Estimating Manure Nutrient Excretion

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Disclaimer

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USDA United States Department of Agriculture

NRCS Natural Resources Conservation Service

Introduction

This fact sheet has been developed to support the implementation of the Natural Resources Conservation Service Feed Management 592 Practice Standard. The Feed Management 592 Practice Standard was adopted by NRCS in 2003 as another tool to assist with addressing resource concerns on livestock and poultry operations. Feed management can assist with reducing the import of nutrients to the farm and reduce the excretion of nutrients in manure.

The Natural Resources Conservation Service has adopted a practice standard called Feed Management (592) and is defined as “managing the quantity of available nutrients fed to livestock and poultry for their intended purpose”. The national version of the practice standard can be found in a companion fact sheet entitled “An Introduction to Natural Resources Feed Management Practice Standard 592”. Please check in your own state for a state-specific version of the standard.

Estimating Manure Nutrient Excretion

The front and back ends of animals are connected. While this principle seems obvious, it has historically been ignored in nutrient planning procedures. This fact sheet describes tools that allow integration of feed management and animal performance into nutrient planning processes for animal feeding operations.

A new standard published by the American Society of Agricultural and Biological Engineers (D384.2, Manure Production and Characteristics) is a tool for developing farm specific Comprehensive Nutrient Management Plans (CNMP). This standard allows accurate estimates of nutrient and solids excretion reflective of feed programs and animal performance. Accurate estimates of manure excretion are critical to estimating land requirements and land application costs, sizing manure storage, and planning treatment technologies. This fact sheet will introduce the new manure excretion standard and its application.

Contents of Standard

An ASABE committee of animal scientists and agricultural engineers developed predictive equations for estimating manure excretion for five species (beef, dairy, horse, poultry, and swine) and "typical" characteristics for excreted and as-removed manure. The standard is found at http://asae.frymulti.com/ followed by a search of "Standards" and "Title" options for "Manure Production". The ASABE standard includes seven sections.

Section 1 lists a new "typical" characteristics tabular summary for individual species and groupings of animals (see Table 1 and 2). These values should provide a reasonable estimate of excretion for animals in the year 2000. As time passes, published typical values become less accurate and should be used with caution for individual herds or flocks. Differences in genetics, feed program, and animal performance between individual farms create a potential for errors when typical values are applied. They may have value for preliminary nutrient planning estimates but should NOT be used in final farm-specific nutrient management plans.

Sections 2 through 7 define the equations for cattle, dairy cattle, horses, poultry (separate sections for meat birds and layers), and swine, respectively. Equation based estimates are provided for all species groups for dry matter, N and P excretion. Equations for estimating additional characteristics are available for some species.

Section 8 of the new standard summarizes As-Removed manure characteristics. The work group summarized a wide range of data sets for inclusion in this section. These values can be beneficial for estimating storage volumes and manure application rates when no other farm-specific information is available. However, when farm specific manure samples are available, they are preferred.

Two Approaches for Estimating Excretion

Two distinctly different approaches were used equation based estimates of excretion. The beef, swine, and poultry work groups used an animal mass balance approach (Figure 1). Excretion is estimated as a difference between feed nutrient intake and retention in body mass or animal products (eggs or milk). intake and retention in body mass or animal products (eggs or milk).

The dairy and horse work groups used existing data sets as a basis for multi-variable regression analysis. The dairy work group proposed equations for lactating cows, dry cows and heifers. The horse work group chose to publish separate equations for exercised and sedentary horses. Table 1. Estimated typical manure (urine and feces combined) characteristics as excreted by meat-producing livestock and poultry. Diet based numbers are in **BOLD**. Source ASAE D384.2 March 2005, Manure Production and Characteristics.

