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Integrating Animal Feeding Strategies Into CNMP Processes: Role Of Updated ASAE Standard D384.2

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Abstract. *The abstract should be no more than 250 words long.*

Keywords. This paper introduces the new ASAE Standard D384.2, Manure Production and Characteristics. This new standard provides an equation-based approach that integrates dry matter and nutrient intake as well as animal performance into the final estimate of total solids, nitrogen, and phosphorus excretion for seven livestock and poultry species. The manure excretion estimates of the new standard are compared with the past ASAE standard as well as other commonly used reference values for three specie groups. Significant differences in excretion are common with the new standard compared to past standards. The paper also details examples of how common industry variations in animal performance and feed program substantially impacts excretion estimates, often further accentuating the differences in the predictions based upon the new ASAE estimates and other reference values. Finally, this paper will review options for integrating this standard into planning procedures for animal manure management systems.

Key Words: Nutrient management, manure, excretion standards, animal feeding

Introduction

This paper summarizes the new ASAE Standard D384.2, Manure Production and Characteristics. It reviews the general procedures used to integrate animal feeding program and performance into the estimates of excretion. This new standard provides an equation-based approach that integrates feed management and animal performance into the estimate of total solids, nitrogen (N), and phosphorus (P) excretion for seven livestock and poultry species. This paper will review the general procedures used for different species and summarize critical assumptions.

To illustrate the value of these equations for site specific planning, this paper will use the equations to estimate the impact of common dietary strategies and performance levels on an estimate of excretion. It will compare these results against other standard values as well as the "typical" values reported in the new standard.

Finally this paper will initiate a discussion on possible applications of these equations into nutrient planning processes such as estimates of land requirements for manure application, manure storage and treatment system sizing, and estimating costs of managing manure. Software based upon the excretion equations will be introduced. This software may provide a key building block for integration and use of feeding program and animal performance on a specific farm into the comprehensive nutrient management planning processes.

Objectives

1) Review the contents of the new ASAE Standard D384.2, Manure Production and Characteristics, and the process for developing that standard.
2) Estimate, using predictive equations, nutrient and solid excretion for a range of conditions representing common dietary intake and performance levels.
3) Compare those results with current standard values.
4) Initiate a review of options for utilizing the standard to integrate feed management into nutrient planning processes.

Literature Review

When nutrients are supplied to animals in excess of that needed for maintenance and production, the excesses are excreted. Although there are unavoidable nutrient excretions, altering the diet formulation to minimize nutrient excesses is the first step towards reducing nutrient excretion. Kerr (1995) concluded that N excretion, in swine, can be reduced by approximately 8.4% for each one-percentage unit reduction in dietary crude protein (CP = 6.25 x N content, %). Powers et al. (2005) demonstrated that dietary reductions in CP of four percentage units, on average over the grow-finish phases, were achievable without negatively affecting animal performance. Corresponding reduction in N excretion, post-storage, was 23%. Greater reductions are possible. In broiler chickens, Ferguson et al. (1998) showed that a 13.3% decrease in N intake corresponded to an 18.2% reduction in litter N content. Similarly, Tomlinson et al. (1996) reported an approximate 20% reduction in N excretion associated with a 3% reduction in dietary CP for lactating dairy cows. As animals are fed closer to true N requirements, further reductions in dietary CP may result in less pronounced reduction in N excretion and ammonia losses.

Similar to N excretions, P excretion can be impacted by reducing dietary P to meet animal needs while minimizing dietary excess. Fecal P excretion in lactating dairy cows has been shown to be reduced 23% following a 0.09 percentage unit reduction in dietary P, with no performance effects (Wu et al., 2000). A 0.26 percentage unit decrease in dietary P content resulted in a 36% reduction in fecal P excretion, the primary source of manure P (Morse et al., 1992). Perhaps the most notable accomplishments for modifying dietary P content to reduce P excretion have been made in mongastrics as a result of the commercial availability of phytase. The use of supplemental phytase in swine and poultry diets has allowed for formulation of diets that meet bioavailable P needs of the animal and reduces the amount of unavailable P offered by improving the overall availability of P in grains. The result has been an industry 'rule-of-thumb' reduction of 25% P excreted when phytase has been fed properly and combined with reduced margins of safety in P formulation (21.5% reduction reported by Harper et al., 1997).

