Swine Waste Volume Component Analysis - March 2013

Background

In 2010, the North Carolina Interagency Nutrient Management Committee (NC INMC), composed of designated specialists from the NCSU Dept of Soil Science, NCDA & CS Division of Soil & Water Conservation, NC DENR Division of Water Quality, NCDA Agronomic Division, and USDA Natural Resources Conservation Service (NRCS), began to review extensive multi-year NCDA sample-based waste analysis data, as well as collected on-farm waste generation and volume information. This information was compiled and presented to the NC INMC by Karl Shaffer (retired NC CES Associate in Waste Management—NCSU Dept of Soil Science) to provide a data-based foundation for group decisions on a revision of the 1993 "Barker" waste data tables used for NC waste management planning. In addition to a redefinition of waste nutrient content values for revised tables based on statistically analyzed NCDA sample data, an objective of the group was to revise waste generation volumes based on collected, sufficient on farm data. After agreeing on revised waste nutrient content values, the group instructed Shaffer to utilize the compiled, analyzed data set for swine to determine if current waste volume generation recommendations were still adequate. A key INMC goal for this effort is to ensure process integrity through documentation of methodology used to guide group consensus and 'approval' of information included in the new tables.

The Shaffer data and INMC waste nutrient content and waste generation volumes recommendations were presented to the Senate Bill 1217 Interagency Group in 2011. The 1217 group expressed concerns with the waste volume recommendations. The primary concern was the inclusion of a severe drought year (2007) in the data representing on-farm yearly land application volume from individual farm records. Land application volumes from each farm included three successive years of data from the '05 through '09 time period. This means that all volume data, by necessity, included the 2007 drought year. The graphs of 2005 – 2009 rainfall data from the NC Climate Center, included in the appendices, depict the below-normal rainfall conditions across all three regions of the Coastal Plains in 2007. The vast majority of swine farms in N.C. are located within these three regions. The 1217 group concerns were based in using the compiled lagoon liquid land application information, which is highly influenced by rainfall, from the 2005 – 2009 time period as a basis for establishing effluent volume estimates for waste management planning. Thus the INMC requested the assistance of Dr. Robert Evans and Dr. Garry Grabow, NCSU BAE, in providing methodology for determination of the current "Barker" waste volumes and whether these volumes needed to be adjusted to represent current conditions.

This report on the compilation of swine waste volumes reflects the combined efforts of NCSU BAE and the NC INMC to use the best available information to achieve INMC objectives of the waste table revision process: (1) to have analyzed, science-based information in the revised tables; and (2) to have a process for group decision-making and data analysis that is recorded and documented. It has been confirmed that the waste volume tables have been established pre 1996.

Manure and Urine Factors

The current, 'original' manure and urine values were derived using the ASAE Manure Production and Characteristics (ASAE, 1989) standard. The standard showed 84 lbs of total manure production per 1,000 lbs given a 135 lb swine. This calculation results in 1.37 gallons of manure and urine per day. The result was then multiplied by the average live weight to differentiate between production types.

(1.37 gal/day / 135 lbs) * Average weight of production type = total manure and urine (gal/animal/day)

Table 1. Excreted Manure and Urine gallons/animal/day

	Average Live Weight (lbs)	Current Manure and Urine (gal/animal/day)	Formula Check (gal/animal/day)
Wean-Feeder	30	0.30	0.30
Feeder-Finish	135	1.40	1.37
Farrow -Wean	433	4.30	4.39
Farrow-Feeder	522	5	5.3
Farrow-Finish	1417	14	14.38

The ASAE Manure Production and Characteristics (ASAE, 2005) standard was consulted for comparison with the current manure and urine values of excreted waste. Production types (groupings) are important when converting the total manure and urine excreted to a value that can be compared with the current volume table. The ASAE Standard of 1989 did not differentiate between animal types, it represented that all swine produced 1.37 gal/animal/day. In the ASAE 2005 standard, it differentiated production groups however they do not directly relate to the production groupings that are referenced in the current 633 waste tables. The summary of swine production types in the ASAE 2005 standard are given in Table 2.

Table 2. ASAE Manure and Production Standard 2005

Production Types	Manure and Urine (gal/135 lb/day)
Nursery (27.5 lb)	1.43
Grow-Finish (154 lb)	1.09
Gestating Sow (440 lb)	0.41
Lactating Sow (423 lb)	0.98

It is difficult to be certain which ASAE production unit would be the preferred grouping for comparative purposes; gestating sow, lactating sow or a combination of both. The volumes comparisons on an annual basis are given in Table 3.

Table 3. Excreted Manure and Urine, gallons per year

Production Types	Current Swine Lagoon Liquid	ASABE (Lactating Sow)	ASABE (Gestating sow)
Wean-Feeder	88.2	85.5	
Feeder-Finish	441	392.7	
Farrow -Wean	1569.5	1145.8	1576.2
Farrow-Feeder	1825	1381.4	1900.2
Farrow-Finish	5110	3749.8	5158.3

To calculate the annual accumulation of manure and urine for Wean – Feeder and Feeder- Finish production types the following formula was used. The groups per year and days per group are based upon values in current Swine Lagoon Liquid Volume Table.

Manure and Urine (gal/animal/day) X groups per year X days per group.

To calculate the annual accumulation of manure and urine for Farrow – Wean, Farrow- Feeder, and Farrow- Finish production types the following formula was used. Because the sows are typically on site for the entire year in each of these production types, 365 days was used instead of groups per year.

Manure and Urine (gal/animal/day) X 365 days

Discussion and Recommendation

The 2005 ASABE standard was developed primarily in response to changes in feed formulation (i.e. change in waster chemical characteristics) and not in change of excreted volumes. In addition, adopting the current ASABE standard would not significantly change the current volume values. Therefore, at this time it is recommended to keep the current manure and urine values as represented in the Swine Lagoon Liquid Volume Table as referenced in the Appendix.

Excess Water Usage Factor

Research on the source and derivation of these numbers yielded no results. Per conversation with Dr. Grabow, Jim Barker said he did not construct these numbers (Barker, personal communication Jan. 30th, 2013). However, the values suggest that the excess wash water is approximately 66% of manure and urine. This is proportionally true for each production type. The excess water usage numbers were included in the NRCS standards 633 (Waste Utilization) and 359 (Waste Treatment Lagoon) dated 1996. Neither document references how these numbers were calculated or by whom.

In-house water use figures for hog operations

NRCS offered cost-share for in-house hog operation water conservation measures. Water metering was done to establish in-house use. The target standard was set for 6 month and 12 month totals based upon the daily use rates shown below in Table 1, plus 5%. The target was offered 3 times, once for a 6-month total and the two others for 1-year totals. There were four years of this program (2005-2008). There were 230 contracts written and 167 of the participants (73%) met the target.

The Murphy-Brown suggested guidance for land application planning purposes when actual water use data is not available is also presented in Table 1.

Table 4. Comparison of NRCS 633 standard, in house water use cost-share standard, and Murphy-Brown guidance.

Operation Type	NRCS 633[1]	NRCS Cost-Share[2]	Murphy-Brown[3]
Wean-Feeder (per head)	0.5	0.8	1.0
Feeder - Finish (per head)	2.3	2.3	2.3
Farrrow to Wean (per sow)	7.2	7.2	7.0
Farrow to Feeder (per sow)	8	8	
Farrow to Finish (per sow)	23	23	

[1]manure and urine and excess water usage.

[2]target based on metered in house water use (well meter records)

[3]Westerbeek, K, and K. Weston. 2012. "Irrigation Scheduling for Animal Operations – Design Considerations", presented at the 48th Annual NC Irrigation Society meeting, Nov. 7, 2012.

Discussion and Recommendation

Three opportunities of meeting the cost-share in-house use rate were available. This means that at any given time, less than 73% of the participants meet the target in-house use rate. The cost-share use rate standard was 5% over the listed table values, which are the current NRCS 663 values with the exception of nursery operations that are higher. Given these conditions and results, it is not recommended to lower the planning in-house use rates given in the NRCS 633 standard (Waste Utilization dated 2/09).

If it becomes available, a synopsis of NRCS standard history and/or record of when these figures were first introduced in the standard would help produce a more effective data review.

Surface Rain Surplus Factor

Method

These numbers were generated from an analysis done by Jim Barker. Dr. Barker used long-term average weather records in several areas to determine rainfall excess, and then applied that to a lagoon surface area based upon a volume determined from sizing a waste treatment lagoon, then using an average depth and side-slope to get a surface area (Barker, personal communication, Jan. 30th, 2013). That volume surface area times rainfall excess was then apportioned on a per head or per sow basis. When

asked about the Doug Jones (Jones, 1996) excess rainfall tables presented by Doug Jones in 1996, he said he was unaware of that data.

To check the per sow or per head surplus rain rates, annual excess rainfall depths for each operation type were computed from lagoon sizing criteria (per head or per sow), and an assumed lagoon depth of 10 feet. This generated an area per animal unit and the 633 standard volume of surface rain excess per year was then applied to obtain an annual depth. This depth ranged from 10-14 inches across operation types. As the average assumed depth did not factor in a side-slope, the annual surface rain surplus depths cited would be conservatively high. The cited depths fall in the range of those reported in the Jones report.