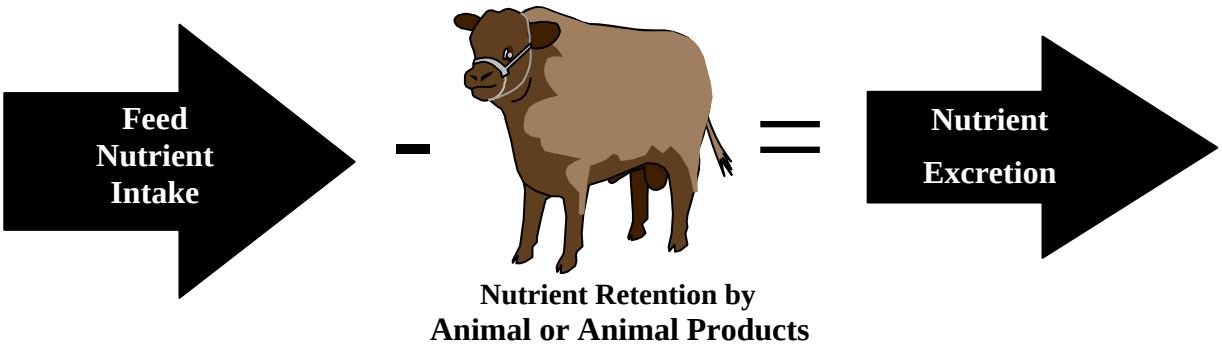

Figure 1. Mass balance approach was used for estimating excretion characteristics for beef cattle, swine, and poultry.

Factors Affecting Nutrient Excretion

The new standard defines the relationship between feed inputs and animal performance and manure excretion characteristics. For example, the quantity of solids excreted is directly tied to the dry matter digestibility of the diet. Since dry matter digestibility for many species is often 80 to 85% (15 to 20% of solids in feed excreted in feces), small changes in dry matter digestibility produce large differences in solids excreted. A dietary modification that changes dry matter digestibility change from 85% to 80% results in 33% more solids in the feces. Similarly, dietary intake of protein and phosphorus is directly related to excreted N and P.

Historically, manure excretion estimates have been based upon standards published by the ASABE, USDA Natural Resources Conservation Service, and Midwest Plan Service. These previous standards varied excretion estimates with species and animal weight only. A linear relationship was assumed between excretion and body weight. However, this approach provides a poor explanation of important biological factors that influence manure excretion. In addition, these standards become dated with time because they do not recognize changes in genetics, animal performance, and feeding options. Current and past excretion estimates based upon species and body weight alone often produce inaccurate estimates of manure excretion for individual farms.

The standard for manure excretion released by ASABE in 2005 was designed to provide farm-specific estimates of excretion reflective of individual farm feed programs and animal performance. In addition, this standard will better adapt to changes in excretion that occur over time due to factors such as improved animal genetics. Thus, the equation based standard for manure excretion released in 2005 should remain accurate well into the future.

Is This Important?

Tables 3, 4, and 5 illustrate excretion estimates for beef, swine, and dairy calculated from the new equations. Some of the more dramatic differences between the current ASABE and other standards are associated with P and total solids excretion. These differences tend to become larger as emerging feed technologies reduce nutrient excretion and as feeding of by-products of corn processing and other food processing industries become increasingly popular. To illustrate the importance of the new ASABE standard for farm specific estimates, comparisons are illustrated below for three species.

Table 1. Estimated Estimated typical manure (urine and feces combined) characteristics as excreted by meat-producing livestock and poultry. Diet based numbers are in **BOLD**. Source ASAE D384.2 March 2005, Manure Production and Characteristics.

Animal Type and Production Grouping	Total solids	Volatile solids[3]	COD[1]	BOD[1]	Nitrogen	P	K	Ca	Total Manure[2]		Moisture[3]	Assumed Finishing Time Period (days)
	lb/ finished animal (f.a.)								lb/ 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 2. Estimated typical manure (urine and feces combined) characteristics as excreted by all other livestock and poultry. Diet based numbers are in **BOLD**. Source ASAE D384.2 March 2005, Manure Production and Characteristics.

Animal Type and Production Grouping	Total solids	Volatile solids[3]	COD[1]	BOD[1]	Nitrogen	P	K	Ca	Mg	Total Manure[2]		Moisture[3]
	lb/ day-animal (d-a)									lb/ d-a.	ft^3/ d-a.	% w.b.
Beef - Cow (confinement)[4]	**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[5]	**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[5]	**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[6]-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. BOD – Biochemical oxygen demand, 5-day, COD – Chemical oxygen demand
2. Total manure is calculated from Total Solids and manure moisture content.
3. Excreted manure was assumed to have a specific gravity of 1.0 to calculate manure volume.
4. Beef cows values are representative of animals during non-lactating period and first six months of gestation. Solids estimates (TS, VS, COD, and BOD) do not include solids in urine.
5. These values apply to a 500 kg horse (representative of 400 to 600 kg) 18 months of age or older that are not pregnant or lactating. “Sedentary” would apply to horses not receiving any imposed exercise. "Intense" represents horses used for competitive activities such as racing..
6. Bold values include contribution of nursing pigs.

