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Manure Production and Characteristics

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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

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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**	**0.066**	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%.

Table 3b – Dietary and performance assumptions – Section 4.

Animal Type and Production Grouping	Live Weight (kg)		Average Daily Gain (kg/da)	Days on Feed	Feed Conversion (kg of feed per kg of gain)	Dietary Assumptions						
	In	Out				DMI (% of avg. body weight)	DMD	OMD	Crude Protein (g/day)	P (g/day)	Ca (g/day)	Ash
Finishing cattle	338	554	1.42	153	6.3	2.0%	80%	83%	1200	28	62	4%
Range: Only feed conversion efficiency and dietary nutrient content or digestibility were varied to determine range for N, P, and Ca.					5.8–6.8		70 – 85%	75 – 88%	1100 – 1300	22 – 45	53 – 80	

no site-specific manure analysis data are available. However, where site-specific data are unavailable, this table may provide initial estimates for planning purposes until those site-specific values are available.

3.0 Typical As-Excreted Manure Production and Characteristics

3.1 Two approaches were used for estimating typical characteristics summarized in Table 1.

1) Manure characteristics listed in **BOLD** are estimated for dietary intake and animal performance levels common for livestock and poultry management in 2003 using the equations listed in Sections 4 through 9. Beef, poultry and swine excretion characteristics are based on a calculation of dietary nutrient intake minus animal nutrient retention using dietary and performance measurements typical for the industry at the time these data were published. Nutrient retention estimates followed common industry methodologies used for recommending feeding programs. Dry matter excretion is estimated to be a function of dry matter intake minus dry matter digestibility (see equations in Sections 4 and 9).

   For estimating dairy and equine manure characteristics, existing research data and regression analysis were used to identify relationship between feeding programs, animal performance, and excretion.

   Total nitrogen, total phosphorus, and dry matter excretion were estimated by these methods for all species. Available research data or models allowed additional excretion estimates for some species. All data in Table 1 based upon animal dietary intake and performance measure is illustrated in **BOLD** with supporting assumptions for dietary intake and performance assumptions and references listed in Sections 4 through 9.

2) Where dietary intake and animal performance level based excretion estimates could not be made, a review of current references including the USDA Agricultural Waste Management Field Handbook, previous ASAE D384 standard, and Manure Characteristics (MWPS-18, Section 1). Those values in Table 1 that are not bold are based upon these references.

3.2 Caution

3.2.1 Manure and nutrient production characteristics for meat producing animals are reported on a unit mass excreted per finished animal. Manure excretion by meat producing animals varies with stage of growth. This format was selected to minimize misuse of a daily average values to represent an entire production phase. Sizing of treatment systems based upon instantaneous loading rates should use the equations in Sections 4 through 9 with appropriate feeding program and performance inputs typical of the later stages of growth. Manure excretion rates for other animals are more constant and thus reported on a daily basis.

3.2.2 In addition, facilities for meat producing animals are rarely in full production 365 days per year due to uneven growth rates of animals, time required for facility cleaning after a group, and availability of animals for restocking a facility. Planning based on number of finished animals provides a more realistic planning estimate for annual manure volume and nutrient production.

3.2.3 It should also be noted that Table 1 estimates and predictive equations in Sections 4 through 9 provide an as-excreted estimate of manure production, excluding any additions of waste feed or dilution water, biochemical degradation of solids, or volatilization of nitrogen and carbon. Manure characteristics after storage and/or treatment of manures are better estimated by site-specific manure samples or, when farm specific information is not available, by the typical as-removed values listed in Section 10.

3.3 References

3.3.1 Fulhage, C. D., 2003. Proposed Revision to ASAE D384.1 for Representative Values of "As-Excreted" Manure Production. Proceedings of the International Symposium for Animal, Agricultural, and Food Processing Wastes IX. ASAE. St. Joseph, MI. 269–276.

4.0 Equations for As-Excreted Manure Characteristics Estimates for Beef

4.1 Fundamental Model

Nutrient Excretion = Feed Nutrient Intake – Nutrient Retention
Dry Matter Excretion = Feed Dry Matter Intake X (1 – Dry Matter Digestibility)*

* Same relationship for organic matter or volatile solids excretion

4.2 See 2.0 Caution

See Table 2, Definitions of Variables – As Excreted – Beef.

4.3 Equations for Estimating Excretions

Equations from the 1996 NRC Nutrient Requirements of Beef Cattle for retained protein and energy equations provide the basis for estimating nitrogen retention. Supplemental information referenced by this publication provides background information on validation of this approach for estimating retained nitrogen.

Retained phosphorus is generally recognized as 3.9 g of retained P per 100 g of retained protein. Retained calcium is generally recognized as 7.1 g per 100 g of retained protein. Therefore, P and Ca retention are calculated as a function of retained protein. Both assumptions originate from the 1996 NRC Nutrient Requirements of Beef Cattle. Additional supporting information is sited by this publication.

4.3.1 *Dry Matter Excretion Equation for Calves and Finishers*[1]

$$DM_E = [DMI * (1 - DMD / 100)] + 20.3 * (0.06 * BW_{AVG}) \quad (1)$$

$$DM_{E-T} = \sum_{x=1}^{n} DMI_x * DOF_x * (1 - DMD_x / 100) + \sum_{x=1}^{n} DOF_x * 20.3 * (0.06 * BW_{AVG}) \quad (2)$$

[1] Estimates dry matter for 1) feces baed upon indigestibility of feed and for 2) urine based upon regression equation from 300 observations of urine excretion by beef cattle finishers ranging in weight from 100 to 620 kg and urine solids content of 6%.

Table 4 – Definition of Variables – As Excreted – Dairy Cattle – Section 5.

Variable	Description	Units
Animal performance characteristics inputs		
Milk	Milk production	kg of milk / animal / day
MF	Milk fat	g / g milk / day
MTP	Milk true protein	g / g milk / day
DIM	Days in milk	days
DP	Dry period length	days
BW	Average live body weight	kg
Feed program characteristics inputs		
DMI	Dry matter intake	kg dry feed / animal / day
DMD	Dry matter digestibility of total ration	% of DMI
OMD	Organic matter digestibility of total ration	% of of OM intake
ASH	Ash concentration of total ration	% of DMI
C_{cp}	Concentration of crude protein of total ration	g crude protein / g dry feed
C_P	Concentration of phosphorus of total ration	g phosphorus / g dry feed
C_K	Concentration of potassium of total ration	g potassium / g dry feed
Excretion outputs		
M_E	Total manure excretion per animal per day	kg / animal / day
N_E	Total nitrogen excretion per animal per day	g / animal / day
P_E	Total phosphorus excretion per animal per day	g / animal / day
K_E	Total potassium excretion per animal per day	g / animal / day
DM_E	Dry matter (solids) excretion per animal per day	kg / animal / day
OM_E	Organic matter (or volatile solids) excretion per animal per day	kg / animal / day
U_E	Urine excretion per animal per day	liters / animal / day

4.3.2 *Organic Matter (or volatile solids) Excretion Equation*

$$OM_E = [DMI*(1-ASH/100)]*(1-OMD/100) + 17*(0.06*BW_{AVG}) \quad (3)$$

$$OM_{E-T} = \sum^{n}_{x=1} [DMI_x*DOF_x*(1-ASH_x/100)]*(1-OMD_x/100) + \sum^{n}_{x=1} DOF_x*17*(0.06*BW_{AVG}) \quad (4)$$

4.3.3 *Nitrogen Excretion Equation*

$$N_{E-T} = \sum^{n}_{x=1}(DMI_x*C_{cp-x}*DOF_x*/6.25)-[41.2*(BW_F - BW_I)] + [0.243*DOF_{Tt}*[(BW_F + BW_I)/2]^{0.75}*(SRW/(BW_F*0.96))^{0.75}*[(BW_F - BW_I)/DOF_T]^{1.097}] \quad (5)$$