Table 5. .

	Treatment Vol. ft^3	Treatment Volume norm.	Total Storage ft^3	Total Storage norm.	Rain Surplus Normalized	ft^2/unit	Excess Rain Inches
Wean-Feeder	30	0.02	60	0.02	0.02	6	10.74
Feeder-Finish	135	0.10	270	0.10	0.10	27	10.84
Farrow -Wean	290	0.20	650	0.23	0.32	65	14.41
Farrow-Feeder	350	0.24	783	0.28	0.40	78.3	14.96
Farrow-Finish	1417	1	2833	1	1	283.3	10.33

Discussion and Recommendation

As the values in NRCS 633 Standard are based on long-term normals (rather than more extreme design recurrence levels) and "back-checking" corroborated reasonable agreement with a third-party analysis (Jones) it is not recommended to decrease the existing NRCS 633 standard values. It could be argued that the values should be increased to account for above normal years, but a re-analysis would take considerable work and may not result in significant changes.

Wean to Finish Volume Recommendations

The use of the Wean-Finish production type has increased in North Carolina. Requests from technical specialists and producers to develop sludge and lagoon liquid values prompted this evaluation. The following tables demonstrate how the values were determined.

Table 6. Calculating Wean to Finish: Sludge volume per animal per year

Sludge Accumulation

	633 Standard gal/hd/yr	633 Standard gal/hd/d
Wean-Feeder	6.7	0.022
Feeder-Finish	33	0.1

1 Sludge Accumulated - Nursery Phase: 112 d/yr x 0.022 gal/hd/d = 2.464 gal/hd/yr

2 Sludge Accumulated - Feeder Phase: 238 d/yr x 0.1 gal/hd/d = 23.8 gal/hd/yr

3 Total Lagoon Sludge Accumulated for Wean Finish Phase: 26.3 gal/hd/yr

Table 7. Calculating Wean to Finish: Lagoon Liquid Volume per Animal per year.

*From the NRCS 633 Standard. *Less groups per yr. than either phase alone.**Assumes Rain surplus of larger finishing lagoon.*

Phase	Application Method	Mean Live Weight	Groups per yr.	Days per group	Lagoon Liquid Accumulation: Manure&Urine	Excess Water	Rain Surplus	Total	Lagoon Capacity in ft^3/hd capacity	Gal/hd/yr
Wean-Feeder (nursery)	Irrigation	30	*2	49	0.3	0.2	**0.5	1	270	191
Feeder-Finish	Irrigation	135	2	105	1.4	0.9	0.5	2.7	270	927

Time Ratio for each Phase:

Wean-Feeder = 49/(49 + 105) = 0.32
Feeder-Finish = 105/(49 + 105) = 0.68

Populated d/yr: *Assume ~2 weeks of downtime. One week between each group. 365 d/yr - 15 d = 350 d
Nursery component: 350 d/yr x 0.32 = 112 d/yr (nursery phase)
Feeder component: 350 d/yr x 0.68 = 238 d/yr (finish phase)

1 **Waste Accumulated in Nursery phase:** 112 d/yr x 1 gal/d =112 gal/yr

2 **Waste Accumulated in Feeder phase:** 238 d/yr x 2.7 gal/d = 642.6 gal/yr

3 **Liquid Accumulated in unpopulated periods:** 15 d x 0.9 gal/d = 13.5 gal/yr
(assume Excess Water of Finishing Phase)

4 **Total lagoon liquid accumulation for Wean-Finish per year:** 112 gal/yr + 642.6 gal/yr +13.5 gal/yr = **768 g**

Summary of Waste Volumes Recommendations

The Interagency Nutrient Management Committee has taken a thorough approach to verifying the recommendations for swine lagoon liquid volumes, with, as outlined in the report Introduction, group priority placed on the process for compilation of the final swine volume recommendation being accurately and adequately documented. This deliberate approach has resulted in a nearly 2 year process for final recommendations. Table 8 shows the comparison of all approaches considered during the analysis.

Table 8. Comparison of waste volume analysis methods.

	In-Field Irrigation Record Study				
Production Type	Average	90th Percentile	Current Swine Lagoon Liquid Volumes	Using 2005 ASABE Standard (Lactating Sow)	Using 2005 ASABE Standard (Gestating Sow)
Wean-Feeder	231	318	191	184	184
Feeder-Fin	524	744	927	869	859
Farrow -Wean	2182	2785	3203	2788	3218
Farrow-Feeder	2741	3741	3861	3206	3725
Farrow-Fin	4949	5692	10478	8860	10268

Based upon the information presented it is the recommendation of the Interagency Nutrient Management Committee to not change the lagoon liquid volume tables at this time, with the exception of the addition of the Wean –Finish production type. Therefore, the table below represents the volume rates for referenced production types.

Table 9. Final INMC Recommendations.

Production Type	Total Lagoon Liquid Generated gal/animal/year	Total Sludge Generated gal/animal/year
Wean-Feeder	191	6.7
Feeder-Finish	927	33
Farrow –Wean	3203	78
Farrow-Feeder	3861	94
Farrow-Finish	10478	382
Wean - Finish	768	26.3

References

ASAE. 2005. Manure production and characteristics. ASAE Standard ASAE D384.2, St. Joseph,MI. 683-685.

ASAE. 1989. Manure production and characteristics. ASAE Standard ASAE D384.1, St. Joseph,MI. 438-439.

Jones, G. D. 1996. "Rainfall and Evaporation Data". Presented at the Area 3 Engineers Conference, Greenville, NC. July 27.

Appendices

Current Approved Swine Lagoon Liquid Volume Table
Manure Production and Characteristics Table 1 and Table 2 ASAE D384.1 1989
Manure Production and Characteristics Table 1 ASAE D384.2 MAR2005
NRCS 633 Standard (Waste Utilization) – 1996
NRCS 359 Standard (Waste Treatment Lagoon) Table 1 – 1996