Diet modification impacts on manure mass are less available in the literature. However, fecal volume is a function of the digestibility of the diet as undigested feed is excreted. Bierman et al. (1999) showed that manure mass removed from a beef feedlot almost tripled when cattle were fed less digestible diets (71.4% dry matter digestibility) containing corn co-products in lieu of corn when compared to a more digestible (83.5% dry matter digestibility) all corn diet. Similar increases in volatile solids in harvested manure were observed for feedlot cattle fed diets lower in digestibility (Montgomery et al., 2004). Bierman, et al. (1999) demonstrated significant differences in excreted and harvested manure N and organic matter when comparing typical feedlot diets based upon 7.5% roughage, all concentrates, and wet corn gluten feed. This article also demonstrates that as corn co-products become more available with increasing numbers of corn processing plants, nutrient management planners need to consider diet formulation affects on manure composition and mass.

ASAE (2004), SCS (1992), and MWPS (2000) have traditionally served as references for estimates of manure and manure component excretion. Estimates made by these references have typically varied only with animal body weight and length of time. However, these estimates have become increasingly questionable as animal genetics, performance and feed programs change.

A search for improved characterization of livestock waste based upon ration composition and related species or site-specific factors is not new. Barth (1985) proposed use of feed digestibility estimates as a means of estimating total, fixed, and volatile solids excretion. Numerous models have follow based upon three common approaches:

- Mass balance approaches (manure = feed intake – retention) have been recommended by various authors including Clanton et al. (1988), Powers and Van Horn (2001), and Van Horn (et al., 1991). NRC (1996 and 1998) provides equation-based estimates for nutrient retention by beef cattle and swine, respectively.
- Single or multiple variable regression analysis have been used to predict N in dairy cattle urine and feces (Tomlinson et al., 1996 and Pell, 1992), P excretion by dairy cattle (Morse et al., 1992) manure and N excretion by dairy cattle (Wilkerson et al., 1997), and manure, N and P excretion by dairy cattle (Weiss, 2004).
- Physiologically based models such as the NCPIG swine growth model (Bridges et al., 1995) are used to predict nutrient excretion and by Kebreab et al. (2002) for estimating N excretion in dairy cattle. Such models demonstrate opportunities for reductions in

nutrient excretion while recognizing potential compromises in animal performance, a feature not generally possible with other approaches.

Beede and Davidson (1999) conducted an extensive comparison and review of different models and their ability to accurately predict excretion when compared to independent data sets. Key conclusions relative to manure P excretion by dairy cattle include:

- A simple mass balance approach proposed by Van Horn et al. (1994) provided the most accurate estimate of P excretion.
- ASAE estimates and a regression-based model by Morse et al. (1992) significantly over estimated P excretion. Estimates in the 1996 ASAE standard produced greater inaccuracies than estimates in the 1980 standard.
- All models tested improved the prediction of P excretion over a wider range of condition as compared to the ASAE standards.

Overview of ASAE Standard

Standard Revision Process

At the 2001 International Meeting of ASAE, the Agricultural Waste Management technical committee (Structures and Environment 412) approved a review of ASAE Standard D384.1 to be led by Wendy Powers and Rick Koelsch. A review committee of more than 30 animal scientists and agricultural engineers was recruited and organized into seven work groups targeting the five species (beef, dairy, horse, poultry, and swine) plus the issues of "typical" average characteristics for excreted manure and as-removed manure. These work groups completed an initial product shared first at the 2003 ASAE meeting. A peer review committee of about 25 animal scientists and agricultural engineers was recruited to review and vote on the proposed standard. An informal peer review (fall 2003) and two formal peer reviews and votes (winter 2004 and fall 2004) were conducted prior to the approval of the final proposed standard. Formal approval of the standard was completed by ASAE in spring 2005.