4.3.4 *Phosphorus Excretion Equation*

$$P_{E-T} = \sum^{n}_{x=1}(DMI_x*C_{P-x}*DOF_x)-[10.0*(BW_F - BW_I)] + \{5.92*10^{-2}*DOF_T*[(BW_F + BW_I)/2]^{0.75}*(SRW/BW_F*0.96)^{0.75}*[(BW_F - BW_I)/DOF_T]^{1.097}\} \quad (6)$$

4.3.5 *Calcium Excretion Equation*

$$Ca_{E-T} = \sum^{n}_{x=1}(DMI_x*C_{Ca-x}*DOF_x)-[18.33*(BW_F - BW_I)] + 0.445*\{0.243*DOF_T*[(BW_F + BW_I)/2]^{0.75}*(SRW/(BW_F*0.96))^{0.75}*[(BW_F - BW_I)/DOF_T]^{1.097}\} \quad (7)$$

4.4 Manure Characteristics Based Upon Typical Performance and Diets – See Tables 3a and 3b.

4.5 References

4.5.1 Anrique, R. G., M. L. Thonney, and H. J. Ayala. 1990. Dietary energy losses of cattle influenced by body type, size, sex, and intake. Anim. Prod. 50:467–474.

4.5.2 Danner, M. L., D. G. Fox, and J. R. Black. 1980. Effect of feeding system on performance and carcass characteristics of yearling steers, steer calves and heifer calves. J. Anim. Sci. 50:394–404.

4.5.3 Ellenberger, H. G., J. A. Newlander, and C. H. Jones. 1950. Composition of the bodies of dairy cattle. Vt. Agric. Exp. Sta. Bull. 558.

4.5.4 Erickson, G. E., B. Auvermann, R. Eigenberg, L.W. Greene, T. Klopfenstein, R. Koelsch. 2003. Proposed Beef Cattle Manure Excretion and Characteristics Standard for ASAE. Proceedings of the International Symposium for Animal, Agricultural, and Food Processing Wastes IX. ASAE. St. Joseph, MI. 269–276.

4.5.5 Fortin, A., S. Simpfendorfer, J. T. Reid, H. J. Ayala, R. Anrique, and A. F. Kertz. 1980. Effect of level of energy intake and influence of breed and sex on the chemical composition of cattle. J. Anim. Sci. 51:604–614.

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5.0 Equations for As-Excreted Manure Characteristics Estimates for Dairy Cattle

5.1 Fundamental Model

5.1.1 The estimates for manure and nutrient excretion were derived from the combination of multiple data sets from Washington State University, University of California – Davis, The Ohio State University, and Pennsylvania State University. The data sets contain records from Holstein cattle and include a wide variety of animal ages, ranging from calves to multiparous lactating cows.

5.1.2 The data for the calves and heifers were divided according to animal body weight and includes four groups, milk fed calves, weaned calves weighing less than 204 kg, heifers weighing between 274 to 613 kg, and veal calves. Excretion estimates for veal calves were adapted from Sutton et al., 1989. Additional classifications of animals include non-lactating and lactating cows.

5.1.3 Lactating cow excretion estimates were derived from regression equations developed using lactating Holstein cows regardless of body weight or milk production. The data set for lactating cows was evaluated to compare the amount of metabolizable protein (MP) required to the MP supplied to the cow using the 2001 Dairy NRC Model. Only cows fed less than 112% of MP requirements were included in the data set. The average values reported for lactating cows were determined using the regression equation for a cow producing 40 kg of milk. The regression equations were developed using PROC MIXED of SAS, with study included as a random variable (St-Pierre, 2001).

5.2 See 2.0 Caution

See Table 4, Definitions of Variables – As Excreted – Dairy Cattle.

5.3 Equations for Estimating Excretion

In many cases, multiple prediction equations are presented. Note, that while the more simplistic equation requires fewer inputs, the result could be less precise due to the influence of dietary intake of nutrients (more developed equation). Regression equations developed using the data set include both residual errors and errors from the variation between the research trials (inter-study errors). Equations with the lowest residual error should be used whenever the input variables are available.

Assumptions:

1) Urine dry matter, estimated at 4.5%, was used for total solids and moisture calculations. The urine volume was calculated by using a specific gravity of 1.038 g/ml.
2) Milk crude protein was converted to milk true protein using a conversion factor for the Holstein breed of 0.940 (http://www.aipl.arsusda.gov/reference/trueprot.htm).

5.3.1 *Total Manure – Lactating cow regression equations:*[1]

$$M_E = (\text{Milk} \times 0.172) + (\text{DMI} \times 2.207) + (\text{MF} \times 171.830) + (\text{MTP} \times 505.310) - 8.170 \quad (1)$$

Inter-study error = 8.50
Residual error = 7.00

$$M_E = (\text{Milk} \times 0.954) + (\text{BW} \times 0.037) + (\text{DIM} \times 0.017) + (\text{MF} \times 186.720) + (\text{MTP} \times 1141.480) - 33.06 \quad (2)$$

Inter-study error = 5.08
Residual error = 8.33

$$M_E = (\text{Milk} \times 0.647) + 43.212 \quad (3)$$

Inter-study error = 6.94
Residual error = 9.19

5.3.2 *Total Manure – Dry cow regression equation:*[1]

$$M_E = (\text{BW} \times 0.022) + 21.844 \quad (4)$$

Inter-study error = 5.93
Residual error = 5.71

5.3.3 *Total Manure – Heifer regression equations:*[1]

$$M_E = (\text{DMI} \times 3.886) - (\text{BW} \times 0.029) + 5.641 \quad (5)$$

Inter-study error = 5.34
Residual error = 2.61

$$M_E = (\text{BW} \times 0.018) + 17.817 \quad (6)$$

Inter-study error = 4.02
Residual error = 3.55

5.3.4 *Total Solids – Lactating cow regression equations:* [2]

$$DM_E = (\text{DMI} \times 0.350) + 1.017 \quad (7)$$

Inter-study error = 1.13
Residual error = 0.76

$$DM_E = (\text{Milk} \times 0.135) + (\text{BW} \times 0.004) + (\text{DIM} \times 0.004) + (\text{MTP} \times 118.370) - 2.456 \quad (8)$$

Inter-study error = 0.63
Residual error = 1.03

$$DM_E = (\text{Milk} \times 0.096) + 5.073 \quad (9)$$

Inter-study error = 0.78
Residual error = 1.13

[1] Total manure equals actual fecal excretion plus actual urine excretion from individual cows collected and weighted on a daily basis.
[2] DM_E = actual fecal dry matter + urine dry matter.

Table 5a – Estimated typical manure (urine and feces combined) characteristics as excreted based upon equations in Section 5 and assumptions in Table 5c.

Animal Type and Production Grouping	Total solids	Nitrogen	P	K	Total Manure[1]	Assumed Moisture
	kg / da-animal					% w.b.
Dairy - Lactating cow	8.9	0.45	0.078	0.10	69	87
Dairy - Dry cow	4.9	0.23			38	87
Dairy - Heifer-440 kg	3.7	0.12	0.020		22	83
	lb / da- animal					% w.b.
Dairy - Lactating cow	20	0.99	0.17	0.23	150	87
Dairy - Dry cow	11	0.50			83	87
Dairy - Heifer-440 kg	8.2	0.26	0.044		48	83
Equation Used for Excretion Estimate						
Dairy - Lactating cow	9	16	22	26	-	
Dairy - Dry cow	11	17	-	-	-	
Dairy - Heifer-440 kg	No Equation	19	24	-	-	

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

Table 5b – Estimated typical manure (urine and feces combined) characteristics as excreted based upon sources cited in Table 5c.

