	1.0	1.0	2.1
6.0	1.0	1.0	1.0	1.0	1.0	2.0
6.5	1.0	1.0	1.0	1.0	1.0	2.0
7.0	1.0	1.0	1.0	1.0	1.0	2.0

Source: Adapted from Colt Industries Hydraulic Handbook, figure 44, Fairbank Morse Pump division, 11th ed.

Table 11-2Maximum application rate (in/hr)

Soil texture	---------- Application amount in inches ----------						
	0.25	**0.50**	**0.75**	**1.00**	**1.25**	**1.50**	**2.00**
Sand	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Loamy sand	6.00	6.00	4.83	4.22	3.86	3.62	3.32
Sandy loam	4.91	2.97	2.32	1.99	1.80	1.67	1.51
Loam	3.11	1.69	1.21	0.98	0.84	0.74	6.62
Silt loam	2.70	1.45	1.03	0.82	0.70	0.61	6.51
Sandy clay loam	1.74	0.96	0.69	0.56	0.48	0.43	6.37
Clay loam	1.27	0.68	0.48	0.39	0.33	0.29	6.24
Silty clay loam	1.09	0.57	0.40	0.32	0.26	0.23	6.19
Sandy clay	0.61	0.33	0.23	0.19	0.16	0.14	6.12
Silty clay	0.84	0.44	0.30	0.24	0.20	0.17	6.14
Clay	0.39	0.21	0.14	0.11	0.09	0.08	6.07

Table 11-3 Reduction coefficients by percent solids							
Soil texture	**---------- Percent solids (by weight) ----------**						
	0.5	**1.0**	**2.0**	**3.0**	**5.0**	**7.0**	**10.0**
Sand	0.88	0.55	0.31	0.22	0.13	0.10	0.07
Loamy sand	0.70	0.54	0.37	0.28	0.19	0.14	0.10
Sandy loam	0.87	0.77	0.63	0.53	0.40	0.32	0.25
Loam	0.97	0.93	0.88	0.83	0.74	0.67	0.59
Silt loam	0.98	0.95	0.91	0.87	0.81	0.75	0.68
Sandy clay loam	0.99	0.97	0.95	0.92	0.87	0.83	0.78
Clay loam	0.99	0.99	0.98	0.97	0.94	0.92	0.89
Silty clay loam	1.00	1.00	0.99	0.99	0.98	0.97	0.96
Sandy clay	1.00	1.00	1.00	1.00	0.99	0.99	0.99
Silty clay	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Clay	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 11-5 Percent of original nutrient content of manure retainiened by various management systems												
Management system	**Beef**			**Dairy**			**Poultry**			**Swine**		
	N	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**
	----------			**Percent----------**								
Manure stored in open lot, cool, humid region	55-70	70-80	55-70	70-85	85-95	85-95				55-70	65-80	55-70
Manure stored in open lot, hot, arid region	40-60	70-80	55-70	55-70	85-95	85-95						
Manure liquids and solids stored in a covered, essentially watertight structure	70-85	85-95	85-95	70-85	85-95	85-95				75-85	85-95	85-95
Manure liquids and solids stored in an uncovered, essentially watertight structure	60-75	80-90	80-90	65-75	80-90	80-90				70-75	80-90	80-90
Manure liquids and solids (diluted less than 50%) held in waste storage pond				65-80	80-95	80-95	55-70	80-95	80-95			
Manure and bedding held in roofed storage				65-80	80-95	80-95						
Manure and bedding held in unroofed storage, leachate lost				55-75	75-85	75-85						
Manure stored in pits beneath slatted floor	70-85	85-95	85-95	70-85	90-95	90-95	80-90	90-95	90-95	70-85	90-95	90-95
Manure treated in anaerobic lagoon or stored in waste storage pond after being diluted more than 50%	20-35	35-50	50-65	20-35	35-50	50-65	20-30	35-50	50-60	20-30	35-50	50-60

Table 11-6
Percentage of nitrogen that in the applied manure still potentially available to the soil (Ammonia volitization causes the predicted losses) (Wilrich, et.al., 1974)

Application method	Percentage remaining/delivered		
Injection		95	
Sprinkling		75	
Broadcast (fresh solids)			
Days between application and incorporation		Soil conditions	
	warm dry	warm wet	cool wet
1	70	90	100
4	60	80	95
7 or more	50	70	90

Table 11-7 An estimate of inorganic nitrogen losses to leaching related to the Soil Leaching Index *