Animal/Manure Type	Application Method	Animal Subclass	NCDACS Code	Animal Live Weight (lbs)			Groups Per Yr.	Days Per Group	Lagoon Liquid Accumulation				Total Nutrient Analysis (lbs/unit volume)				Organic N Min. Rate	Plant Availability Coefficient			NCDACS Lab Manure Testing			Total Anaerobic Lagoon Liquid Capacity (ft3/hd capac.)			Total Lagoon Liquid Surplus		PAN			PAN		
				Initial	Final	Mean			manure and urine	excess water usage	surface rain surplus	total	N	NH_3N	P_2O5	K_2O		N	P_2O5	K_2O	N	P_2O5	K_2O	single stage	2-stage, first	2-stage, second	gal/ animal/yr	ac-in/ animal/yr	N	P_2O5	K_2O	N	P_2O5	K_2O
													lbs/ acre-inch	% tot N or tkn	lbs/ acre-inch	lbs/ acre-inch													lbs/ac-in			lbs/animal unit/year		
Swine Anaerobic Lagoon Liquid	Irrigated	Wean-Feeder	ALS-IR	10	50	30	6	49	.30	.20	.11	.61	136	82	53	133	0.50	0.50	0.70	0.70	0.50	0.70	0.80	60	45	15	191	0.007	68	37	93	0.48	0.26	0.66
Swine Anaerobic Lagoon Liquid	Irrigated	Feeder-Fin		50	220	135	3	105	1.4	.9	.5	2.7	136	82	53	133	0.50	0.50	0.70	0.70				270	200	70	927	0.034	68	37	93	2.3	1.3	3.2
Swine Anaerobic Lagoon Liquid	Irrigated	Gilt Dev		50	250	150	2	140	1.5	1.0	.5	3.0	136	82	53	133	0.50	0.50	0.70	0.70				300	225	75	1015	0.037	68	37	93	2.5	1.4	3.5
Swine Anaerobic Lagoon Liquid	Irrigated	Boar Stud		250	550	400	1	365	4.0	2.7	1.4	8.1	68	82	26	67	0.50	0.50	0.70	0.70				500	375	125	2959	0.11	34	19	47	3.7	2	5.1
Swine Anaerobic Lagoon Liquid	Irrigated	Farrow - Wean		---	---	433	2	11	4.3	2.9	1.6	8.8	91	82	35	89	0.50	0.50	0.70	0.70				650	435	215	3203	0.12	45	25	62	5.4	2.9	7.3
Swine Anaerobic Lagoon Liquid	Irrigated	Farrow-Feeder		---	---	522	2	63	5	3	2	11	91	82	35	89	0.50	0.50	0.70	0.70				783	523	260	3861	0.14	45	25	62	6.5	3.5	8.8
Swine Anaerobic Lagoon Liquid	Irrigated	Farrow-Fin		---	---	1417	2	168	14	9	5	29	136	82	53	133	0.50	0.50	0.70	0.70				2833	2125	708	10478	0.39	68	37	93	26	14	36
									manure and urine	excess water usage	surface rain surplus	total	lbs/ 1000 gal	% tot N or tkn	lbs/ 1000 gal	lbs/ 1000 gal								single stage	2-stage, first	2-stage, second	gal/ animal/yr	ac-in/ animal/yr	lbs/1000 gal			lbs/animal unit/year		
Swine Anaerobic Lagoon Liquid	Soil Injected	Wean-Feeder	ALS-IN	10	50	30	6	49	.30	.20	.11	.61	5.0	82	1.9	4.9	0.50	0.87	0.80	0.80	0.86	0.80	0.90	60	45	15	191	0.007	4.4	1.6	3.9	0.83	0.3	0.75
Swine Anaerobic Lagoon Liquid	Soil Injected	Feeder-Fin		50	220	135	3	105	1.4	.9	.5	2.7	5.0	82	1.9	4.9	0.50	0.87	0.80	0.80				270	200	70	927	0.034	4.4	1.6	3.9	4	1.4	3.6
Swine Anaerobic Lagoon Liquid	Soil Injected	Gilt Dev		50	250	150	2	140	1.5	1.0	.5	3.0	5.0	82	1.9	4.9	0.50	0.87	0.80	0.80				300	225	75	1015	0.037	4.4	1.6	3.9	4.4	1.6	4
Swine Anaerobic Lagoon Liquid	Soil Injected	Boar Stud		250	550	400	1	365	4.0	2.7	1.4	8.1	2.5	82	1.0	2.5	0.50	0.87	0.80	0.80				500	375	125	2959	0.11	2.2	0.78	2	6.4	2.3	5.8
Swine Anaerobic Lagoon Liquid	Soil Injected	Farrow - Wean		---	---	433	2	11	4.3	2.9	1.6	8.8	3.3	82	1.3	3.3	0.50	0.87	0.80	0.80				650	435	215	3203	0.12	2.9	1	2.6	9.3	3.3	8.4
Swine Anaerobic Lagoon Liquid	Soil Injected	Farrow-Feeder		---	---	522	2	63	5	3	2	11	3.3	82	1.3	3.3	0.50	0.87	0.80	0.80				783	523	260	3861	0.14	2.9	1	2.6	11	4	10
Swine Anaerobic Lagoon Liquid	Soil Injected	Farrow-Fin		---	---	1417	2	168	14	9	5	29	5.0	82	1.9	4.9	0.50	0.87	0.80	0.80				2833	2125	708	10478	0.39	4.4	1.6	3.9	46	16	41
Swine Anaerobic Lagoon Liquid	Soil Incorporated	Wean-Feeder	ALS-SI	10	50	50	6	49	.30	.20	.11	.61	5.0	82	1.9	4.9	0.50	0.79	0.75	0.75	0.78	0.80	0.90	60	45	15	191	0.007	3.9	1.5	3.7	0.75	0.28	0.7
Swine Anaerobic Lagoon Liquid	Soil Incorporated	Feeder-Fin		50	220	225	3	105	1.4	.9	.5	2.7	5.0	82	1.9	4.9	0.50	0.79	0.75	0.75				270	200	70	927	0.034	3.9	1.5	3.7	3.7	1.4	3.4
Swine Anaerobic Lagoon Liquid	Soil Incorporated	Gilt Dev		50	250	150	2	140	1.5	1.0	.5	3.0	5.0	82	1.9	4.9	0.50	0.79	0.75	0.75				300	225	75	1015	0.037	3.9	1.5	3.7	4	1.5	3.7
Swine Anaerobic Lagoon Liquid	Soil Incorporated	Boar Stud		250	550	400	1	365	4.0	2.7	1.4	8.1	2.5	82	1.0	2.5	0.50	0.79	0.75	0.75				500	375	125	2959	0.11	2	0.73	1.8	5.8	2.2	5.4
Swine Anaerobic Lagoon Liquid	Soil Incorporated	Farrow - Wean		---	---	433	2	11	4.3	2.9	1.6	8.8	3.3	82	1.3	3.3	0.50	0.79	0.75	0.75				650	435	215	3203	0.12	2.6	0.97	2.5	8.4	3.1	7.9
Swine Anaerobic Lagoon Liquid	Soil Incorporated	Farrow-Feeder		---	---	522	2	63	5	3	2	11	3.3	82	1.3	3.3	0.50	0.79	0.75	0.75				783	523	260	3861	0.14	2.6	0.97	2.5	10	3.8	9.5
Swine Anaerobic Lagoon Liquid	Soil Incorporated	Farrow-Fin		---	---	1417	2	168	14	9	5	29	5.0	82	1.9	4.9	0.50	0.79	0.75	0.75				2833	2125	708	10478	0.39	3.9	1.5	3.7	41	15	39
Swine Anaerobic Lagoon Liquid	Broadcast	Wean-Feeder	ALS-BR	10	50	50	6	49	.30	.20	.11	.61	5.0	82	1.9	4.9	0.50	0.46	0.70	0.70	0.50	0.70	0.80	60	45	15	191	0.007	2.3	1.4	3.4	0.44	0.26	0.66
Swine Anaerobic Lagoon Liquid	Broadcast	Feeder-Fin		50	220	225	3	105	1.4	.9	.5	2.7	5.0	82	1.9	4.9	0.50	0.46	0.70	0.70				270	200	70	927	0.034	2.3	1.4	3.4	2.1	1.3	3.2
Swine Anaerobic Lagoon Liquid	Broadcast	Gilt Dev		50	250	150	2	140	1.5	1.0	.5	3.0	5.0	82	1.9	4.9	0.50	0.46	0.70	0.70				300	225	75	1015	0.037	2.3	1.4	3.4	2.3	1.4	3.5
Swine Anaerobic Lagoon Liquid	Broadcast	Boar Stud		250	550	400	1	365	4.0	2.7	1.4	8.1	2.5	82	1.0	2.5	0.50	0.46	0.70	0.70				500	375	125	2959	0.11	1.2	0.68	1.7	3.4	2	5.1
Swine Anaerobic Lagoon Liquid	Broadcast	Farrow - Wean		---	---	433	2	11	4.3	2.9	1.6	8.8	3.3	82	1.3	3.3	0.50	0.46	0.70	0.70				650	435	215	3203	0.12	1.5	0.91	2.3	4.9	2.9	7.3
Swine Anaerobic Lagoon Liquid	Broadcast	Farrow-Feeder		---	---	522	2	63	5	3	2	11	3.3	82	1.3	3.3	0.50	0.46	0.70	0.70				783	523	260	3861	0.14	1.5	0.91	2.3	5.9	3.5	8.8
Swine Anaerobic Lagoon Liquid	Broadcast	Farrow-Fin		---	---	1417	2	168	14	9	5	29	5.0	82	1.9	4.9	0.50	0.46	0.70	0.70				2833	2125	708	10478	0.39	2.3	1.4	3.4	24	14	36

* References: Depts of Biological & Agricultural Engineering, Animal Science; NC State University, 1990; Agronomic Division, NCDACS
** Assumes 400 lb sow and boar on limited feed, 3 week old weanling, 50 lb feeder pig, 220 lb market hog and 20 pigs/sow
*** Estimated total lagoon liquid includes total liquid manure plus average annual rainfall surplus incidental to lagoon surface; does not account for seepage.
***** Soil injected: Lagoon liquid injected directly into soil and covered immediately.
***** Soil incorporated: surface spread liquid plowed or disked into soil surface within 2 days.
***** Broadcast: Surface spread liquid uncovered for 1 month or longer.

**** Irrigated: Sprinkler irrigated liquid uncovered for 1 month or longer.
***** Wean-Feeder, Feeder-Finish are per head capacity. Farrow-Wean, Farr-Feeder, & Farr-Finish are per active sow.

MANURE PRODUCTION AND CHARACTERISTICS

Developed by the Engineering Practices Subcommittee of the ASAE Agricultural Sanitation and Waste Management Committee; approved by the ASAE Structures and Environment Division Standards Committee; adopted by ASAE December 1976; reconfirmed December 1981, December 1982, December 1983, December 1984, December 1985, December 1986, December 1987; revised June 1988.

SECTION 1—PURPOSE AND SCOPE

1.1 Data on livestock manure production and characteristics are presented to assist in the planning, design and operation of manure collection, storage, pretreatment and utilization systems for livestock enterprises.

1.2 These data are combined from a wide base of published and unpublished information on livestock manure production and characterization. Users of this information should recognize that the mean values for each parameter are determined by an arithmetic average consisting of one data point per reference source per year. The values represent fresh (as voided) feces and urine. Actual values vary due to differences in animal diet, age, usage, productivity and management. Whenever site specific data are available or actual sample analyses can be performed, such information should be considered in lieu of the mean values presented here.