Contents of Standard

The standard consists of seven sections. Section 1 includes a new "typical" characteristics tabular summary for individual species and groupings of animals (see table 1). The values reported in this table are from two sources:

1. Values based upon species-specific equations for which "typical" dietary and performance related characteristics of that animal group were estimated. Some species teams were able to estimate industry averages based upon 1990's to 2000's surveys of those characteristics. Other work groups lacking field survey data made their best professional judgment as to typical characteristics at the time the standard was assembled. For this reason, the team chose to identify the table's values as "typical" and not "average" characteristics. All values originating from the species-specific equations are in bold text.
2. For those values identified by the committee as critical but not originating from the species specific equations, a review of existing standards data and literature values was completed by a work group charged with finalizing the section 1 Table (Fulhage, 2003).

Sections 2 through 7 define the equations for estimating excretion characteristics of beef cattle, dairy cattle, horses, poultry (separate sections for meat birds and layers), and swine. At a minimum, the species groups reported a dry matter, N and P excretion characteristic. Some species groups defined equations for estimating additional characteristics.

Section 8 of the new standard summarizes As-Removed manure characteristics. The work group reviewed a wide range of data sets for inclusion in this section (Fulhage, 2003). Reporting of the as-removed characteristics proved to be the most controversial component during the peer review process.

<u>Two Approaches for Estimating Excretion</u>

The species-specific work groups developing the equation based estimates worked independently in identifying appropriate predictive equations. As a result, the work groups used two distinctly different approaches for their proposed equations.

The beef, swine, and poultry work groups used an animal mass balance approach where excretion is estimated as a difference between intake and retention in body mass or animal products (eggs or milk). Nutrient intake is calculated as a product of feed intake (mass) and nutrient concentration in the feed. Beef and swine equations used retention estimates for N published by NRC (1996) and NRC (1998), respectively (Erickson et al., 2003; Carter et al., 2003). For P retention, literature value s were used. Dry matter retention was based upon estimates of feed dry matter digestibility, a value that is originally estimated based upon measured feed intake and feces solids values. Because dry matter digestibility does not account for solids in the urine, total solids excreted included an adjustment to the dry matter digestibility calculation for solids in the urine. The poultry work group reviewed the peer-

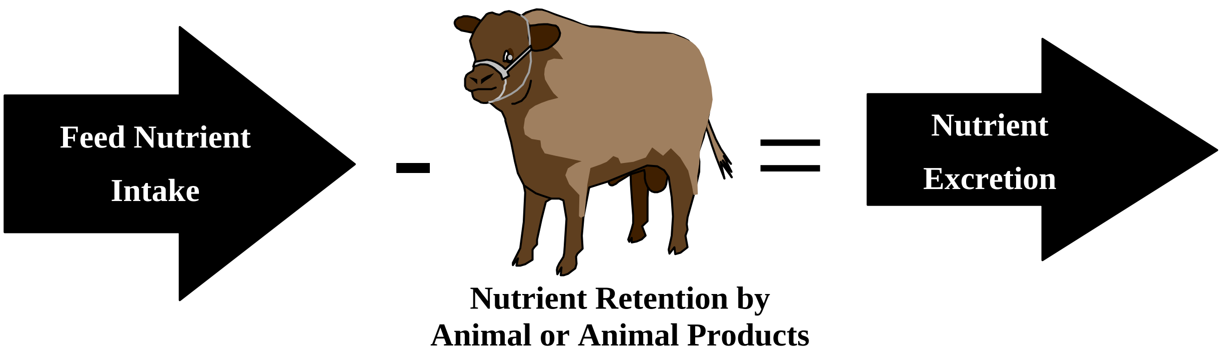


Figure 1. Mass balance approach was used for estimating excretion characteristics for beef cattle, swine, and poultry.

reviewed literature to establish retention factors for broilers, turkeys and ducks (Applegate et al., 2003a) and a mass balance model for layers (Applegate et al., 2003b).