Animal Type and Production Grouping	Total solids	Nitrogen	P	K	Total Manure[1]	Assumed Moisture
	kg / da-animal					% w.b.
Dairy - Milk fed calves		0.0079				
Dairy - Calf-150 kg	1.4	0.063			8.5	83
Dairy - Veal-118 kg	0.12	0.015	0.0045	0.020	3.5	96.5
	lb / da- animal					% w.b.
Dairy - Milk fed calves		0.017				
Dairy - Calf-150 kg	3.2	0.14			19	83
Dairy - Veal-118 kg	0.27	0.033	0.0099	0.044	7.8	96.5

Table 5c – Dietary and performance assumptions.

Animal Type and Production Grouping	Average Live Weight (kg)	Milk Production (kg)	Dietary Assumptions				Comments or Written Description of Assumptions
			Dry Matter Intake (% of average body weight)	Crude Protein (g/day)	P (g/day)	K (g/day)	
Lactating cow Range	624 437–810	40 9.8–86.1	3.4 1.1–4.9	3720 1356–5250	94.7 40–144	283 168–443	Averages are based on 367 cows
Dry cow Range	755 413–934	NA	1.4 0.7-2.2	1525			Averages are based on 18 cows
Milk Fed Calves	57.1	NA	1.0	136			Averages based on 16 calves
Calf-150 kg Range	153 86–204	NA	2.21 1.56–3.37	558 275–880			Averages based on 46 calves
Dairy Veal	40 to 85 85 to 150	NA	1.89 2.09	284 491	10 18		
Heifer-420 kg Range	437 274–613	NA	1.91 1.43–2.44	923 500–1688			Averages are based on 60 heifers

5.3.5 *Total Solids – Dry cow regression equation:*[1]

$$DM_E = (DMI \times 0.178) + 2.733 \quad (10)$$

Inter-study error = 0.74
Residual error = 0.45

$$DM_E = (BW \times 0.004) + 1.863 \quad (11)$$

Inter-study error = 0.42
Residual error = 0.59

5.3.6 *Urine Volume – Lactating cow regression equations:*

$$U_E = (Milk \times 0.114) + (BW \times 0.016) + (MF \times 97.709) + (MTP \times 353.280) + (C_{CP} \times 62.036) - 16.389 \quad (12)$$

Inter-study error = 3.87
Residual error = 5.56

$$U_E = (BW \times 0.017) + 11.704 \quad (13)$$

Inter-study error = 4.67
Residual error = 5.68

(Note: Urine volume could be considerably different, depending on ration mineral content. Insufficient data were available to derive regression equations based on intake of minerals)

5.3.7 *Nitrogen Excretion – Lactating cow regression equations:* [2]

$$N_E = (Milk \times 2.303) + (DIM \times 0.159) + (DMI \times C_{CP} \times 70.138) + (BW \times 0.193) - 56.632 \quad (14)$$

Inter-study error = 53.07
Residual error = 102.71

$$N_E = (Milk \times 5.959) + (DIM \times 0.237) + (BW \times 0.347) + (MTP \times 4547.910) + (C_{CP} \times 1793.730) - 476.530 \quad (15)$$

Inter-study error = 42.48
Residual error = 107.01

$$N_E = (Milk \times 4.204) + 283.300 \quad (16)$$

Inter-study error = 57.8
Residual error = 110.8

5.3.8 *Nitrogen Excretion – Dry cow regression equation:* [2]

$$N_E = (DMI \times 12.747) + (C_{CP} \times 1606.290) - 117.500 \quad (17)$$

Residual error = 45.51

5.3.9 *Nitrogen Excretion – Heifer regression equations:* [2]

$$N_E = ((DMI \times 1000) \times (C_{CP} / 6.25) \quad (18)$$

$$N_E = (DMI \times C_{CP} \times 78.390) + 51.350 \quad (19)$$

Inter-study error = 24.47
Residual error = 10.76

5.3.10 *Phosphorus Excretion – Lactating cow regression equations:*[1]
If diets contain less than 0.004 g P/g dry feed[1]*:*

$$P_E = ((DMI \times 1000) \times \mathbf{C_P}) - (Milk \times 0.9) \quad (20)$$

If diets contain 0.004 g P/g dry feed or greater:

$$P_E = (Milk \times 0.565) + (MTP \times 816.260) + (DMI \times \mathbf{C_P} \times 421.410) - 9.697 \quad (21)$$

Inter-study error = 10.81
Residual error = 11.47

$$P_E = (Milk \times 0.773) + 46.015 \quad (22)$$

Inter-study error = 10.83
Residual error = 14.48

5.3.11 *Phosphorus Excretion – Dry cow regression equation:*[1,2]

$$P_E = (((DMI \times 1000) \times \mathbf{C_P} \times DP) - 264.386) / DP \quad (23)$$

5.3.12 *Phosphorus Excretion – Heifer regression equation:*[1]

$$P_E = ((DMI \times 1000) \times \mathbf{C_P}) \quad (24)$$

5.3.13 *Potassium – Lactating cow regression equations:* [3]

$$K_E = (Milk \times 1.822) + (MTP \times 2688.880) + (DMI \times \mathbf{C_K} \times 156.930) - 91.755 \quad (25)$$

Inter-study error = 16.77
Residual error = 25.27

$$K_E = (Milk \times 1.800) + 31.154 \quad (26)$$

Inter-study error = 18.89
Residual error = 26.94

5.3.14 *Potassium – Dry cow and heifer regression equation:*[3]

$$K_E = ((DMI \times 1000) \times \mathbf{C_K}) \quad (27)$$

5.4 Manure Characteristics Based Upon Typical Performance and Diets – See Tables 5a, 5b, and 5c.

5.5 Reference

5.5.1 Nennich, T., J Harrison, D. Meyer, W. Weiss, A. Heinrichs, R. Kincaid, W. Powers, R. Koelsch, P. Wright. 2003. Development of Standards Method to Estimate Manure Production and Nutrient Characteristics from Dairy Cattle. Proceedings of the International Symposium for Animal, Agricultural, and Food Processing Wastes IX. ASAE. St. Joseph, MI. 263–268.

6.0 Equations for As-Excreted Manure Characteristics Estimates for Horses

6.1 Fundamental Model

Equations for as-excreted manure characteristics are based upon regression analysis from available data sets for N, P, K, Ca and Mg. Other estimates are based on survey data or dietary recommendations (NRC, 1989). The nitrogen data set contained 46-paired values (intake and excretion), with intakes ranging from 130 to 530 mg/kg BW/day (median = 250 g N/kg BW). For P, 128 paired values were used (range = 19–121 mg/kg BW/day; median = 42.8 mg P/kg BW). For K, 28 paired values were used (range 50–404 mg/kg BW/day; median = 193.3 mg K/kg Bw). For Ca, 106 paired values were used (range 9.1 to 247 mg/kg BW/d; median 69.7 mg Ca/kg BW). For Mg, 50 paired values were used (range 18.6 to 131.6 mg Mg/kg BW/d; median 28.2 mg Mg/kg BW).

[1] DM_E = actual fecal dry matter + urine dry matter.
[2] Nitrogen excretion = actual fecal N + actual urine N.

[1] Phosphorus excretion = actual fecal P + actual urine P.
[2] The constant was derived from the 2001 Dairy NRC equation (p. 112) for absorbed phosphorus and assumes a 60 day dry period.
[3] Potassium excretion = actual fecal K + actual urine K.

Table 6 – Definition of Variables – As Excreted - Horses – Section 6.

Variable	Description	Units
	Animal performance characteristics input	
BW	Average live body weight	Kg
	Feed program characteristics inputs	
DMI	Dry matter intake	g dry feed / day
DMD	Dry matter digestibility of total ration	%
OMD	Organic matter digestibility of total ration	%
ASH	Ash concentration of total ration	%
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
C_K	Concentration of potassium of total ration	g of potassium / g of dry feed
C_{Ca}	Concentration of calcium of total ration	g of calcium / g of dry feed
C_{Mg}	Concentration of magnesium of total ration	g of magnesium / g of dry feed
	Excretion outputs	
N_E	Total nitrogen excretion per animal per day	g / animal / day
P_E	Total phosphorus excretion per animal per day	g / animal / day
K_E	Total potassium excretion per animal per day	g / animal / day
Ca_E	Total calcium excretion per animal per day	g / animal / day
Mg_E	Total magnesium excretion per animal per day	g / animal / day
DM_E	Dry matter excretion (feces + urine) per animal per day	g / animal / day
DM_F	Dry matter excretion (feces only) per animal per day	g / animal / day
F_E	Feces (wet weight) excretion per animal per day	g / animal / day
U_E	Urine excretion per animal per day	g / animal / day

6.2 See 2.0 Caution

See Table 6, Definition of Variables – As Excreted - Horses.