TABLE 1—FRESH MANURE PRODUCTION AND CHARACTERISTICS PER 1 000 kg LIVE ANIMAL MASS PER DAY

Parameter	Units*		Typical Live Animal Masses										
			Dairy 640 kg†	Beef 360 kg	Veal 91 kg	Swine 61 kg	Sheep 27 kg	Goat 64 kg	Horse 450 kg	Layer 1.8 kg	Broiler 0.9 kg	Turkey 6.8 kg	Duck 1.4 kg
Total manure‡	kg	mean§	86	58	62	84	40	41	51	64	85	47	110
		std. deviation	17	17	24	24	11	8.6	7.2	19	13	13	**
Urine	kg	mean	26	18	**	39	15	**	10	**	**	**	**
		std. deviation	4.3	4.2	**	4.8	3.6	**	0.74	**	**	**	**
Density	kg/m^3	mean	990	1 000	1 000	990	1 000	1 000	1 000	970	1 000	1 000	**
		std. deviation	63	75	**	24	64	**	93	39	**	**	**
Total solids	kg	mean	12	8.5	5.2	11	11	13	15	16	22	12	31
		std. deviation	2.7	2.6	2.1	6.3	3.5	1.0	4.4	4.3	1.4	3.4	15
[illegible] solids	kg	mean	10	7.2	2.3	8.5	9.2	**	10	12	17	9.1	19
		std. deviation	0.79	0.57	**	0.66	0.31	**	3.7	0.84	1.2	1.3	**
Biochemical oxygen demand, 5-day	kg	mean	1.6	1.6	1.7	3.1	1.2	**	1.7	3.3	**	2.1	4.5
		std. deviation	0.48	0.75	**	0.72	0.47	**	0.23	0.91	**	0.46	**
Chemical oxygen demand	kg	mean	11	7.8	5.3	8.4	11	**	**	11	16	9.3	27
		std. deviation	2.4	2.7	**	3.7	2.5	**	**	2.7	1.8	1.2	**
pH		mean	7.0	7.0	8.1	7.5	**	**	7.2	6.9	**	**	**
		std. deviation	0.45	0.34	**	0.57	**	**	**	0.56	**	**	**
Total Kjeldahl nitrogen‖	kg	mean	0.45	0.34	0.27	0.52	0.42	0.45	0.30	0.84	1.1	0.62	1.5
		std. deviation	0.096	0.073	0.045	0.21	0.11	0.12	0.063	0.22	0.24	0.13	0.54
Ammonia nitrogen	kg	mean	0.079	0.086	0.12	0.29	**	**	**	0.21	**	0.080	**
		std. deviation	0.083	0.052	0.016	0.10	**	**	**	0.18	**	0.018	**
Total phosphorus	kg	mean	0.094	0.092	0.066	0.18	0.087	0.11	0.071	0.30	0.30	0.23	0.54
		std. deviation	0.024	0.027	0.011	0.10	0.030	0.016	0.026	0.081	0.053	0.093	0.21
Orthophosphorus	kg	mean	0.061	0.030	**	0.12	0.032	**	0.019	0.092	**	**	0.25
		std. deviation	0.005 8	**	**	**	0.014	**	0.007 1	0.016	**	**	**
Potassium	kg	mean	0.29	0.21	0.28	0.29	0.32	0.31	0.25	0.30	0.40	0.24	0.71
		std. deviation	0.094	0.061	0.10	0.16	0.11	0.14	0.091	0.072	0.064	0.080	0.34
Calcium	kg	mean	0.16	0.14	0.059	0.33	0.28	**	0.29	1.3	0.41	0.63	**
		std. deviation	0.059	0.11	0.049	0.18	0.15	**	0.11	0.57	**	0.34	**
Magnesium	kg	mean	0.071	0.049	0.033	0.070	0.072	**	0.057	0.14	0.15	0.073	**
		std. deviation	0.016	0.015	0.023	0.035	0.047	**	0.016	0.042	**	0.007 1	**
Sulfur	kg	mean	0.051	0.045	**	0.076	0.055	**	0.044	0.14	0.085	**	**
		std. deviation	0.010	0.005 2	**	0.040	0.043	**	0.022	0.066	**	**	**
Sodium	kg	mean	0.052	0.030	0.086	0.067	0.078	**	0.036	0.10	0.15	0.066	**
		std. deviation	0.026	0.023	0.063	0.052	0.027	**	**	0.051	**	0.012	**
Chloride	kg	mean	0.13	**	**	0.26	0.089	**	**	0.56	**	**	**
		std. deviation	0.039	**	**	0.052	**	**	**	0.44	**	**	**
Iron	mg	mean	12	7.8	0.33	16	8.1	**	16	60	**	75	**
		std. deviation	6.6	5.9	**	9.7	3.2	**	8.1	49	**	28	**
Manganese	mg	mean	1.9	1.2	**	1.9	1.4	**	2.8	6.1	**	2.4	**
		std. deviation	0.75	0.51	**	0.74	1.5	**	2.1	2.2	**	0.33	**
B	mg	mean	0.71	0.88	**	3.1	0.61	**	1.2	1.8	**	**	**
		std. deviation	0.35	0.064	**	0.95	0.30	**	0.48	1.7	**	**	**
Molybdenum	mg	mean	0.074	0.042	**	0.028	0.25	**	0.083	0.30	**	**	**
		std. deviation	0.012	**	**	0.030	0.38	**	0.033	0.057	**	**	**

TABLE 1—FRESH MANURE PRODUCTION AND CHARACTERISTICS PER 1 000 kg LIVE ANIMAL MASS PER DAY (cont'd)

Parameter	Units*		Typical Live Animal Masses										
			Dairy 640 kg†	Beef 360 kg	Veal 91 kg	Swine 61 kg	Sheep 27 kg	Goat 64 kg	Horse 450 kg	Layer 1.8 kg	Broiler 0.9 kg	Turkey 6.8 kg	Duck 1.4 kg
Zinc	mg	mean	1.8	1.1	13	5.0	1.6	**	2.2	19	3.6	15	**
		std. deviation	0.65	0.43	**	2.5	1.0	**	2.1	33	**	12	**
Copper	mg	mean	0.45	0.31	0.048	1.2	0.22	**	0.53	0.83	0.98	0.71	**
		std. deviation	0.14	0.12	**	0.84	0.066	**	0.39	0.84	**	0.10	**
Cadmium	mg	mean	0.003 0	**	**	0.027	0.007 2	**	0.005 1	0.038	**	**	**
		std. deviation	**	**	**	0.028	**	**	**	0.032	**	**	**
Nickel	mg	mean	0.28	**	**	**	**	**	0.62	0.25	**	**	**
		std. deviation	**	**	**	**	**	**	**	**	**	**	**
Lead	mg	mean	**	**	**	0.084	0.084	**	**	0.74	**	**	**
		std. deviation	**	**	**	0.012	**	**	**	**	**	**	**
Total coliform bacteria	colonies#	mean	1 100	63	**	45	20	**	490	110	**	**	**
		std. deviation	2 800	59	**	33	26	**	490	100	**	**	**
Fecal coliform bacteria	colonies	mean	16	28	**	18	45	**	0.092	7.5	**	1.4	180
		std. deviation	28	27	**	12	27	**	0.029	2.0	**	**	180
Fecal streptococcus bacteria	colonies	mean	92	31	**	530	62	**	58	16	**	**	590
		std. deviation	140	45	**	290	73	**	59	7.2	**	**	**

*All values wet basis.
†Typical live animal masses for which manure values represent. Differences within species according to usage exist, but sufficient fresh manure data to list these differences was not found.
‡Feces and urine as voided.
§Parameter means within each animal species are comprised of varying populations of data. Maximum numbers of data points for each species are: dairy, 85; beef, 50; veal, 5; swine, 58; sheep, 39; goat, 3; horse, 31; layer, 74; broiler, 14; turkey, 18; and duck, 6.
‖ All nutrients and metals values are given in elemental form.
#Mean bacteria colonies per 1 000 kg animal mass multiplied by 10^{10}. Colonies per 1 000 kg animal mass divided by kg total manure per 1 000 kg animal mass multiplied by density (kg/m^3) equals colonies per m^3 of manure.
**Data not found.