The dairy and horse work groups used existing data sets to perform multi-variable regression analysis (Nennich et al., 2003; Lawrence et al., 2003). The dairy work group proposed equations for lactating cows, dry cows and heifers. Regression equations were developed for total manure, total solids, urine volume as well as excretion of N, P, and potassium. The horse work group chose to publish separate equations for exercised and sedentary horses for excretion of N, P, potassium, calcium, magnesium, and dry matter.

Table 1. Sample of tabular summary of “typical” manure characteristics for meat producing animals (Part A) and all other animals (Part B)

Part A. Characteristics are typically reported in unit mass (or volume) per finished animal.

Animal Type and Production Grouping	Total solids	Volatile solids	COD	BOD	Nitrogen	P	K	Ca	Total Manure		Moisture	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
	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

Part B. Characteristics are typically reported in unit mass (or volume) per animal per day.

Animal Type and Production Grouping	Total solids	Volatile solids	COD	BOD	Nitrogen	P	K	Ca	Mg	Total Manure		Moisture
	kg/ day-animal (d-a)									kg/ (d-a)	liter/ d-a.	% w.b.
Beef - Cow (confinement)	**6.6**	**5.9**	6.2	1.4	**0.19**	**0.044**	0.14	**0.089**		-	-	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		87
	lb/ day-animal (d-a)									lb/ d-a.	ft^3/ d-a.	% w.b.
Beef - Cow (confinement)	**15**	**13**	14	3.0	**0.42**	**0.097**	0.30	**0.20**		-	-	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

Bold values are based on species-specific equations.

VS, COD, and BOD were calculated from TS using relationships from past ASAE and SCS (1992) standards

Non-bold K and moisture content values are based upon past ASAE standard, SCS (1992), and other relevant literature.

Total manure is based upon equation estimate of total solids divided by 1 minus moisture content.

Comparison of Equation Results

Tables 2, 3, and 4 illustrate excretion estimates for beef, swine, and dairy calculated from the new equations and provide a basis for two comparisons:

- “Typical” excretion values are compared against average values published by USDA Natural Resources Conservation Service (NRCS), Mid West Plan Service (MWPS), and past ASAE standards.
- “Typical” excretion values are compared with a likely range of excretions for common feeding strategies and performance levels.

Although differences exist in these various estimating procedures, the most dramatic differences are associated with P and total solids excretion. In addition, the differences tend to become larger for emerging technologies that tend to reduce excretion and for feeding of by-products of corn processing which is becoming increasingly popular in the beef and dairy industries. These growing range of excretion levels for individual situations suggest an increasing importance for site-specific estimates of excretion based upon feeding program and performance. Assuming that animals perform the same, these equations are needed to adjust to dietary changes in the industry and more accurately estimate excretion levels. Otherwise, using current data will produce increasingly inaccurate nutrient management plans.

<u>Beef</u>

Comparison of excretion characteristics estimated by the new ASAE standard with the past ASAE standard and other accepted values show discrepancies (rows A – D, Table 2). As a general rule, previous estimates of N are in reasonable agreement with both the “typical” beef N excretion estimate.

All current or past estimating procedures over-estimate P excretion when compared to the new ASAE standard. Current or past estimates appear to be in line with P excretion only when significant levels of corn processing by-products are included in a feedlot ration (feed P level of 0.5%). In many situations, past estimates suggest that P excretion is exceeding average P intake by feedlot cattle as measured by Galyean and Gleghorn (1991).