6.3 Equations for Estimating Excretions

6.3.1 *Nitrogen Excretion*

#1: Sedentary horses: $N_E = (55.4*BW*10^{-3}) + (0.586*DMI*C_{cp})/6.25$

$(R^2 = 0.76)$

#2: Exercised horses: $N_E = (42.9*BW*10^{-3}) + (0.492*DMI*C_{cp})/6.25$

$(R^2 = 0.94)$

6.3.2 *Phosphorus Excretion*

#3: Sedentary or exercised horses: $P_E = (4.56*BW*10^{-3}) + (0.793*DMI*C_p)$ (1)

$(R^2 = 0.85)$

6.3.3 *Potassium Excretion*

#4: Sedentary or exercised horses: $K_E = (19.4*BW*10^{-3}) + (0.673*DMI*C_k)$ (2)

$(R^2 = 0.62)$

6.3.4 *Calcium Excretion*

#5: Sedentary horses: $Ca_E = (26.6*BW*10^{-3}) + (0.497*DMI*C_{Ca})$ (3)

$(R^2 = 0.65)$

#6: Exercised horses: $Ca_E = (-5.98*BW*10^{-3}) + (0.804*DMI*C_{Ca})$ (4)

$(R^2 = 0.73)$

6.3.5 *Magnesium Excretion*

#7: Sedentary or exercised horses: $Mg_E = (9.08*BW*10^{-3}) + (0.545*DMI*C_{Mg})$ (5)

$(R^2 = 0.68)$

6.3.6 *Dry Matter Excretion (feces)*

#8: Sedentary: $DM_F = [(0.03*BW + 1.4)/2.0]*425$ (6)

#9: Exercised: $DM_F = \{[2.0*(0.03*BW + 1.4)]/2.85\}*310$ (7)

6.3.7 *Dry Matter Excretion (combined urine and feces):*[1]

#10: Sedentary: $DM_E = 7.2*BW + 220$ (8)

#11: Exercised: $DM_E = 7.3*BW + 230$ (9)

6.3.8 *Optional estimate of dry matter excretion (feces) for all horses:*

#12: $DM_F = DMI*(1-DMD/100)$ (10)

6.3.9 *Optional estimate of dry matter excretion (combined urine and feces) for all horses:* [2]

#13: $DM_E = [DMI*(1-DMD/100)] + 0.64*BW$ (11)

[1] Sum of total feces and total urine (equations 12 and 13) and multiplied by an assumed moisture content of 15%.

[2] Alternate approach: Sum of total urine (equation 13) multiplied by assumed urine solids content of 4% and dry matter excretion (equaiton 10).

6.3.10 *Total Feces*

Sedentary or exercised horses: $F_E = DM_E/0.20$ (12)

6.3.11 *Total Urine*

Sedentary or exercised horses: $U_E = 16*BW$ (13)

6.4 Manure Characteristics Based Upon Typical Performance and Diets – See Tables 7a and 7b.

6.5 References

6.5.1 Lawrence, L., J. Bicudo, E. Wheeler. 2003. Horse Manure Characteristics Literature and Database Review. Proceedings of the International Symposium for Animal, Agricultural, and Food Processing Wastes IX. ASAE. St. Joseph, MI. 277–284.

6.5.2 Gallagher, K., J. Leech and H. Stowe. 1992. Protein, energy and dry matter consumption by racing thoroughbreds: A field survey. J. Equine Vet Sci. 12:43–48.

6.5.3 NRC. 1989. Nutrient Requirements of Horses. National Academy Press, Washington DC.

Table 7a – Estimated typical manure (urine and feces combined) characteristics as excreted based upon equations in Section 6 and assumptions in Table 7b.

Animal Type and Production Grouping	Total Solids	Nitrogen	P	K	Ca	Mg
	g / da-animal					
Horse-Sedentary-500 kg [1]	3,800	89	13	27	23	9
Horse-Intense exercise-500 kg [1]	3,900	150	33	95	69	18
	lb / da-animal					
Horse-Sedentary-1,100 lb [1]	8.4	0.20	0.029	0.060	0.051	0.020
Horse-Intense exercise-1,100 lb[1]	8.6	0.34	0.073	0.21	0.15	0.040

[1] 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. Under type of horse, classifications are made on amount of regular exercise imposed on horses.

Table 7b – Dietary and performance assumptions.

Animal Type and Production Grouping[1]	Average Live Weight (kg)	Dietary Assumptions						
		Dry Matter Intake (% of average body weight)	Dry Matter Digestibility	Crude Protein (g/day)	P (g/day)	K (g/day)	Ca (g/day	Mg (g/day)
Sedentary- mature[2]	500	1.6	57.5%	656	14	25	20	7.5
Range	400–600	1.6–1.7	57.5%	536–776	11–17	20–30	16–24	6–9
Intense exercise (race horses)[3]	500	2.3	69%	1660	39	127	89	25.3
Range	400–600	2.3–2.4	69%	1328–1992	31–47	101–152	71–106	20–30

[1] 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.

[2] "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).

[3] "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).

Table 8 – Definition of Input Variables – As Excreted – Poultry (Broilers, Turkeys, and Ducks) – Section 7.

Variable	Description	Units
Feed program characteristics		
FI_{PH}	Feed intake per phase. Dry matter intake assumed to be 88% of feed intake.	g feed / phase (wet basis)
C_{cp}	Concentration of crude protein of total ration	g of protein / g of feed (wet basis)
C_P	Concentration of phosphorus of total ration	g of phosphorus / g feed (wet basis)
x	Phase number (e.g. number assigned to starter, grower, finisher, withdrawal phase rations)	
n	Total number of phases fed	
DM_{RF}	Retention Factor for dry matter	fraction
N_{RF}	Retention Factor for nitrogen	fraction
P_{RF}	Retention Factor for phosphorus	fraction
K_{RF}	Retention Factor for potassium	fraction
Excretion outputs		
$N_{E\text{-}PH}$	Nitrogen excretion per phase	g of nitrogen / phase
$N_{E\text{-}T}$	Total nitrogen excretion per finished animal	g of nitrogen / finished animal
$P_{E\text{-}PH}$	Phosphorus excretion per phase	g of phosphorus / per phase
$P_{E\text{-}T}$	Total phosphorus excretion per finished animal	g of phosphorus / finished animal
$K_{E\text{-}PH}$	Potassium excretion per phase	g of potassium / per phase
$K_{E\text{-}T}$	Total potassium excretion per finished animal	g of potassium / finished animal
$DM_{E\text{-}PH}$	Dry matter excretion per phase	g of dry matter / per phase
$DM_{E\text{-}T}$	Total dry matter excretion per finished animal	g of dry matter / finished animal

7.0 Equations for As-Excreted Manure Characteristics Estimates for Poultry (Broilers, Turkeys, and Ducks)

7.1 Fundamental Model

Nutrient Excretion = Feed Nutrient Intake − Nutrient Retention

7.2 See 2.0 Caution

See Table 8, Definition of Input Variables – As excreted – Poultry (Broilers, Turkeys, and Ducks).