TABLE 2—FRESH MANURE PRODUCTION AND CHARACTERISTICS PER 1,000 lb LIVE ANIMAL MASS PER DAY

Parameter	Units*		Typical Live Animal Masses										
			Dairy 1400 lb†	Beef 800 lb	Veal 200 lb	Swine 135 lb	Sheep 60 lb	Goat 140 lb	Horse 1000 lb	Layer 4 lb	Broiler 2 lb	Turkey 15 lb	Duck 3 lb
Total manure‡	lb	mean§	86	58	62	84	40	41	51	64	85	47	110
		std. deviation	17	17	24	24	11	8.6	7.2	19	13	13	**
Urine	lb	mean	26	18	**	39	15	**	10	**	**	**	**
		std. deviation	4.3	4.2	**	4.8	3.6	**	0.74	**	**	**	**
Density	lb/ft^3	mean	62	63	62	62	64	63	63	60	63	63	**
		std. deviation	4.0	4.7	**	1.5	4.0	**	5.8	2.4	**	**	**
Total solids	lb	mean	12	8.5	5.2	11	11	13	15	16	22	12	31
		std. deviation	2.7	2.6	2.1	6.3	3.5	1.0	4.4	4.3	1.4	3.4	15
Volatile solids	lb	mean	10	7.2	2.3	8.5	9.2	**	10	12	17	9.1	19
		std. deviation	0.79	0.57	**	2.3	0.31	**	3.7	0.84	1.2	1.3	**
Biochemical oxygen demand, 5-day	lb	mean	1.6	1.6	1.7	3.1	1.2	**	1.7	3.3	**	2.1	4.5
		std. deviation	0.48	0.75	**	0.72	0.47	**	0.23	0.91	**	0.46	**
Chemical oxygen demand	lb	mean	11	7.8	5.3	8.4	11	**	**	11	16	9.3	27
		std. deviation	2.4	2.7	**	5.3	2.5	**	**	2.7	18	1.2	**
pH		mean	7.0	7.0	8.1	7.5	**	**	7.2	6.9	**	**	**
		std. deviation	0.45	0.34	**	0.57	**	**	**	0.56	**	**	**
Total Kjeldahl nitrogen‖	lb	mean	0.45	0.34	0.27	0.52	0.42	0.45	0.30	0.84	1.1	0.62	1.5
		std. deviation	0.096	0.073	0.045	0.21	0.11	0.12	0.063	0.22	0.24	0.13	0.54
Ammonia nitrogen	lb	mean	0.079	0.086	0.12	0.29	**	**	**	0.21	**	0.080	**
		std. deviation	0.083	0.052	0.016	0.10	**	**	**	0.18	**	0.018	**
Total phosphorus	lb	mean	0.094	0.092	0.066	0.18	0.087	0.11	0.071	0.30	0.30	0.23	0.54
		std. deviation	0.024	0.027	0.011	0.10	0.030	0.016	0.026	0.081	0.053	0.093	0.21
Orthophosphorus	lb	mean	0.061	0.030	**	0.12	0.032	**	0.019	0.092	**	**	0.25
		std. deviation	0.058	**	**	**	0.014	**	0.0071	0.016	**	**	**
Potassium	lb	mean	0.29	0.21	0.28	0.29	0.32	0.31	0.25	0.30	0.40	0.24	0.71
		std. deviation	0.094	0.061	0.10	0.16	0.11	0.14	0.091	0.072	0.064	0.080	0.34
Calcium	lb	mean	0.16	0.14	0.059	0.33	0.28	**	0.29	1.3	0.41	0.63	**
		std. deviation	0.059	0.11	0.049	0.18	0.15	**	0.11	0.57	**	0.34	**
Magnesium	lb	mean	0.071	0.049	0.033	0.070	0.072	**	0.057	0.14	0.15	0.073	**
		std. deviation	0.016	0.015	0.023	0.035	0.047	**	0.016	0.042	**	0.0071	**
Sulfur	lb	mean	0.051	0.045	**	0.076	0.055	**	0.044	0.14	0.085	**	**
		std. deviation	0.010	0.0052	**	0.040	0.043	**	0.022	0.066	**	**	**
Sodium	lb	mean	0.052	0.030	0.086	0.067	0.078	**	0.036	0.10	0.15	0.066	**
		std. deviation	0.026	0.023	0.063	0.052	0.027	**	**	0.051	**	0.012	**
Chloride	lb	mean	0.13	**	**	0.26	0.089	**	**	0.56	**	**	**
		std. deviation	0.039	**	**	0.052	**	**	**	0.44	**	**	**
Iron	lb	mean	0.012	0.0078	0.00033	0.016	0.0081	**	0.016	0.060	**	0.075	**
		std. deviation	0.0066	0.0059	**	0.0097	0.0032	**	0.0081	0.049	**	0.028	**

TABLE 2–FRESH MANURE PRODUCTION AND CHARACTERISTICS PER 1,000 lb LIVE ANIMAL MASS PER DAY (cont'd)

Parameter	Units*		Typical Live Animal Masses									
			Dairy 1400 lb†	Beef 800 lb	Veal 200 lb	Swine 135 lb	Sheep 60 lb	Goat 140 lb	Horse 1000 lb	Layer 4 lb	Broiler 2 lb	Turkey 15 lb	Duck 3 lb
Manganese	lb	mean	0.0019	0.0012	**	0.0019	0.0014	**	0.0028	0.0061	**	0.0024	**
		std. deviation	0.00075	0.00051	**	0.00074	0.0015	**	0.0021	0.0022	**	0.00033	**
Boron	lb	mean	0.00071	0.00088	**	0.0031	0.00061	**	0.0012	0.0018	**	**	**
		std. deviation	0.00035	0.000064	**	0.00095	0.00030	**	0.00048	0.0017	**	**	**
Molybdenum	lb	mean	0.000074	0.000042	**	0.000028	0.00025	**	0.000083	0.00030	**	**	**
		std. deviation	0.000012	**	**	0.000030	0.00038	**	0.000033	0.000057	**	**	**
Zinc	lb	mean	0.0018	0.0011	0.013	0.0050	0.0016	**	0.0022	0.019	0.0036	0.015	**
		std. deviation	0.00065	0.00043	**	0.0025	0.0010	**	0.0021	0.033	**	0.012	**
Copper	lb	mean	0.00045	0.00031	0.000048	0.0012	0.00022	**	0.00053	0.00083	0.00098	0.00071	**
		std. deviation	0.00014	0.00012	**	0.00084	0.000066	**	0.00039	0.00084	**	0.00010	**
Cadmium	lb	mean	0.0000030	**	**	0.000027	0.0000072	**	0.0000051	0.000038	**	**	**
		std. deviation	**	**	**	0.000028	**	**	**	0.000032	**	**	**
Nickel	lb	mean	0.00028	**	**	**	**	**	0.00062	0.00025	**	**	**
		std. deviation	**	**	**	**	**	**	**	**	**	**	**
Lead	lb	mean	**	**	**	0.000084	0.000084	**	**	0.00074	**	**	**
		std. deviation	**	**	**	0.000012	**	**	**	**	**	**	**
Total coliform bacteria	colonies#	mean	500	29	**	21	9.0	**	220	50	**	**	**
		std. deviation	1300	27	**	15	12	**	220	46	**	**	**
Fecal coliform bacteria	colonies	mean	7.2	13	**	8.0	20	**	0.042	3.4	**	0.62	81
		std. deviation	13	12	**	5.4	12	**	0.013	0.91	**	**	81
Fecal streptococcus bacteria	colonies	mean	42	14	**	240	28	**	26	7.4	**	**	270
		std. deviation	63	21	**	130	33	**	27	3.3	**	**	**

*All values wet basis.
†Typical live animal masses for which manure values represent. Differences within species according to usage exist, but sufficient fresh manure data to list these differences was not found.
‡Feces and urine as voided.
§Parameter means within each animal species are comprised of varying populations of data. Maximum numbers of data points for each species are: dairy, 85; beef, 50; veal, 5; swine, 58; sheep, 39; goat, 3; horse, 31; layer, 74; broiler, 14; turkey, 18; and duck, 6.
‖ All nutrients and metals values are given in elemental form.
#Mean bacteria colonies per 1,000 lb animal mass multiplied by 10^{10}. Colonies per 1,000 lb animal mass divided by lb total manure per 1,000 lb animal mass multiplied by density (lb/ft^3) equals colonies per ft^3 of manure.
**Data not found.

ASAE D384.2 MAR2005
Manure Production and Characteristics

American Society of Agricultural Engineers

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ASAE-The Society for engineering in agricultural, food, and biological systems
2950 Niles Rd., St. Joseph, MI 49085-9659, USA ph. 269-429-0300, fax 269-429-3852, hq@asae.org

Manure Production and Characteristics

Developed by the Engineering Practices Subcommittee of the ASAE Agricultural Sanitation and Waste Management Committee; approved by the Structures and Environment Division Standards Committee; adopted by ASAE December 1976; reconfirmed December 1981, December 1982, December 1983, December 1984, December 1985, December 1986, December 1987; revised June 1988; revised editorially and reaffirmed December 1993; revised editorially March 1995; reaffirmed December 1998, December 1999, December 2001, February 2003; revised March 2005 by a joint committee of ASAE and Federation of Animal Science Societies members.

1.0 Purpose

1.1 This standard provides three types of information for estimating characteristics of livestock and poultry manure:

- Typical characteristics for manure "as-excreted" by livestock and poultry based on typical diets and animal performance levels in 2002 (Section 3);
- Equations for estimating manure excretion characteristics based on animal performance and dietary feed and nutrient intake specific to an individual situation (Sections 4 through 9);
- Typical characteristics for manure "as-removed" from manure storage or animal housing (Section 10).

1.2 Typical or average estimates of manure excreted become obsolete due to changes in animal genetics, performance potential, feeding program strategies, and available feeds. To minimize future concerns, a set of equations for predicting nutrient excretion (primarily nitrogen and phosphorus), dry matter, and, depending upon species, other potential characteristics have been assembled for beef, dairy, swine, horses and poultry. The Equation Estimates sections (Sections 4 through 9) allow an estimate of manure characteristics that is relevant to a wide range of dietary options and animal performance levels commonly observed in commercial production.

1.3 It is more appropriate to use the equations in Sections 4 through 9 for the following situations:

- When comprehensive nutrient management plans are being developed specific to an individual animal feeding operation (AFO);
- When farm specific data is available for an AFO's feeding program and animal performance;
- When feed intake, feed nutrient concentration, feed digestibility, or animal performance varies from the assumptions used to estimate the typical values in Table 1.
- When Table 1 has not been updated to address industry trends.

1.4 It may be more appropriate to use the typical values found in Table 1 for the following situations:

- When planning estimates are being made on a scale larger than a single farm (e.g. county or regional estimate of nutrient excretion)
- When a rough approximation is needed for farm planning;
- When farm-specific information of animal performance and feed intake is not available.