Beef. A comparison of excretion characteristics estimated by the new ASABE standard with past standards (rows A – C, Table 3) suggests that previous estimates are in reasonable agreement for N excretion but in poor agreement with P excretion. A significant effort to better match beef cattle rations with phosphorus requirements has reduced P excretion substantially.

Considerable variation exists between individual cattle feedlots relative to performance and feed program strategies. Substantial variation in N and P excretion is anticipated when comparing a corn based ration (Table 3, Row C) and a ration with 40% distillers grains (Table3, Row, D). Combining feed program variation with typical ranges in animal performance can produce a 2-fold range in N excretion and a 3-fold range in P excretion (Table 3 Rows F and G). Large errors in beef cattle excretion estimates are common unless performance and feed program are considered in estimating excretion.

Swine. Typical nitrogen excretion estimates for swine for the new standard have changed little from the past ASAE standard (Table 4, Rows A – B). However, phosphorus excretion is substantially lower than other standards. Total solids excretion is also generally lower than previously accepted values.

Table 4 illustrates the importance of a standard that responds to emerging feeding strategies (Table 4, Rows C). Diets based on use of crystalline amino acids and phytase have the potential for lowering dietary CP and P levels and N and P excretion. A low CP diet would produce N excretion levels up to 40% less than new standard typical value. Low P diets would reduce P excretions levels by 33 to 40% from new typical values.

Dairy Cattle. Generally the new ASABE standard predicts greater excretion of nutrients and solids as compared to the past ASAE standard and other existing accepted values for lactating cattle (Table 5, Row A and B). Steadily increasing milk production will create an even larger disparity between predicted excretion by the new ASABE standard and other past values.

Tools for Applying ASAE Standard

The proposed ASAE equations complicate the process of estimating nutrient and solid excretion. Software tools based upon these equations provides one option for improving the utility of equations and their application to farm specific CNMPs. Two spreadsheet tools use the ASABE estimate of excreted nutrients as a basis for estimating land requirements for managing manure nutrients. A Nutrient Inventory comes with instructions and a one-hour video discussing its application (available at http://cnmp.unl.edu). A second tool nearing completion (FNMP$) will estimate land requirements, cost and time required for land applying manure, and potential economic benefits of manure nutrients (will be available at above web site).

A simplified hand calculator of nutrient excretion was introduced in a MWPS publication, Manure Characteristics (Table 6). It uses a mass nutrient balance procedure for estimating excretion for beef, dairy, poultry and swine. It provides a simplified approach that produces similar answers to procedures used in the ASABE standard.

Table 3. Comparison of beef cattle excretion (lb/finished animal) for two methods of estimating excretion and variations in feed characteristics and animal performance.

Source	Dry Matter Intake (lb)	% Crude Protein	% P	Dry Matter Digesti-bility (%)	Feed Efficiency (feed/gain) and Days to Finish	Excretion (lb/finished animal)			Take Home Message
						N	P	TS	
Typical or Average Excretion									
A. New ASABE	19.7	13.3	0.31	80	6.3 / 153	55	7.0	770	Old standard overestimated P and solids excretion
B. Old ASAE	--	--	--	--	--	51	13.7	1280	
Changes in fee d characteristics while all other assumptions remain constant									
C. New ASABE	19.7	12.5	0.25	80	6.3 / 153	51	5.3	770	Excess ration protein and P produce high N & P excretion
D. New ASABE	19.7	18.7	0.50	80	6.3 / 153	82	12.8	770	
Changes in feed efficiency and feed characteristics									
E. New ASABE	19.7	12.5	0.25	80	5.69 / 138	46	4.6	710	Typical range of nutrient excretion by beef cattle
F. New ASABE	19.7	18.7	0.50	80	6.95 / 168	157	14.3	860	

1. All assumptions are held constant with exception of days to finish. High and low feed efficiency scenarios assume feeding period of 138 and 168 days to market weight, respectively.

Caution – In practice, a change in one feed characteristic may impact performance or other diet characteristics. This table may not always reflect those impacts.

Table 4. Comparison of grow-finish swine excretion (lb/finished animal) for current and past estimating methods and feeding technologies designed to reduce excretion.