MWPS and NRCS estimates for solids excretion are in reasonable agreement with the new ASAE standard but do not recognize the potential range in solids excretion for individual farms. The past ASAE standard generally over-estimates total solids excretion. Past estimates fail to account for the higher total solids excretion resulting from less digestible diets common with diets containing higher forage or higher corn processing by-product levels.

Considerable variation exists between individual cattle feedlots relative to performance and feed program strategy. These variation may produce excretion levels not represented by the “typical” values (Table 2, Row A) in the new standard. Excretion variation is illustrated in Table 2 (Rows E – L) for commonly observed variations within the industry for feed nutrient concentration, dry matter digestibility and feed efficiency. Although a typical or average animal would excrete 3.2 kg of P per finished animal, based upon conditions observed for individual farms, P excretion would be expected to vary from 2.1 to 6.4 kg per finished animal. Variation in diets fed to cattle due to possible use of forages, corn, or corn processing by-products can produce significant differences in diet digestibility. Such variation would suggest that total solids excretion ranging from 270 to 520 Kg per finished animal is also possible. Variations also occur in total N excretion. Recognition of farm specific factors that contribute to such variations should be reflected in planning estimates of land requirements for manure application, manure application equipment requirements, cost for manure application, and ammonia emissions estimates.

Table 2. Comparison of beef cattle excretion (kg/finished animal) based upon New ASAE standard for typical industry feed nutrient concentrations and feed efficiencies. Table also illustrates estimated excretion for other current and past excretion estimating standards.

Source	Dry Matter Intake (kg)	% Crude Protein	% P	Dry Matter Digest-ibility (%)	Feed Efficiency (feed/ gain) and Days to Finish	Excretion (kg/finished animal)		
						N	P	TS
Typical or Average Excretion								
A. New ASAE	8.92	13.3	0.31	80	6.3 / 153	25	3.2	350
B. Old ASAE	--	--	--	--	--	23	6.2	580
C. MWPS	--	--	--	--	--	34	5.7	390
D. NRCS	--	--	--	--	--	20	6.4	400
Changes in feed characteristics while all other assumptions remain constant								
E. New ASAE	8.92	12.5	0.25	80	6.3 / 153	23	2.4	350
F. New ASAE	8.92	18.7	0.50	80	6.3 / 153	37	5.8	350
G. New ASAE	8.92	--	--	85	6.3 / 153	--	--	290
H. New ASAE	8.92	--	--	70	6.3 / 153	--	--	490
Changes in feed efficiency while all other assumptions remain constant[1]								
I. New ASAE	8.92	13.3	0.31	80	5.69 / 138	23	2.9	330
J. New ASAE	8.92	13.3	0.31	80	6.95 / 168	27	3.6	380
Changes in feed efficiency and feed characteristics								
K. New ASAE	8.92	12.5	0.25	80	5.69 / 138	21	2.1	320
L. New ASAE	8.92	18.7	0.50	80	6.95 / 168	41	6.5	390

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.

<u>Swine</u>

Comparisons of different standard values for grow-finish swine are summarized in Table 3. Nitrogen excretion estimates for the new standard have changed little from the past ASAE standard but are significantly different from other commonly accepted valued (Table 3, Rows A – D). Phosphorus excretion is substantially below that of other standards and accepted values.

These differences will become greater for those swine operations using low P diets resulting from technologies such as phytase are adopted. Total solids excretion is generally lower than previously accepted values.

Table 3 also illustrates the importance of a standard that responds to emerging feeding strategies and improvements in animal performance Table 3, Rows E – J). Diets based on use of crystalline amino acids and phytase or low-phytate corn have the potential for lower 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 (Row E). Low P diets would reduce P excretions levels by 33 to 40% from new typical values (Row E). Higher digestibility diets such as diets based upon degermed and dehulled corn from a dry milling process will produce less manure

Table 3. Comparison of grow-finish swine excretion (kg/finished animal) based upon New ASAE standard for typical industry feed nutrient concentrations and feed efficiencies. Table also illustrates estimated excretion for other current and past excretion estimating standards.