2.0 Caution

2.1 Section 3. Typical As-Excreted Manure Production and Characteristics. The user of these data should recognize that the reported typical values may become obsolete with time due to changes in animal genetics, feeding programs, alternative feeding technologies, and available feeds. In addition, users should also recognize that under current conditions, excretion of nutrients and other related characteristics will vary for individual situations from the currently listed values due to variations in animal feed nutrient intake, animal performance, and individual farm management. Sections 4 – 9 provide an alternative, and often more accurate, methodology for estimating nutrient excretion for individual production systems.

Table 1. Section 3 – Estimated typical manure (urine and feces combined) characteristics as excreted[1] by:
Table 1.a – Meat-producing livestock and poultry. Diet based numbers are in **BOLD**. See footnotes 2 and 3 for source of non-bold values.

Animal Type and Production Grouping	Total solids[3]	Volatile solids[3]	COD[3,4]	BOD[3,4]	Nitrogen	P	K	Ca	Total Manure[5]		Moisture[6]	Assumed Finishing Time Period (days)
	kg / finished animal (f.a.)								kg / f.a.	liter / f.a.	% w.b.	
Beef - Finishing cattle	**360**	**290**	300	67	**25**	**3.3**	17.1	**7.7**	4,500	4,500	92	153
Poultry - Broiler	**1.3**	0.95	1.05	0.30	**0.053**	**0.016**	**0.031**		4.9	4.9	74	48
Poultry - Turkey (male)	**9.2**	7.4	8.5	2.4	**0.55**	**0.16**	0.26		36	36	74	133
Poultry - Turkey (females)	**4.4**	3.5	4.0	1.1	**0.26**	**0.074**	0.11		17	17	74	105
Poultry - Duck	**1.7**	1.0	1.4	0.28	**0.062**	**0.022**	0.031		6.5	6.5	74	39
Swine - Nursery pig (12.5 kg)	4.8	4.0	4.4	1.5	**0.41**	**0.068**	0.16		48	48	90	36
Swine - Grow-finish (70 kg)	**56**	45	47	17	**4.7**	**0.76**	2.0		560	560	90	120
	lb / finished animal (f.a.)									ft^3 / f.a.	% w.b.	
Beef - Finishing cattle	**780**	**640**	670	150	**55**	**7.3**	38	**17**	9,800	160	92	153
Poultry - Broiler	**2.8**	2.1	2.3	0.66	**0.12**	**0.035**	**0.068**		11	0.17	74	48
Poultry - Turkey (male)	**20**	16	19	5.2	**1.2**	**0.36**	0.57		78	1.3	74	133
Poultry - Turkey (females)	**9.8**	7.8	8.8	2.4	**0.57**	**0.16**	0.25		38	0.61	74	105
Poultry - Duck	**3.7**	2.2	3.0	0.61	**0.14**	**0.048**	0.068		14	0.23	74	39
Swine - Nursery pig (27.5 lb)	10	8.7	9.7	3.4	**0.91**	**0.15**	0.35		87	1.4	90	36
Swine - Grow-finish (154 lb)	**120**	99	104	38	**10**	**1.7**	4.4		1200	20	90	120

Table 1.b – Section 3 – All other livestock and poultry. Diet based numbers are in **BOLD**. See footnotes 2 and 3 for source of non-bold values.

Animal Type and Production Grouping	Total solids[3]	Volatile solids[3]	COD[3,4]	BOD[3,4]	Nitrogen	P	K	Ca	Mg	Total Manure[5]		Moisture[6]
	kg / day-animal (d-a)									kg / (d-a)	liter / d-a.	% w.b.
Beef - Cow (confinement)[7,10]	**6.6**	**5.9**	6.2	1.4	**0.19**	**0.044**	0.14	**0.089**		-	-	88
Beef - Growing Calf (confinement)	**2.7**	**2.3**	2.3	0.52	**0.13**	**0.025**	0.085	**0.040**		22	22	88
Dairy - Lactating cow	**8.9**	7.5	8.1	1.30	**0.45**	**0.078**	**0.103**			68	68	87
Dairy - Dry cow	**4.9**	4.2	4.4	0.626	**0.23**	0.03	0.148			38	3	87
Dairy - Milk fed calves					0.0079							
Dairy - Calf-150 kg	1.4				0.063					8.5	8.5	83
Dairy - Heifer-440 kg	3.7	3.2	3.4	0.54	**0.12**	**0.020**				22	22	83
Dairy - Veal-118 kg	0.12				0.015	0.0045	0.0199			3.5	3.5	96
Horse - Sedentary-500 kg[8]	**3.8**	3.0		0.48	**0.089**	**0.013**	**0.027**	**0.023**	**0.009**	25	25	85
Horse - Intense exercise -500 kg[8]	**3.9**	3.1		0.49	**0.15**	**0.033**	**0.095**	**0.069**	**0.018**	26	26	85
Layer	**0.022**	0.016	0.018	0.0050	**0.0016**	**0.00048**	0.00058	**0.0022**		0.088	0.088	75
Swine - Gestating sow-200 kg	0.50	0.45	0.47	0.17	**0.032**	**0.009**	0.022			5.0	5.0	90
Swine - Lactating sow[9] -192 kg	1.2	1.0	1.1	0.38	**0.085**	**0.025**	.053			12	12	90
Swine - Boar-200 kg	0.38	0.34	0.27	0.13	0.028	0.0097	.0176			3.8	3.8	90
	lb / day-animal (d-a)									lb / d-a.	ft^3 / d-a.	% w.b.
Beef - Cow (confinement)[7,10]	**15**	**13**	14	3.0	**0.42**	**0.097**	0.30	**0.20**		-	-	88
Beef - Growing Calf (confinement)	**6.0**	**5.0**	5.2	1.1	**0.29**	**0.055**	0.19	**0.088**		50	0.81	88
Dairy - Lactating cow	**20**	17	18	2.9	**0.99**	**0.17**	**0.23**			150	2.4	87
Dairy - Dry cow	**11**	9.2	9.7	1.4	**0.50**	**0.086**	0.33			83	1.3	87
Dairy - Milk fed calves					0.017							
Dairy - Calf-330lb	3.2				0.14					19	0.30	83
Dairy - Heifer-970 lb	8.2	7.1	7.5	1.2	**0.26**	**0.044**				48	0.78	83
Dairy - Veal-260 lb	0.27				0.033	0.0099	0.044			7.8	0.12	96
Horse - Sedentary-1,100 lb[8]	**8.4**	6.6		1.1	**0.20**	**0.029**	**0.060**	**0.051**	**0.020**	56	0.90	85
Horse - Intense exercise -1,100 lb[8]	**8.6**	6.8		1.1	**0.34**	**0.073**	**0.21**	**0.15**	**0.040**	57	0.92	85
Layer	**0.049**	0.036	0.039	0.011	**0.0035**	**0.0011**	0.0013	0.0048		0.19	0.0031	75
Swine - Gestating sow-440 lb	1.1	0.99	1.0	0.37	**0.071**	**0.020**	0.048			11	0.18	90
Swine - Lactating sow[9] 423 lb	2.5	2.3	2.4	0.84	**0.19**	**0.055**	0.12			25	0.41	90
Swine - Boar-440 lb	0.84	0.75	0.60	0.29	0.061	0.021	0.039			8.4	0.13	90

[1] Prior to any changes due to dilution water addition, drying, volatilization or other physical, chemical or biological processes.

[2] Non-bold table numbers indicate that predictive equations were not available from Sections 4 – 9 for estimating this characteristic. These numbers are average values taken from MWPS-18 Section 1, NRCS Agricultural Waste Management Field Handbook, and the previous version ASAE D384.1 or calculated based upon procedures used in footnote 3.

[3] Total Solids (TS) is estimated for most animal groups by equations in Sections 4 – 9. For beef cattle, volatile solids is also based upon equations. For all other species, volatile solids are calculated from TS and literature values of the ratio of VS to TS. Similarly, BOD and COD values are calculated using VS and the literature values of the ratio of BOD and COD to VS. Literature values are taken from MWPS-18 Section 1, NRCS Agricultural Waste Management Field Handbook, and the previous version ASAE D384.1.

[4] BOD – Biochemical oxygen demand, 5-day, COD – Chemical oxygen demand.

[5] Total manure is calculated from Total Solids and manure moisture content.

[6] As-excreted manure moisture contents range from 75 to 90 percent. At these moisture levels as-excreted manure has a density nearly equal to that of water, and a specific gravity of 1.0 was assumed in calculation of manure volume.

[7] Solids estimates (TS, VS, COD, and BOD) do not include solids in urine.

[8] These values apply to horses 18 months of age or older that are not pregnant or lactating. The representative number applies to 500 kg horses and the range represents horses from 400 to 600 kg. "Sedentary" would apply to horses not receiving any imposed exercise. Dietary inputs are based on minimum nutrient requirements specified in "Nutrient Requirements of Horses" (NRC, 1989). "Intense" represents horses used for competitive activities such as racing. Dietary inputs are based on a survey of race horse feeding practices (Gallagher et al, 1992) and typical feed compositions (forage = 50% alfalfa, 50% timothy; concentrate = 30% oats, 70% mixed performance horse concentrate).