7.3 Equations for Estimating Excretions – See Table 9 – Retention Factors for Broilers, Turkeys, and Ducks.

7.3.1 *Dry Matter Excretion Equation*

$$DM_{E-PH} = FI_{PH} * 0.88 * (1 - DM_{RF}) \quad (1)$$

$$DM_{E-T} = \sum\nolimits^{n}_{x=1} FI_x * 0.88 * (1 - DM_{RF}) \quad (2)$$

7.3.2 *Nitrogen Excretion Equation*

$$N_{E-PH} = [FI_{PH} * (C_{cp} / 6.25)] * (1 - N_{RF}) \quad (3)$$

$$N_{E-T} = \sum\nolimits^{n}_{x=1} [FI_x * (C_{cp-x} / 6.25)] * (1 - N_{RF}) \quad (4)$$

7.3.3 *Phosphorus Excretion Equation*

$$P_{E-PH} = (FI_{PH} * C_p) * (1 - P_{RF}) \quad (5)$$

$$P_{E-T} = \sum\nolimits^{n}_{x=1} (F_x * C_p) * (1 - P_{RF}) \quad (6)$$

Note that P_{RF} varies for broilers less than and greater than 32 days of age.

7.3.4 *Potassium Excretion Equation*

$$K_{E-PH} = (FI_{PH} * C_K) * (1 - K_{RF}) \quad (7)$$

$$K_{E-T} = \sum\nolimits^{n}_{x=1} (F_x * C_K) * (1 - K_{RF}) \quad (8)$$

7.4 Manure Characteristics Based Upon Typical Performance and Diets – See Tables 10a and 10b.

7.5 References

7.5.1 Applegate,T., L. Potturi, R. Angel. 2003. Model for Estimating Poultry Manure Nutrient Excretion: A Mass Balance Approach. Proceedings of the International Symposium for Animal, Agricultural, and Food Processing Wastes IX. ASAE. St. Joseph, MI. 296–302.

7.5.2 Angel, R., T. Applegate, S. Bastyr. 2003. Comparison of Two methods for Estimating Broiler Manure Nutrient Excretion: Biological Mass Balance Versus Model Based on Mass Balance Approach. Proceedings of the International Symposium for Animal, Agricultural, and Food Processing Wastes IX. ASAE. St. Joseph, MI. 303–309.

7.3.5 Table 9 – Retention Factors for Broilers, Turkeys, and Ducks.

Species	Dry Matter (DM_{RF})	Nitrogen (N_{RF})	Phosphorus (P_{RF})	Potassium (K_{RF})
Broiler if < 32 days of age	0.6884	0.602	0.493	0.182
Broiler if >= 32 days of age			0.4102	0.182
Turkey Toms and Hens	0.7479	0.588	0.4798	
Ducks	0.6937	0.657	0.4635	

8.0 Equations for As-Excreted Manure Characteristics Estimates for Poultry (Laying Hens)

8.1 Fundamental Model

Nutrient Excretion = Feed Nutrient Intake − Nutrient Retention

The laying hen model varies from other poultry specie to account for egg production. As such, the model assumes dry matter retention by the hen is equivalent to the sum of energy expenditure for maintenance, heat increment, and egg production as well as solids content within the egg, as is described below.

8.2 See 2.0 Caution

See Table 11, Definition of Input Variables – As Excreted – Poultry (Laying Hens).

8.3 Equations for Estimating Excretions

8.3.1 *Dry Matter Excretion*

$$DM_E = [FI * 0.88] - \{(FI * 0.88 * 0.85) * [1-(\{KCAL_I - [KCAL_m + KCAL_h + (KCAL_e * Egg_{prod})]\} / KCAL_I)] + (0.3319 * Egg_{wt} * Egg_{prod})\}$$

OR (1)

$$DM_E = [FI * 0.88] - \{(FI * 0.88 * 0.85) * [1-(\{KCAL_I - [140 + (53 * Egg_{prod})]\} / KCAL_I)] + (0.3319 * Egg_{wt} * Egg_{prod})\}$$

8.3.2 *Nitrogen Excretion*

$$N_E = (FI * C_{cp} / 6.25) - (0.0182 * Egg_{wt} * Egg_{prod}) \quad (2)$$

Table 10a – Estimated typical manure (urine and feces combined) characteristics as excreted based upon equations in Section 7 and assumptions in Table 10b.

Animal Type and Production Grouping	Total solids	Nitrogen	Phosphorus	Potassium	Total Manure[1]
	kg / finished animal				
Poultry - Broiler	1.3	0.053	0.016	0.031	4.9
Poultry - Turkey (male)	9.2	0.55	0.16		36
Poultry - Turkey (females)	4.4	0.26	0.074		17
Poultry – Duck	1.7	0.062	0.022		6.5
	lb / finished animal				
Poultry - Broiler	2.8	0.12	0.035	0.068	11
Poultry - Turkey (male)	20	1.2	0.36		78
Poultry - Turkey (females)	9.8	0.57	0.16		38
Poultry - Duck	3.7	0.14	0.048		14

[1] Total manure is calculated from total solids and assumed moisture of 74%.

Table 10b – Dietary and performance assumptions.

Animal Type and Production Grouping	Live Weight (kg)		Days on Feed	Feed Conversion (kg of feed per kg of gain)	Dietary Assumptions			Comments, Assumption or References
	In	Out			Dry Matter Intake (kg per phase)	Crude Protein (kg per phase)	P (kg per phase)	
Broiler	n/a	2.36	47.7	1.95	4.05 kg to 47.7 d	0.835 kg to 47.7 d	0.0288 kg to 47.7 d	Represents 95.8% of broilers marketed July 2002 (662 million birds or 1.53 billion kg live weight). Agristats, 2002 Four diet feeding program is assumed.
Turkey (male)	n/a	15.45	133	2.70	36.7 kg to 133 d	8.37 kg to 133 d	0.309 kg to 133 d	Represents 45.5 million turkey toms (Ferket 2001). Six diet feeding program is assumed.
Turkey (females)	n/a	6.82	105	2.34	17.6 kg to 105 d	3.94 kg to 105 d	0.143 kg to 105 d	Represents 59.5 million turkey hens (Ferket 2001). Six diet feeding program is assumed.
Duck	n/a	3.182	39	1.97	5.51 kg to 39 d	1.12 kg to 39 d	0.0402 kg to 39 d	Represents 13 million ducks (Applegate et al., 2003) Assumes two diet feeding program.

Assumptions: Feed is 88% dry matter.

Table 11 – Definition of Input Variables – As Excreted – Poultry (Laying Hens) – Section 8.

Variable	Description	Units
FI	Feed intake per day (wet weight). Dry matter intake assumed to be 88% of feed intake for poultry rations.	Grams / day
$KCAL_i$	Kcal intake Default: 270 kcal – Light layer strains Default: 292 kcal – Heavy layer strains	Kcal / day
$KCAL_m$	Kcal required for maintenance of body weight Default: 100 kcal	Kcal / day
$KCAL_h$	Kcal required for heat increment in thermo-neutral environment Default: 40 kcal	Kcal / day
$KCAL_e$	Kcal required for egg production of one egg Default: 53 kcal	Kcal / egg
Egg_{wt}	Egg weight Default: 60 g – Light layer strains Default: 63 g – Heavy layer strains	Grams
Egg_{prod}	Fraction of eggs that are produced each day Default: 0.80	Eggs / hen / day
C_{cp}	Concentration of crude protein of total ration	g of protein / g of feed (wet basis)
C_P	Concentration of phosphorus of total ration	g of phosphorus / g feed (wet basis)
C_{Ca}	Concentration of calcium of total ration	g of calcium / g feed (wet basis)
	Excretion outputs	
DM_E	Dry matter excretion per hen per day	g of dry matter / hen - day
N_E	Total nitrogen excretion per hen per day	g of nitrogen / hen - day
P_E	Total phosphorus excretion per hen per day	g of phosphorus / hen - day
Ca_E	Total calcium excretion per hen per day	g of phosphorus / hen - day

8.3.3 *Phosphorus Excretion*

$$P_E = (FI * C_P) - (0.0024 * Egg_{wt} * Egg_{prod}) \quad (3)$$

8.3.4 *Calcium Excretion*

$$Ca_E = (FI * C_{Ca}) - (0.00383 * Egg_{wt} * Egg_{prod}) \quad (4)$$

8.4 Assumptions: Diet contains 15% ash content and corrects diet energy retention to an ash-free, dry matter basis. Egg contains 33.19% solids, 1.82% N, 0.24% P, & 3.83% Ca. DM retention by hen is equivalent to energy expenditure for maintenance (100 kcal/hen, NRC, 1994; Lasiewski and Dawson, 1967), heat increment (40 kcal; NRC, 1994; MacLeod and Jewitt, 1988), and egg production (53 kcal/egg; NRC, 1994).