Leaching Index	Inorganic N losses by leaching (%)
< 2	5
2-10	10
>10	15

* This table should be used to provide general guidance in planning

Table 11-8
Approximate N denitrificatuion estimates for various soils -- See footnote for adjustments because of tillage, manure N, irrigatoin, drainage and special soil conditions (Meisinger & Randall, 1991)

Soil organic matter content	Soil drainage classification				
	Excessively well drained	Well drained	Moderately well drained	Somewhat poorly drained	Poorly drained
%	% of inorganic N (fert., precip.) denitrified *				
<2	2-4	3-9	4-4	6-20	10-30
2-5	3-9	4-16	6-20	10-25	15-45
>5	4-12	6-20	10-25	15-35	25-55

*** Adjust for tillage, manure, irrigation, and special soils as follows: For no-tillage, use one class wetter drainage; for manure N, double all values; for tile drained soils, use one class better drainage; for paddy culture, use values under poorly drained; for irrigation or humid climates, use value at upper end of range; for arid or semi-arid nonirrigated sites, use values at lower end of range; for soils with compacted, very slowly permeable layer below plow depth, but above 4 feet deep, use one class wetter drainage.**

Table 11-9
General mineralization rates for nitrogen, phosphorus, and potassium *

Waste and mangement	Years after initial application								
	1	2	3	1	2	3	1	2	3
	Nitrogen			Phosphorus			Potassium		
Fresh poultry manure	90	92	93	80	88	93	85	93	98
Fresh swine or cattle manure	75	79	81	80	88	93	85	93	98
Layer manure from pit storage	80	82	83	80	88	93	85	93	98
Swine or cattle manure stored in covered storage	65	70	73	75	85	90	80	88	93
Swine or cattle manure stored in open structure or pond (undiluted)	60	66	68	75	85	90	80	88	93
Cattle manure with bedding stored in roofed area	60	66	68	75	85	90	80	88	93
Effluent from lagoon or diluted waste storage pond	40	46	49	75	85	90	80	88	93
Manure stored on open lot, cool-humid	50	55	57	80	88	93	85	93	98
Manure stored on open lot, hot-arid	45	50	53	75	85	90	80	88	93

*** Table assumes annual applications on the same site. If a one time application, the decay series can be estimated by subtracting year 1 from year 2 and year 2 from year 3. For example, the decay series for nitrogen from fresh poultry manure would be 0.90, 0.02, 0.01; the decay series for phosphorus from manure stored in open lot, cool-humid, would be 0.80, 0.08 and 0.05. The decay rate becomes essentially constant after 3 years.**

AWMFH, Table 12-9 Waste pump characteristics summary (MWPS 1985, Patronsky) 1978)

Pump type	Max solids (%)	Agitate distance (ft)	Pump rate (gpm)	Pump head (ft)	Power (hp)
Hi-pressure centrifugal	<10	40-60	1,000	200-300	80+
Chopper agitator	10-12	50-75	<4,000	25-75	
Impeller agitator	10-12	75-100	<5,000	30-35	60+
Submersible	10-12	25-50	<1,000	10-30	<15
Helical screw	4-6	30-40	<300	200+	40+
Hollow piston	18-20	-	<150	30-40	<15
Solid piston	18-20	-	<150	30-50	<10
Pneumatic	12-15	-	<150	30-40	<10
Vacuum	8-10	20-25	<300	-	50+
Diaphragm	10-12	-	<300	100+	25+

AWMFH, Table 12-11
Irrigation system selection factors (Patronsky 1978, Shuyler 1973)

Factor	Handmove sprinkler	Towline	Sideroll	Travel gun	Center pivot
Effluent solids	Up to 4% solids	Up to 4% solids	Up to 4% solids	Up to 10% solids	Up to 10% solids
Operation size	Small	Small to medium	Small to medium	All sizes	All sizes
Labor need	High	Medium	Medium	Medium to low	Low
Initial investment	Low	Low	Medium to high	Medium to high	High
Operation costs	Medium	Medium to high	Medium to high	Medium to high	Medium to high
Expansion	Purchase more pipe and equipment	Purchase more pipe and equipment	Purchase more pipe and equipment	Purchase more pipe and equipment	Purchase more pipe and equipment
Hourly attention	Medium	Medium	Medium	Medium	Low
Soil type	Suitable to wide range of intake rates	Suitable to wide range of intake rates	Suitable to wide range of intake rates	Suitable to wide range of intake rates	Suitable to wide range of intake rates
Surface topography	Wide	Wide	Wide	Wide	Wide
Crop height	Adaptable	Low	Low	Adaptable	Adaptable