[9] Bold values include contribution of nursing pigs.

[10] Beef cows values are representative of animals during non-lactating period and first six months of gestation.

Table 2. Definition of Variables – As Excreted - Beef – Section 4.

Variable	Description	Units
	Animal performance characteristics input	
BW_F	Live body weight at finish of feeding period (market weight)[2]	kg
BW_I	Live body weight at start of feeding period (purchase weight)[2]	kg
BW_{AVG}	Average live body weight for feeding period [2]	kg
SRW[3]	Standard reference weight for expected final body fat	478 kg for Choice (28% marbling) 462 kg for Select (26.8% marbling)
	Feed program characteristics inputs	
DMI	Dry matter intake	g dry feed / day
DMD	Dry matter digestibility of total ration	% of DMI
OMD	Organic matter digestibility of total ration	% of OMI
ASH	Ash concentration of total ration	% of DMI
C_{cp}	Concentration of crude protein of total ration	g of protein / g of dry feed
C_P	Concentration of phosphorus of total ration	g of phosphorus / g of dry feed
DOF	Days on feed for individual ration	days
x	Ration number	
n	Total number of rations fed	
	Excretion outputs	
N_{E-T}	Total nitrogen excretion per finished animal	g of nitrogen / finished animal
P_{E-T}	Total phosphorus excretion per finished animal	g of phosphorus / finished animal
Ca_{E-T}	Total calcium excretion per finished animal	g of calcium / finished animal
DM_E	Dry matter excretion per animal per day	g of dry matter / day / animal
DM_{E-T}	Total dry matter excretion per finished animal	g of dry matter / finished animal
OM_E	Organic matter (or volatile solids) excretion per animal per day	g of organic matter / day / animal
OM_{E-T}	Total organic matter (or volatile solids) excretion per finished animal	g of organic matter / finished animal

[1] Data specific to individual herd performance or feed analysis should be used when data is available. If situation specific information is not available, a default value from the Assumptions Table for Typical Manure Characteristics at the conclusion of this section may be the next best alternative.
[2] For beef cow/calf pairs (including pregnancy), assume $BW_F - BW_I$ equals weaning weight of calves. For beef cows on maintenance diet, assume the $BW_F - BW_I$ equals 0.
[3] If SRW is unknown, recommend using 478 kg as standard reference weight.

2.2 Sections 4 – 9. Equations for As-Excreted Manure Characteristics Estimates for Individual Species. These sections demonstrate the impact of dietary changes on nutrient excretion. However, this is not intended to be used as a ration-balancing tool, nor is this the appropriate tool for estimating the nutrient needs of the animal. Nutrient needs are best defined in the National Research Council's publication series or by using University recommendations. Both sources of information can provide estimates that reflect biological inefficiencies and digestibility limitations.

2.3 In using Sections 4 – 9 to evaluate the impact of alternative rations, it is important to recognize that these equations accurately estimate excretion only when animals are fed diets that meet or exceed the animal's minimum nutrient requirements. Estimates of excretion based on dietary options that do not meet an animal's minimum needs will not be accurate. Sections 4 – 9 are to be used following ration development by an animal nutrition professional.

2.4 New research data on excretion will be of value for confirming or improving the accuracy of the equations estimating excreting. The authors of this standard are very interested in comparing new research data with these equations. Authors can be contacted through the ASAE Standards staff.

2.5 Section 10. Typical As-Removed Manure Production and Characteristics. Many physical, chemical, and biological processes can alter manure characteristics from its original as-excreted form. The as-removed manure production and characteristics values reported in this table allow for common modifications to excreted manure (Section 3) resulting from water addition or removal, bedding addition, and/or treatment processes. These values represent typical values based on available data sources (see end of Section 10). These estimates may be helpful for individual farm long-term planning prior to any samples being available and for planning estimates addressing regional issues. Whenever possible, site-specific samples or other more localized estimates should be used in lieu of national tabular estimates. **This table should not be used to develop individual year nutrient management plans for defining field specific application rates, unless absolutely**

Table 3a: Estimated manure (urine and feces combined) characteristics as excreted based upon equations in Section 4 and assumptions in Table 3b.

Animal Type and Production Grouping	Total solids	Volatile Solids	Nitrogen	Phosphorus	Calcium	Total Manure[1]
	kg / finished animal					
Finishing cattle	360	290	25	3.3	7.7	3,400
	lb / finished animal					
Finishing cattle	780	640	55	7.3	17	7,400

[1] Total manure is calculated from total solids and assumed moisture of 92%.

Swine Anaerobic Lagoon Liquid Land Application Spreadsheet

This spreadsheet uses values from existing NCSU/NCDA data bases to calculate the fertilizer nutrients, application rates and land areas needed for agronomic usage of broadcast swine anaerobic lagoon liquid. Values in cells I25-P56 represent inputs which need to be entered to use this spreadsheet. Values in cells C25-I56 are typical values which may be used if more specific information is not available. If actual lagoon liquid nutrient analyses are used, then a corresponding change in lagoon liquid volumes should also be entered. Application rates and land areas are calculated for a range of fertilization rates. Actual fertilization rates based on crop yield may be entered into cells J66-J68 with the results calculated in columns W and AE in Table C. The spreadsheet also computes herd live weight equivalents, lagoon capacities, and estimated annual lagoon liquid volumes to be land applied.

		Typical							Actual							
		Wean-Feedr	Feedr-Fin	Gilt Dev	Boar Stud	Farrow-to-Wean	Farrow-to-Feedr	Farrow-to-Fin	Wean-Feedr	Feedr-Fin	Gilt Dev	Boar Stud	Farrow-to-Wean	Farrow-to-Feedr	Farrow-to-Fin	
		-----per head cap-----				-per active sow-			-----per head cap-----				-per active sow-			
Animal live weight:	initial:	10	50	50	250				10	50	50	250				lbs
	final:	50	220	250	550				50	220	250	550				lbs
	mean:	30	135	150	400	433	522	1417	30	135	150	400	433	522	1417	lbs
Groups per year:		6	3	2	1	2	2	2	6	3	2	1	2	2	2	groups/yr
Days per group:		49	105	140	365	11	63	168	49	105	140	365	11	63	168	days/group
Lagoon liquid capacity:	(does not include freeboard or 25-yr storm storage)															
design treatment:		30	135	150	200	289	348	1417	30	135	150	200	289	348	1417	ft3/an cap
sludge storage:		15	68	75	100	144	174	708	15	68	75	100	144	174	708	ft3/an cap
temporary storage:		15	68	75	200	217	261	708	15	68	75	200	217	261	708	ft3/an cap
		60	270	300	500	650	783	2833	60	270	300	500	650	783	2833	ft3/an cap
Lagoon liquid accumulation:																
manure and urine:		.30	1.4	1.5	4.0	4.3	5	14	.30	1.4	1.5	4.0	4.3	5	14	gal/an/day
excess water usage:		.20	.9	1.0	2.7	2.9	3	9	.20	.9	1.0	2.7	2.9	3	9	gal/an/day
surface rain surplus:		.11	.5	.5	1.4	1.6	2	5	.11	.5	.5	1.4	1.6	2	5	gal/an/day
total:		.61	2.7	3.0	8.1	8.8	11	29	.61	2.7	3.0	8.1	8.8	11	29	gal/an/day
Lagoon liquid total nutrient analysis:																
Tot N:		5.0	5.0	5.0	2.5	3.3	3.3	5.0	5.0	5.0	5.0	2.5	3.3	3.3	5.0	lb/1000gal
NH3N:		82	82	82	82	82	82	82	82	82	82	82	82	82	82	% N or tkn
P2O5:		1.9	1.9	1.9	1.0	1.3	1.3	1.9	1.9	1.9	1.9	1.0	1.3	1.3	1.9	lb/1000gal
K2O:		4.9	4.9	4.9	2.5	3.3	3.3	4.9	4.9	4.9	4.9	2.5	3.3	3.3	4.9	lb/1000gal
Org N mineralizat rate:		.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	
Plant nutrient availability coefficients:	(from application method box)															
N:		.46	.46	.46	.46	.46	.46	.46	.46	.46	.46	.46	.46	.46	.46	
P2O5:		.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	
K2O:		.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	

Application method	NH3N	N	P&K
soil injection:	.95	.87	.80
soil incorp:	.85	.79	.75
broadcast:	.45	.46	.70
irrigation:	.50	.50	.70

% x 2266 = lbs/acre-inch
ppm x 0.2266 = lbs/acre-inch
lbs/1000 gals x 27.154 = lbs/acre-inch

Crop fertilization rate:	N:	50	lbs/ac/yr
	P2O5:	20	lbs/ac/yr
	K2O:	50	lbs/ac/yr

Scroll down for results.