Source	Dry Matter Intake (lb)	% Crude Protein	% P	Dry Matter Digesti-bility (%)	Feed Efficiency (feed/ gain) and Days to Finish	Excretion (lb/finished animal)			Take Home Message
						N	P	TS	
Typical or Average Excretion									
A. New ASABE	5.25	15.6	0.43	82	2.86 / 120	10.4	1.7	140	Old standard overestimated P and TS excretion
B. Old ASAE	--	--	--	--	--	9.7	3.3	200	
Low CP and P diets while all other assumptions remain constant									
C. New ASABE	5.25	11.5	0.33	82	2.86 / 120	6.4	1.0	140	Feed technologies reduce N & P

Table 5. Comparison of dairy cattle excretion (kg/animal/day) for current and past standards.

Source	Dry Matter Intake (lb)	% Crude Protein	% P	Milk Production (lb/day)	Excretion (lb/animal/day)			Take Home Message
					N	P	TS	
Typical or Average Excretion								
A. New ASABE	21.2	17.5	0.45	40	1.04	0.172	18.5	Old standard underestimated N and P excretion
B. Old ASAE	--	--	--	--	0.62	0.130	16.5	

Table 6. Total manure nutrients excreted by a livestock operation based on feed rations.

This worksheet only considers feed intake and not feed disappearance. If excess feed ends up in the manure, then the amount of excess feed and its nutrients needs to be added to the nutrient excreted values for an accurate estimation. Date:_____

I. Feed Nutrient Intake

Animal Group	A. Daily Feed Intake (lbs DM/day)	B. Feed Nutrient Concentration			C. Total Nutrient in Feed (lbs) = A X B	
		Protein	N[a]	P	N (lbs)	P (lbs)
Beef Example	*27,000*	*0.135*	*0.0216*	*0.0035*	*583*	*94.5*

II. Nutrients Retained

a. **Animal**

Animal Group	D. Number of Animals	E. Average Daily Gain	F. Live Weight Nutrient Concentration		G. Nutrients Retained by Animal (lbs) = D x E x F	
			N	P	N (lbs)	P (lbs)
Beef Example	*1,000*	*4.08*	*0.016*	*0.0070*	*65.3*	*28.6*
Beef			0.016	0.0070		
Dairy			0.012	0.0070		
Pork			0.023	0.0072		
Hens			0.022	0.0060		
Broilers			0.026	0.0060		
Turkeys			0.021	0.0060		

b. **Animal Products**

Animal Product	H. Production (lbs/day)	I. Animal Products Nutrient Concentration		J. Nutrients Retained by Animal Products (lbs) = H x I	
		N	P	N (lbs)	P (lbs)
Milk[b]		0.0050	0.0010		
Eggs[b]		0.0166	0.0021		

III. Nutrients Excreted

Animal Group	K. Days Fed per Year	L. Animal Nutrient Excreted in Elemental Form = K x (C - G) or = K x (C - J)		
		N (lbs/yr)	P (lbs/yr)	P_2O_5[c] (lbs/yr)
Beef Example	*350*	*181,195*	*23,065*	*52,358*

[a] N in feed = Protein) 6.25
[b] N in milk = Protein) 6.28; N in eggs = Protein) 6.25; Assumes 3.2% and 10.4% protein in milk and eggs, respectively.
[c] lbs P_2O_5 = lbs P x 2.29

Source: J. Lorimor, W. Powers, and A. Sutton. 2000. Manure Characteristics. MWPS-18 Manure Management Systems Series.

Information Requirements for Using New Standard

The information requirements of the new standard are greater than with past standards. Farm specific information is needed for animal performance (e.g. weight gain or milk production) and feed program (dry matter intake and nutrient concentration). Those input requirements are summarized in Table 7.

Table 7. Information requirements for using ASABE procedures to estimate excretion.

Information Requirement	**Beef (finishers)**	**Dairy (lactating cows)**	**Poultry (Egg Production)**	**Poultry (Meat Production)**	**Swine (finishers)**
Performance Information Requirements					
Live Weight Entering	X			X	X
Live Weight Exiting	X			X	X
Average Weight		X	X		
Number of animals	Per Turn	X	X	X	Per Turn
Turns or flocks per year	X			X	X
Grade of marketed beef	X				
Average dressing percent at final weight					X
Average fat free lean gain at final weight[2]					X
Milk production		X			
Milk protein		X			
Layer strain heavy or light)			X		
% of layers producing egg in one day			X		
Egg weight			X		
Average broiler age				X	
Feed Program Information Requirements					
Average Days on Feed	X		X	X	X
Daily Feed Intake	X	X	X	X	X
Dry Matter Digestibility	X				X
Organic Matter Digestibility	X				
% Crude Protein in Diet	X	X	X	X	X
% Phosphorus in Diet	X	X	X	X	X
Energy intake			X		

Applications of New ASAE Standard

Most nutrient planning processes follow a step-wise procedure similar to that illustrated in Figure 2. At this time, the equation-based estimates of solids and nutrients will have their greatest utility in the strategic or long-term planning. These strategic plans are of greatest value to a new or expanded facility or when a regulatory permit is being assembled.