Source	Dry Matter Intake (kg)	% Crude Protein	% P	Dry Matter Digest-ibility (%)	Feed Efficiency (feed/ gain) and Days to Finish	Excretion (kg/finished animal)		
						N	P	TS
Typical or Average Excretion								
A. New ASAE	2.38	15.6	0.43	82	2.86 / 120	4.7	0.76	62
B. Old ASAE	--	--	--	--	--	4.4	1.51	92
C. MWPS	--	--	--	--	--	9.6	2.62	120
D. NRCS	--	--	--	--	--	3.5	1.34	53
Low CP and P diets while all other assumptions remain constant								
E. New ASAE	2.38	11.5	0.33	82	2.86 / 120	2.9	0.47	62
Changes in feed efficiency while all other assumptions remain constant								
F. New ASAE	2.38	15.6	0.43	82	2.57 / 108	4.0	0.64	56
G. New ASAE	2.38	15.6	0.43	82	3.14 / 132	5.5	0.89	68
Changes in feed dry matter digestibility while all other assumptions remain constant								
H. New ASAE	2.38	--	--	80 (high fiber diet)	2.86 / 120	--	--	68
I. New ASAE	2.38	--	--	84 (low fiber diet)	2.86 / 120	--	--	56
J. New ASAE	2.38	--	--	95 (dry milled corn[1])	2.86 / 120 [1]	--	--	24

1. Degermed, dehulled corn from corn dry milling processes. Increasing digestibility should reduce number of days to finish further reducing total solids excretion estimated on a finished animal basis.

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

solids. The equation based approach estimates 60% lower solids (Row J) than the "typical" value in the new standard comparing favorably with results from Moeser et al. (2002). Failure to recognize diet dry matter digestibility and nutrient concentrations will have significant impacts on the design of treatment systems (e.g. anaerobic lagoons and anaerobic digesters), ammonia emission estimates, land requirements, and possibly storage size.

Dairy Cattle

Generally the new ASAE standard predicts greater excretion of nutrients and solids as compared to the past ASAE standard and other existing accepted values for lactating cattle (Table 4, Row A - D). Greater milk production and greater nutrient concentrations will create an even larger disparity between predicted excretion by the new ASAE standard and other accepted values (Table 4, Rows E - G). Increases in milk production and dry matter and nutrient intake by dairy cattle are likely to cause greater separation in actual excretion from previously used excretion values. Again a standard that reflects changes in performance and dietary program is critical to accurately predicting excretion characteristics.

A comparison of the new ASAE standard was made with a mass balance procedure used by Van Horn (1991) was identified by Beede and Davidson (1999) as being a more accurate method of estimating P excretion. Both methods produce similar estimates of nutrient and solid excretion in some situations (Table 5, Rows A - B). However, changes in single inputs produce different responses for the two models. The mass balance approach predicted lower N

Table 4. Comparison of dairy cattle excretion (kg/animal/day) based upon New ASAE standard for typical industry dietary and performance variations. Table also illustrates estimated excretion for other current and past methods.

Source	Modification	Dry Matter Intake (kg)	% Crude Protein	% P	Milk Production (kg/day)	Excretion (kg/animal/day)		
						N	P	TS
Typical or Average Excretion								
A. New ASAE	Typical	21.2	17.5	0.45	40	0.47	0.078	8.4
B. Old ASAE	Average	--	--	--	--	0.28	0.59	7.5
C. MWPS	Average	--	--	--	--	0.37	0.083	6.4
D. NRCS	Average	--	--	--	--	0.28	0.044	6.2
High Feed CP and P levels								
E. New ASAE	Excess Dietary CP & P	21.2	19.5	0.60	40	0.64	0.092	8.4
Changes in feed efficiency while all other assumptions remain constant								
F. New ASAE	Low Milk Production	21.2	17.5	0.45	27	0.43	0.071	8.4
G. New ASAE	High Milk Production	21.2	17.5	0.45	48	0.48	0.079	8.4