8.5 Manure Characteristics Based Upon Typical Performance and Diets – See Tables 12a and 12b.

8.6 References

8.6.1 Applegate, T., L. Potturi, R. Angel. 2003. Model for Estimating Poultry Manure Nutrient Excretion: A Mass Balance Approach.

Table 12a – Estimated typical manure (urine and feces combined) characteristics as excreted based upon equations in Section 8 and assumptions in Table 12b.

Animal Type and Production Grouping	Total solids	Nitrogen	Phosphorus	Calcium	Total Manure[1]
	kg / da–animal				
Layer	0.022	0.0016	0.00048	0.0022	0.088
	lb / da–animal				
Layer	0.049	0.0035	0.0011	0.0048	0.19

[1] Total manure is calculated from total solids and assumed moisture of 75%.

Table 12b – Dietary and performance assumptions.

Animal Type and Production Grouping	Average Live Weight (kg)	Feed Conversion (kg of feed per kg of product)	Dietary Assumptions			Comments or Written Description of Assumptions Reference [1]
			Dry Matter Intake (g per phase)	Crude Protein (g per phase)	P (g per phase)	
Layer	1.3–1.45 at start	1.994	36.64 kg from 20–80 wk	6500.4 g from 20–80 wk	249.0 g from 20–80 wk	20–80 wk production cycle. Feed is 88% dry matter 64% and 36% of industry is light (1.28 kg) and heavy (1.45) weight strains, respectively. A weekly change in diet formulation, feed consumption, and egg production was assumed from average performance.

Table 13 – Definition of Output Variables (used for all swine groups) – Section 9.

Variable	Description	Units
	Nutrient Intake	
N_I	Daily nitrogen intake	g / day
N_{I-T}	Nitrogen intake per finished animal or period (e.g. lactation)	g / finished animal or g / period
P_I	Daily phosphorus intake	g / day
P_{I-T}	Phosphorus intake per finished animal or period (e.g. lactation)	g / finished animal or g / period
	Nutrient Retention	
N_R	Daily nitrogen retained	g / day
N_{R-T}	Nitrogen retained per finished animal or period (e.g. lactation)	g / finished animal or g / period
WBN_F	Whole body nitrogen content at final body weight	g
WBN_I	Whole body nitrogen content at initial body weight	g
P_R	Daily phosphorus retained	g / day
P_{R-T}	Phosphorus retained per finished animal or period (e.g. lactation)	g / finished animal or g / period
	Nutrient Excretion	
N_E	Daily nitrogen excretion	g / day
N_{E-T}	Total nitrogen excretion per finished animal or period (e.g. lactation)	g / finished animal or g / period
P_E	Daily phosphorus excretion	g / day
P_{E-T}	Total phosphorus excretion per finished animal or period (e.g. lactation)	g / finished animal or g / period
DM_E	Daily dry matter excretion	g / day
DM_{E-T}	Total dry matter excretion per finished animal or period (e.g. lactation)	g / finished animal or g / period

Table 14 – Input Variables—Grow-finish Pigs (20 to 120 kg) – Section 9.3.

Variable	Description	Units
	Animal performance characteristics	
BW_I	Initial body weight	kg
BW_F	Final body weight (market weight)	kg
BW_{AVG}	Average of initial and final body weight	kg
DOF_G	Days on feed to finish animal (grow-finish phase)	days
DP_F	Average dressing percent (yield) at final weight. Typically from packer kill sheet.	%
$FFLP_F$	Average fat-free lean percentage at final weight. Typically from packer kill sheet.	%
	Feed program characteristics	
$ADFI_G$	Average daily feed intake over finishing period (grow – finish phase). User provided or see NRC (1998)	g / d
FI_G	Feed Intake per finished animal (grow – finish phase)	g/finished animal
C_{CP}	Concentration of crude protein in total (wet) ration	%
C_P	Concentration of phosphorus in total (wet) ration	%
C_{DM}	Dry matter concentration of diet	%
DMD	Dry matter digestibility of total ration	%

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9.0 Equations for As-Excreted Manure Characteristics Estimates for Swine

9.1 Fundamental Model

Nutrient Excretion = Nutrient Feed Intake − Nutrient Retention

9.2 See 2.0 Caution

See Table 13, Definition of Output Variables (using all swine groups).

9.3 Equations for Estimating Excretions– See Table 14, Input Variables—Grow-finish Pigs (20 to 120kg).

9.3.1 *Nutrient and Solids Excretion—Grow-finish Pigs (20 to 120 kg)*

$$N_{E-T} = N_{I-T} - N_{R-T} \quad (1)$$

$$P_{E-T} = P_{I-T} - P_{R-T} \quad (2)$$

$$DM_{E-T} = [C_{DM} * FI_G * (100-DMD) / 10{,}000] + [0.025 * DOF_G * (20 * BW_{AVG} + 2{,}100)] \quad (3)$$

9.3.2 *Nutrient Intake – Grow-finish Pigs (20 to 120 kg)*

$$N_{I-T} = ADFI_G * C_{CP} * DOF_G / 625 \text{ OR } FI_G * C_{CP} / 625 \quad (4)$$

$$P_{I-T} = ADFI_G * C_P * DOF_G / 100 \text{ OR } FI_G * C_P / 100 \quad (5)$$

Table 15 – Definition of Input Variables - Weanling Pigs (5 to 20 kg) – Section 9.4.

Variable	Description	Units
	Animal performance characteristics	
BW_{I-N}	Initial body weight in nursery phase	kg
BW_{F-N}	Final body weight in nursery phase	kg
DOF_N	Days on feed to finish animal (nursery phase)	days
DP_{120}	Average dressing percent (yield) at 120 kg. Typically from packer kill sheet.	%
$FFLG_G$	Average fat-free lean gain from 20 to 120 kg. Recommended values: 350 g/day High lean growth capacity pigs 325 g/day High-moderate lean growth capacity pigs 300 g/day Moderate lean growth capacity pigs Source: National Research Council. 1998. Nutrient Requirements of Swine. National Academy Press. Washington, D. C. 189 pages.	g / d
	Feed program characteristics	
$ADFI_N$	Average daily feed intake over finishing period (nursery phase). User provided or see NRC (1998)	g / d
FI_N	Feed Intake per finished animal (nursery phase)	g / finished animal
C_{CP}	Concentration of crude protein in total (wet) ration	%
C_P	Concentration of phosphorus in total (wet) ration	%
C_{DM}	Dry matter concentration of diet	%
DMD	Dry matter digestibility of total ration	%

Table 16 – Input Variables - Gestating Sows – Section 9.5.