Figure 2 illustrates a second critical planning phase, the Tactical or Annual Plan. For decisions such as manure application rates, timing, and location, constantly changing conditions such as weather and residual soil nutrients must be considered. On-farm data such as manure samples will likely be of greater value to annual planning processes than the predictions made by the new ASABE equations

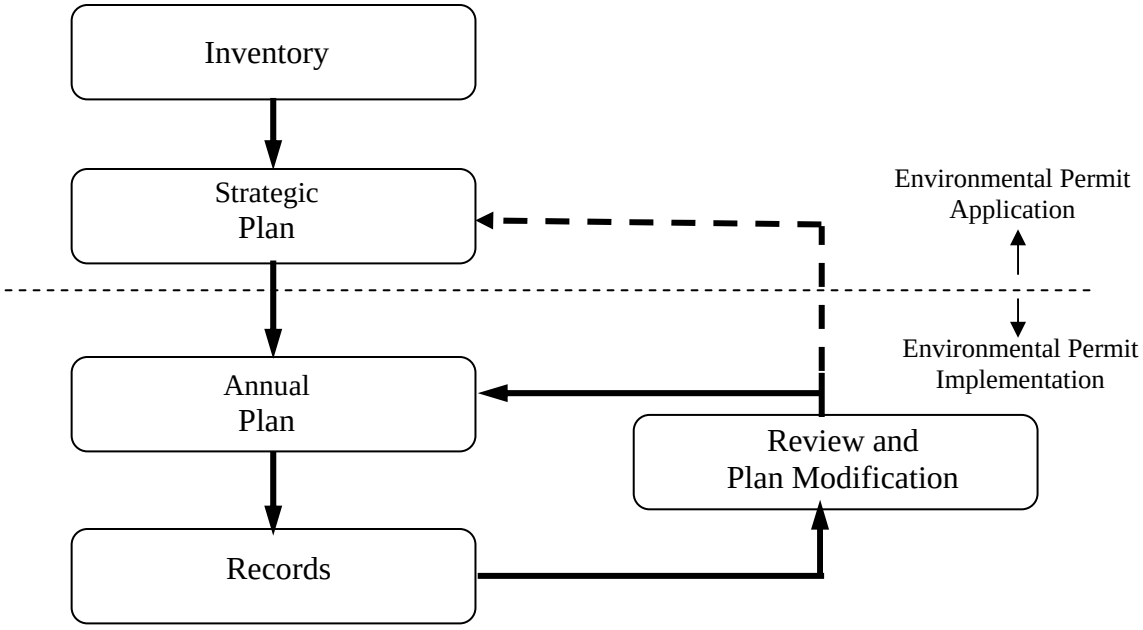

Figure 2. Common planning procedure used for nutrient management planning.

Improvements in nutrient excretion estimates offered by the new equations should improve the accuracy of farm-specific planning for:

- *Land requirements for managing N and P*. The equations provide a more accurate estimate of nutrient driven land requirements for manure application when on-farm data on manure production is not available. Nitrogen volatilization and availability estimates remain a weak point for this planning process.
- *Cost of manure application*. The ASABE equations are being used to estimate manure nutrient value as well as time, equipment, and labor requirements for handling manure (Kissinger et al., 2005).
- *Ammonia emissions*. Ammonia emissions from animal facilities are of increasingly interest to the regulatory community. The equations should provide a mechanism for adjusting farm emission estimates based upon several farm-specific factors.

The equations also allow a prediction of dry matter excretion and possibly volatile solids excretion if feed digestibility values are known. This approach will allow farm specific estimates

of solids excretion that will benefit planning estimates of:

- *Anaerobic and aerobic lagoon sizing*,
- *Anaerobic digester sizing and gas production*,
- *Storage sizing* if solids estimates are combined with known moisture contents resulting from specific manure handling systems

Summary

The new ASABE standard for manure excretion provides an important tool for key strategic planning activities important to a comprehensive nutrient management plans. In addition, the new standard provides an important tool for integrating feed management decisions into CNMPs and deciding the environmental and economic benefits and costs of feed program options.

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