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

excretion than the ASAE equations. Lower dietary concentration produced reduced excretion estimates for nutrients. However, the mass balance model estimated much larger excretion changes resulting from the dietary change than the new ASAE equations (Rows C and D). For changes in milk production when all other factors are held constant (Rows E and F), the two models reacted differently. The ASAE equation suggested a decline in nutrient excretion resulting from reduced milk production (similar to observation in Table 4) while the mass balance model suggested an increase in nutrient excretion.

Table 5. Comparison of dairy cattle excretion (kg/animal/day) based upon New ASAE standard and mass balance approach used by Van Horn et al. (1991) for common industry dietary and performance variations.

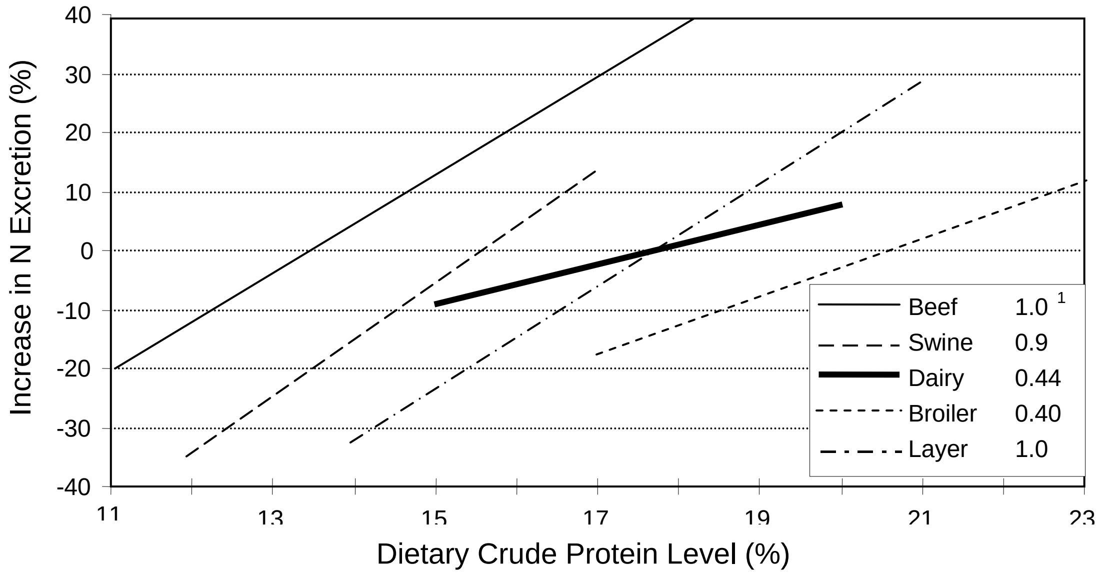
Source	Dry Matter Intake (Kg)	% Crude Protein	% P	Milk Production (kg/day)	Excretion (Kg/finished animal)		
					N	P	TS
High CP and P diet while all other assumptions remain constant							
A. New ASAE	21.0	16.4	0.60	31.8	0.43	0.087	8.4
B. Van Horn	21.0	16.4	0.60	31.8	0.39	0.094	8.0
Low CP and low P diet while all other assumptions remain constant							
C. New ASAE	21.0	14.8	0.40	31.8	0.41	0.069	8.4
D. Van Horn	21.0	14.8	0.40	31.8	0.33	0.052	8.0
Lower milk production with while all other assumptions remain constant							
E. New ASAE	21.0	16.4	0.60	22.7	0.41	0.082	8.4
F. Van Horn	21.0	16.4	0.60	22.7	0.44	0.103	8.0

<u>Equation Response to Feed Nutrient Intake Changes</u>

To further examine how the equations respond to changes in dietary intake of nutrients when all other factors are held constant, feed nutrient concentrations were varied over a range in which no anticipated impact on animal performance was anticipated. The resulting impact of nutrient intake changes on excretion changes are illustrated in Figures 2 and 3. All equations produced a linear response of excretion to changes in dietary intake. However, the slope of the equations for the broiler and dairy species is noticeably different from the slope of the beef, swine, and layers.