Table 18B. SWINE ANAEROBIC LAGOON LIQUID FERTILIZER NUTRIENTS *

Type of Production Unit **	Animal Unit	Animal Unit Equivalent Live Weight, init	final	mean	Total Anaerobic Lagoon Liquid Capacity, ft3/animal unit, single stage	2-stage 1st + 2nd	Total Lagoon Liquid Surplus,*** per animal unit/year, gals	acre-inch	Plant Nutrient	Plant Nutrient Availability Coefficients, broadcast ****	Total Nutrients, lbs/1000 gals	Plant Available Nutrients broadcast, lbs/1000 gals	lbs/animal unit/year
		lbs											
Weanling-to-Feeder	per head capacity	10	50	30	60	45	15	191	.0070	N	.46	5.0	2.3	.44
										P2O5	.70	1.9	1.4	.26
										K2O	.70	4.9	3.4	.66
Feeder-to-Finish	per head capacity	50	220	135	270	200	70	927	.034	N	.46	5.0	2.3	2.1
										P2O5	.70	1.9	1.4	1.3
										K2O	.70	4.9	3.4	3.2
Gilt Developmt	per head capacity	50	250	150	300	225	75	1015	.037	N	.46	5.0	2.3	2.3
										P2O5	.70	1.9	1.4	1.4
										K2O	.70	4.9	3.4	3.5
Boar stud	per head capacity	250	550	400	500	375	125	2959	.11	N	.46	2.5	1.2	3.4
										P2O5	.70	1.0	.68	2.0
										K2O	.70	2.5	1.7	5.1
Farrow-to-Weanling	per active sow			433	650	435	215	3203	.12	N	.46	3.3	1.5	4.9
										P2O5	.70	1.3	.91	2.9
										K2O	.70	3.3	2.3	7.3
Farrow-to-Feeder	per active sow			522	783	523	260	3861	.14	N	.46	3.3	1.5	5.9
										P2O5	.70	1.3	.91	3.5
										K2O	.70	3.3	2.3	8.8
Farrow-to-Finish	per active sow			1417	2833	2125	708	10478	.39	N	.46	5.0	2.3	24
										P2O5	.70	1.9	1.4	14
										K2O	.70	4.9	3.4	36

* References: Depts of Biological and Agricultural Engineering, Animal Science; North Carolina State University; Jan 1990 Agronomic Division, North Carolina Department of Agriculture

** Assumes 400-lb sow and boar on limited feed, 3-wk old weanling, 50-lb feeder pig, 220-lb market hog and 20 pigs/sow/year

*** Estimated total lagoon liquid includes total liquid manure plus average annual rainfall surplus incidental to lagoon surface; does not account for seepage.

**** Broadcast: surface spread liquid uncovered for one month or longer.

Table 18C. LAND APPLICATION OF SWINE ANAEROBIC LAGOON LIQUID *

Type of Production Unit	Animal Unit	Rate-Limiting Nutrient	Lagoon Liquid Application Rate ** broadcast, lbs/acre/year								Minimum Land Area for Liquid Application ** broadcast, lbs/acre/year							
		N	50	100	150	200	250	300	350	400	50	100	150	200	250	300	350	400
		P2O5	20	40	60	80	100	120	140	160	20	40	60	80	100	120	140	160
		K2O	50	100	150	200	250	300	350	400	50	100	150	200	250	300	350	400
			gallons/acre/year								acres/animal unit							
Weanling-to-Feeder	per head capacity	N	21712	43423	65135	86847	1.1e5	1.3e5	1.5e5	1.7e5	.0088	.0044	.0029	.0022	.0018	.0015	.0013	.0011
		P2O5	14654	29307	43961	58614	73268	87921	1.0e5	1.2e5	.013	.0065	.0043	.0033	.0026	.0022	.0019	.0016
		K2O	14543	29085	43628	58170	72713	87255	1.0e5	1.2e5	.013	.0066	.0044	.0033	.0026	.0022	.0019	.0016
Feeder-to-Finish	per head capacity	N	21712	43423	65135	86847	1.1e5	1.3e5	1.5e5	1.7e5	.043	.021	.014	.011	.0085	.0071	.0061	.0053
		P2O5	14654	29307	43961	58614	73268	87921	1.0e5	1.2e5	.063	.032	.021	.016	.013	.011	.0090	.0079
		K2O	14543	29085	43628	58170	72713	87255	1.0e5	1.2e5	.064	.032	.021	.016	.013	.011	.0091	.0080
Gilt Developmt	per head capacity	N	21712	43423	65135	86847	1.1e5	1.3e5	1.5e5	1.7e5	.047	.023	.016	.012	.0093	.0078	.0067	.0058
		P2O5	14654	29307	43961	58614	73268	87921	1.0e5	1.2e5	.069	.035	.023	.017	.014	.012	.0099	.0087
		K2O	14543	29085	43628	58170	72713	87255	1.0e5	1.2e5	.070	.035	.023	.017	.014	.012	.010	.0087
Boar Stud	per head capacity	N	43423	86847	1.3e5	1.7e5	2.2e5	2.6e5	3.0e5	3.5e5	.068	.034	.023	.017	.014	.011	.0097	.0085
		P2O5	29307	58614	87921	1.2e5	1.5e5	1.8e5	2.1e5	2.3e5	.10	.050	.034	.025	.020	.017	.014	.013
		K2O	29085	58170	87255	1.2e5	1.5e5	1.7e5	2.0e5	2.3e5	.10	.051	.034	.025	.020	.017	.015	.013
Farrow-to-Weanling	per active sow	N	32568	65135	97703	1.3e5	1.6e5	2.0e5	2.3e5	2.6e5	.098	.049	.033	.025	.020	.016	.014	.012
		P2O5	21980	43961	65941	87921	1.1e5	1.3e5	1.5e5	1.8e5	.15	.073	.049	.036	.029	.024	.021	.018
		K2O	21814	43628	65442	87255	1.1e5	1.3e5	1.5e5	1.7e5	.15	.073	.049	.037	.029	.024	.021	.018
Farrow-to-Feeder	per active sow	N	32568	65135	97703	1.3e5	1.6e5	2.0e5	2.3e5	2.6e5	.12	.059	.040	.030	.024	.020	.017	.015
		P2O5	21980	43961	65941	87921	1.1e5	1.3e5	1.5e5	1.8e5	.18	.088	.059	.044	.035	.029	.025	.022
		K2O	21814	43628	65442	87255	1.1e5	1.3e5	1.5e5	1.7e5	.18	.088	.059	.044	.035	.029	.025	.022
Farrow-to-Finish	per active sow	N	21712	43423	65135	86847	1.1e5	1.3e5	1.5e5	1.7e5	.48	.24	.16	.12	.097	.080	.069	.060
		P2O5	14654	29307	43961	58614	73268	87921	1.0e5	1.2e5	.72	.36	.24	.18	.14	.12	.10	
		K2O	14543	29085	43628	58170	72713	87255	1.0e5	1.2e5	.72	.36	.24	.18	.14	.12	.10	

* References: Depts of Biological & Agricultural Engineering, Soil Science, Crop Science; North Carolina St Univ; Jan 1990

** N fertilization rate should be consistent with realistic crop yield.
N leaching and denitrification and P2O5 soil immobilization unaccounted for.

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Table 1. LIVESTOCK FRESH MANURE CHARACTERISTICS

	Average Animal Weight	Manure Production (Feces & Urine)		Nitrogen		Phosphorus P_2O_5	Potassium K_2O
				Total N	Ammonia NH_3N		
	(lb)	(gal/day)	(ton/yr)	<==========(lbs/ton)==========>			
Dairy	1400	14.6	21.9	10.5	1.8	5.0	8.2
Beef	800	5.53	7.9	11.9	3.0	7.3	8.8
Veal	200	1.49	2.0	8.6	4.0	4.9	11.0
Swine	135	1.37	1.9	12.4	6.8	9.6	8.3
Sheep	60	0.28	0.4	20.8	6.2	9.9	19.4
Goat	140	0.69	1.1	21.8	6.5	12.1	17.7
Horse	1000	5.95	9.2	12.0	2.4	6.5	12.0
Rabbit	10	0.08	0.06	23.0	6.9	20.6	10.8
Layer	4	0.03	0.05	26.2	6.6	21.1	11.4
Broiler	2	0.25	0.03	26.0	6.5	16.3	11.2
Turkey	15	0.08	0.12	26.7	3.4	22.5	12.3
Duck	3	0.04	0.05	27.8	5.3	22.5	15.6

Fresh Water
The following amount of excess water is to be added to the temporary storage:

Type of Operation	Live Weight	Excess Water
Nursery	30 lbs	0.2 gals/hd/day
Finishing	135 lbs	0.9 gals/hd/day
Farrow-Weanling	433 lbs	2.9 gals/sow/day
Farrow-Feeder	522 lbs	3.5 gals/sow/day
Farrow-Finish	1,417 lbs	9.5 gals/sow/day
Boar-Stud	400 lbs	2.7 gals/animal/day
Gilt	150 lbs	1.0 gals/animal/day
Dairy	1,400 lb	6.0 gals/animal/day
Layers	4 lbs	0.013 gals/bird/day

Anaerobic waste treatment lagoons are designed on the basis of daily Volatile Solids (VS) loading per 1,000 ft^3 of lagoon volume. Maximum loading for anaerobic lagoons shall be as indicated in Figure B (See Fig. 10-22, page 10-29 of AWMFH) or Table 2. Animal weights are expressed as average values for the purpose of lagoon design.