Variable	Description	Units
	Animal performance characteristics	
GLTG	Gestation Lean Tissue Gain Recommended value: 19.205 kg	kg
GL	Gestation period length (assumed to be 115 days)	days
SW_{Breed}	Sow body weight at breeding	kg
SW_{PF}	Sow body weight post farrowing	kg
LW_{Birth}	Litter weight at birth	kg
LITTER	Number of pigs in litter	Number of pigs
	Feed program characteristics	
$ADFI_S$	Average daily feed intake during gestation	g / d
C_{CP}	Concentration of crude protein	%
C_P	Concentration of phosphorus	%
C_{DM}	Dry matter concentration of diet	%
DMD	Dry matter digestibility of total ration	%

9.3.3 *Nutrient Retention – Grow-finish Pigs (20 to 120 kg)*[1]

$$N_{R-T} = [(BW_F * DP_F * FFLP_F) / 159.4] - \{BW_I * [DP_F - 0.05 * (BW_F - BW_I)] * [FFLP_F + 0.07 * (BW_F - BW_I)]\} / 159.4 \quad (6)$$

$$P_{R-T} = (0.2256 * N_{RT}) - [8.0 * 10^{-6} * N_{RT} * (WBN_I + WBN_F)] \quad (7)$$

$$WBN_F = (BW_F * DP_F * FFLP_F) / 159.4 \quad (8)$$

$$WBN_I = BW_I * \{DP_F - [0.05 * (BW_F - BW_I)]\} * \{FFLP_F + [0.07 * (BW_F - BW_I)]\}/159.4 \quad (9)$$

Daily excretion of solids, nitrogen and phosphorus can be estimated by dividing total excretion estimated above by days on feed for the grow-finish phase (DOF_G).

9.4 Equations for Estimating Excretions – See Table 15, Definition of Input Variables – Weanling Pigs (5 to 20kg).

[1] P retention based on relation to N (Jongbloed, 1987).

9.4.1 *Nutrient and Solids Excretion—Weanling Pigs (5 to 20 kg)*[1]

$$N_{E-T} = N_{I-T} - N_{R-T} \quad (1)$$

$$P_{E-T} = P_{I-T} - P_{R-T} \quad (2)$$

$$DM_{E-T} = C_{DM} * ADFI_N * DOF_N * (100–DMD) / 10{,}000 \;^{1} \quad (3)$$

9.4.2 *Nutrient Intake – Weanling Pigs (5 to 20 kg)*

$$N_{I-T} = ADFI_N * C_{CP} * DOF_N / 625 \quad OR \quad FI_N * C_{CP} / 625 \quad (4)$$

$$P_{I-T} = ADFI_N * C_P * DOF_N / 100 \quad OR \quad FI_N * C_P / 100 \quad (5)$$

9.4.3 *Nutrient Retention – Weanling Pigs (5 to 20 kg)*[2]

$$N_{R-T} = DOF_N * FFLG_G * \{1+[0.137 * (BW_{F-N} + BW_{I-N})]\} / 125.8 \quad (6)$$

$$P_{R-T} = 4.7494 * (BW_{F-N} - BW_{I-N}) \quad (7)$$

[1] Dry matter excretion in feces only.
[2] P retention based on relation to N (Jongbloed, 1987).

Table 17 – Input Variables – Lactating Sows – Section 9.6.

Variable	Description	Units
Animal performance characteristics		
LLTG	Lactation Lean Tissue Gain Recommended value: -4.20 kg	kg
LL	Lactation length (or time to weaning)	days
SW_{WEAN}	Sow body weight at litter weaning	kg
SW_{PF}	Sow body weight post farrowing	kg
LW_{WEAN}	Litter weight at weaning	kg
LW_{BIRTH}	Litter weight at birth	kg
Feed program characteristics		
$ADFI_{LACT}$	Average daily feed intake during lactation	g / d
C_{CP}	Concentration of crude protein	%
C_{P}	Concentration of phosphorus	%
C_{DM}	Dry matter concentration of diet	%
DMD	Dry matter digestibility of total ration	%

Table 18a – Estimated typical manure (urine and feces combined) characteristics as excreted based upon equations in Section 9 and assumptions in Table 18b.

Animal Type and Production Grouping	Total solids	Nitrogen	P	Total solids[1]	Nitrogen	P
	kg / finished animal			lb / finished animal		
Swine - Nursery pig (12.5 kg)		0.41	0.068		0.91	0.15
Swine - Grow-finish (70 kg)	56	4.7	0.76	120	10	1.7
	kg / day−animal			lb / day−animal		
Swine - Gestating sow-200 kg		0.032	0.009		0.071	0.020
Swine - Lactating sow-192 kg		0.085	0.025		0.19	0.055

[1]Total solids include urine and feces.

Table 18b – Dietary and performance assumptions of growing swine.[1,2]

Animal Type and Production Grouping	Live Weight (kg)		Average Daily Gain (kg/da)	Days on Feed	Feed Conversion (kg of feed per kg of gain)	Dietary Assumptions			
	In	Out				Dry Matter Intake (% of avg. body weight)	Dry Matter Digestibility	Crude Protein (g/day)	P (g/day)
Nursery pig (12.5 kg)[1,2]	5	20	0.412	36	1.50	5.0	80%	137	3.88
Grow-finish (70 kg)[1,2]	20	120	0.84	120	2.80	3.4	82%	371	10.3

[1] Feed is 88% dry matter. Corn-soybean meal-animal protein (weanling pig) or corn-soybean meal (grow-finish) diet meets the lysine requirement.
[2] N and P intake is based on NRC (1998). N and P retention are based on NRC (1998). P retention is based on Mahan and Newton (1995).

Table 18c – Dietary and performance assumptions of sows.[1,2]

Animal Type and Production Grouping	Average Live Weight (kg)	Production	Dietary Assumptions				Comments or Written Description of Assumptions Reference[1]
			Dry Matter Intake (% of average body weight)	Dry Matter Digestibility	Crude Protein (g/day)	P (g/day)	
Gestating sow-200 kg (start 175 kg, end 225 kg)[1,2] 115 day gestation period	200	12 pigs / litter	1.00	82%	259	12.4	Wt gain = 50 kg with 27 kg wt gain with litter & 23.0 kg wt gain for dam Gestation lean tissue gain = 17.6 kg
Lactating sow-192 kg (Start 198 kg, end 185 kg)[1,2] 20 day lactation period	192	10 pigs nursing	2.60	82%	967	34	Wt change = −13 kg Lactation lean tissue change = −5.3 kg

[1] Assumes corn-soy diet that is 88 % dry matter and meets the lysine requirement.
[2] N and P intake is based on NRC (1998). N retention is based on NRC (1998). P retention is based on Mahan and Newton (1995).

Table 19 – As-Removed Manure Production and Characteristics. The numbers in parenthesis are coefficients of variation.

	Moisture (% wb)	TS (% wb)	VS (% TS)	Ash (% TS)	Heat (BTU/lb wb)	TKN (% wb)	NH3-N (% wb)	P (% wb)	K (% wb)	Ca (% wb)	Na (ppm wb)	Mg (ppm wb)	Fe (ppm wb)	S (ppm wb)	Cl (ppm wb)	Zn (ppm wb)	Mn (ppm wb)	Cu (ppm wb)	Mass (Kg/hd/d)
Beef																			
Earthen Lot	33.1 (28)	67.2 (14)	30.2 (30)	69.9 (24)	1136 (15)	1.18 (33)	0.10 (102)	0.50 (36)	1.25 (25)	1.21 (46)	3012 (67)	3650 (27)	1305 (55)	2841 (37)	7396 (52)	85 (63)	393 (109)	14 (70)	7.5 (0.58)
Poultry																			
Leghorn pullets	65.20 (14)	40				2.13 (31)	0.85 (22)	1.00 (25)	1.10 (29)	1.49 (33)		2700 (26)							No data
Leghorn hen	59.27 (14)	40				1.85 (30)	0.88 (39)	1.21 (34)	1.31 (28)	6.40 (41)		4400 (32)							0.03
Broiler litter	31.00 (24)	70	70			3.73 (14)	0.75	0.60 (22)	1.37 (13)	1.82 (17)									0.02
Turkey litter	30.00					2.18		0.33	1.23	5.00									0.11
Dairy																			
Scraped earthen lots	54 (28)	46 (33)		43		0.70 (106)		0.25 (82)	0.67 (71)	0.45 (78)	311 (45)	100 (64)	4.6 (66)		86.0	1.2 (42)	1.4	0.2 (21)	35
Scraped concrete lots	72	25				0.53		0.13	0.40	0.31	32	9	1.3			0.4	0.7	0.1	40
Lagoon effluent	98	2	52			0.073	0.08	0.016	0.11	0.04	7	3	2.5		1.7	0.9	1.4	2	106
Slurry (liquid)	92 (1)	8 (16)	66			0.30	0.14	0.13	0.40	0.40	905	1535	735	625		25	40	75	67
Equine																			
Solid manure	43.4 (16.1)	64.9 (19.7)	26.3 (10.3)			0.76 (0.36)		0.24 (0.11)	0.99 (0.58)	1.13 (0.72)		0.3 (0.18)	3614 (4722)			51.7 (33.66)	135 (60)	12.70 (6.02)	32.2 (residential) 46 (commercial)
Swine																			
Finisher-Slurry, wet-dry feeders	91.00	9.00				0.70	0.50	0.21	0.24	0.25	380			400		85.0		50	3–4
Slurry storage-Dry feeders	93.90	6.10 (86)				0.47 (43)	0.34 (43)	0.18 (83)	0.24 (36)	0.25 (98)	380 (24)			180 (55)		68 (53)		30 (56)	4.5
Flush building	98.00	2.00				0.20	0.14	0.07	0.17	0.04	300	290		155		33.6	14.4	31.2	16
Agitated solids and water	97.80	2.20				0.10	0.05	0.06	0.06	0.08	215	300		180		44.4	15.6	19.2	
Lagoon surface water	99.6	0.40				0.06	0.04	0.02	0.07	0.01	215	55		37		3.6	1.2	2.4	
Lagoon sludge	90.0	10.0				0.26	0.07	0.25	0.07	0.04	191	132		79		22	80	90	

Table 20 – References

The numbers in the table are rounded averages gathered from across the U.S. They are best estimate interpretations based on the research data collected.

BEEF earthen lots	**Concrete lots**		
Nebraska unpub (12 lots, 96 hd ea) NC State (n~30) Texas AM University (n~4) Oklahoma State University (n = 72) Ward lab (n = 1026) Σ = **1144**	Iowa unpublished data (N ~ 6) NC State (n ~ 27) NOTE: not enough data to publish estimates for conc. lots		
DAIRY ESTIMATES			
Scraped Earthen lots Jones (Texas, n ~ 17) TAMU (n ~ 5) Dairyland (n ~ 77) Agsource (n ~ 367) Σ = 476	**Scraped Concrete lots** N.C. State data (n ~ 187) TAMU (n ~ 3) ISU (n ~ 18) KSU (n ~ 9) Σ = 190	**Lagoon effluent** N.C. State data (~160) Meyer (n~ 518) NY (n~57) TAMU (n~18) Σ = 753	**Liquid Slurry** N.C. State data (n ~ 400) Minn (n ~ 21) NY (n ~ 39) Kansas (n ~ 18, Stram et al.) Wisc (n ~ 746) Dairyland (n ~ 216) Agsource (n ~ 514) NRAES-31, 1989, Collins et al.) Σ = 1954
SWINE			
Deep Pit Slurry ISU Jaranilla (n = 24) ISU NIR data (n = 268) (1999 & 2000 data) Σ = 292	**Flush water** SE US data (Chastain)	**Lagoon Surface Water** SE US data (Chastain) Mo. Data ISU NIR data (n = 189) Σ = 189+	**Agitated liquid & solids** SE US data (Chastain)
POULTRY			
Pullets Patterson	**Layer hens** Patterson ISU (Lorimor & Xin, n = 48)	**Broiler litter** ISU (Mo & Okla samples, n = 95)	**Turkey litter**

Daily excretion of solids, nitrogen and phosphorus can be estimated by dividing total excretion estimated above by days on feed for nursery phase (DOF_N).

9.5 Equations for Estimating Excretions – See Table 16, Input Variables – Gestating Sows.

9.5.1 *Nutrient and Solids Excretion – Gestating Sows*[1]

$$N_{E-T} = N_{I-T} - N_{R-T} \quad (1)$$

$$P_{E-T} = P_{I-T} - P_{R-T} \quad (2)$$

$$DM_{E-T} = C_{DM} * ADFI_S * GL * (100 - DMD) / 10{,}000$$

$$= C_{DM} * ADFI_S * 0.0115 * (100 - DMD)^1 \quad (3)$$

9.5.2 *Nutrient Intake – Gestating Sows*[1]

$$N_{I-T} = ADFI_S * C_{CP} * GL / 625 = ADFI_S * C_{CP} * 0.184 \quad (4)$$

$$P_{I-T} = ADFI_S * C_P * GL / 100 = ADFI_S * C_P * 1.15 \quad (5)$$

9.5.3 *Nitrogen Retention – Gestating Sows*[2]

$$N_{R-T} = (GLTG \times 36.8) + (LITTER \times 39.1) \quad (6)$$

[1] Dry matter excretion in feces only.
[2] Assumes gestation period length of 115 days.

$$P_{R-T} = 93.039 + \{3.9717 \times [(SW_{PF} - SW_B) - (2.277 * LITTER)]\} + (LW_{Birth} \times 5.7) + \{[(2.277 \times LITTER) - LW_{Birth}] \times 0.80\} \quad (7)$$

Note: N_{R-T} accounts for nitrogen retention in maternal weight gain and the developing litter. P_{R-T} considers phosphorus retention in maternal weight gain, developing litter and placenta tissue.

Daily excretion of solids, nitrogen and phosphorus can be estimated by dividing total excretion estimated above by gestation length (GL) in days.

9.6 Equations for Estimating Excretions – See Table 17, Input Variables – Lactating Sows.

9.6.1 *Nutrient and Solids Excretion – Lactating Sows*

$$N_{E-T} = N_{I-T} - N_{R-T} \quad (1)$$

$$P_{E-T} = P_{I-T} - P_{R-T} \quad (2)$$

$$DM_{E-T} = C_{DM} * ADFI_L * LL * (100-DMD) / 10{,}00 \quad (3)$$

9.6.2 *Nutrient Intake – Lactating Sows*

$$N_{I-T} = ADFI_{LACT} * C_{CP} * LL/625 \quad (4)$$

[1] Dry matter excretion in feces only.

$$P_{I-T} = ADFI_{LACT} * C_P * LL/100 \quad (5)$$

9.6.3 *Nutrient Retention – Lactating Sows*

$$N_{R-T} = [36.8 \times LLTG] + (LW_{WEAN} \times 32) - (LW_{BIRTH} \times 36.8) \quad (6)$$

$$P_{R-T} = [(SW_{WEAN} \times 4.84) - (SW_{PF} \times 5.28)] + [(LW_{WEAN} \times 6.4) - (LW_{BIRTH} \times 5.7)] \quad (7)$$

Daily excretion of solids, nitrogen and phosphorus can be estimated by dividing total excretion estimated above by lactation length (LL) in days.

9.7 Manure Characteristics Based Upon Typical Performance and Diets – See Tables 18a, 18b, and 18c.

9.8 References

9.8.1 Carter, S., G. Cromwell, P. Westerman, J. Park, and L. Pettey. 2003. Prediction of Nitrogen, Phosphorus, and Dry Matter Excretion by Swine Based on Diet Chemical Composition, Feed Intake, and Nutrient Retention. Proceedings of the International Symposium for Animal, Agricultural, and Food Processing Wastes IX. ASAE. St. Joseph, MI. 285–295.

10.0 As-Removed Manure Production and Characteristics

10.1 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). The variances on the data presented in Section 10, As-Removed Manure Production and Characteristics, are significantly high, and strongly correlated to the geographic location and the type of manure management system in use. 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 no site-specific manure analysis data are available.** Where site-specific data are unavailable, this table may provide initial estimates for planning purposes until site-specific values are available.

See Tables 19 and 20.

10.2 References (continued)

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