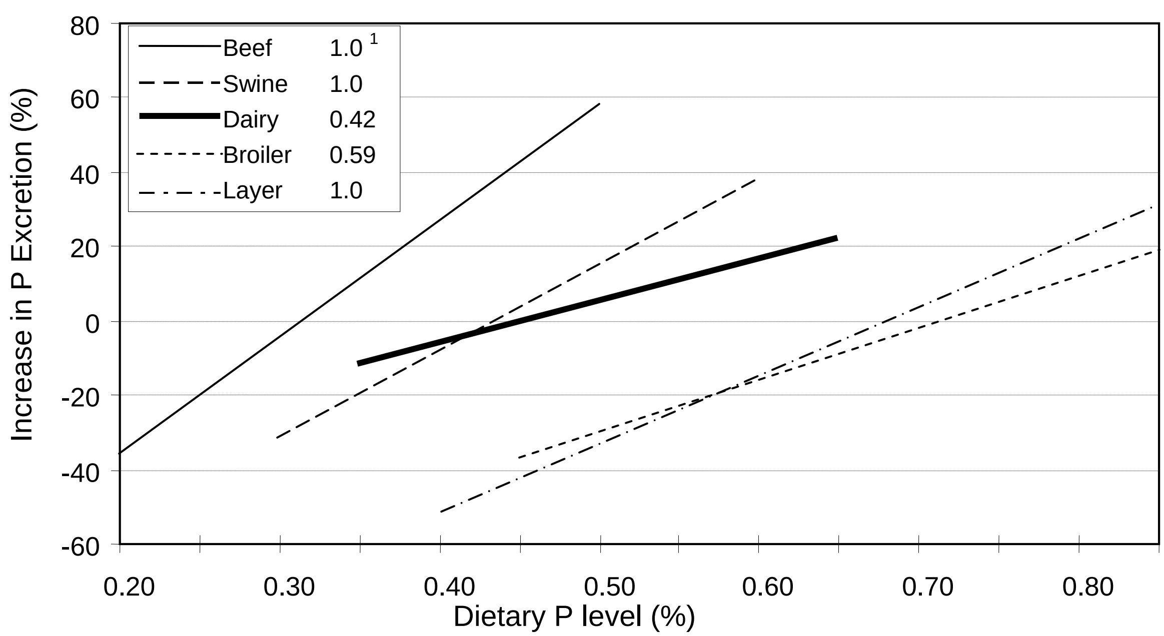
Figures 2 and 3 also list the unit change in excretion for a one-unit change in feed nutrient intake. Beef, swine, and layers all produce a one unit increase in N or P excretion for a one unit increase in N or P intake assuming that all other factors remain constant. Both dairy and broilers account for roughly half of the increased dietary intake of a nutrient in the excretion. It is generally assumed that a 1-unit increase in excretion per unit increase in dietary intake is an accurate assumption. The validity of that assumption and the need to modify equations to approach that one-to-one relationship will need to be reviewed in the future.

Figure 2. Change in nitrogen excretion resulting from changes in dietary crude protein level as predicted by excretion equations (ASAE, 2005).



[1] Ratio of units (e.g. kg) increased N excretion for every unit increase in N dietary intake.

Figure 3. Change in phosphorus excretion resulting from changes in dietary phosphorus level as predicted by excretion equations (ASAE, 2005).

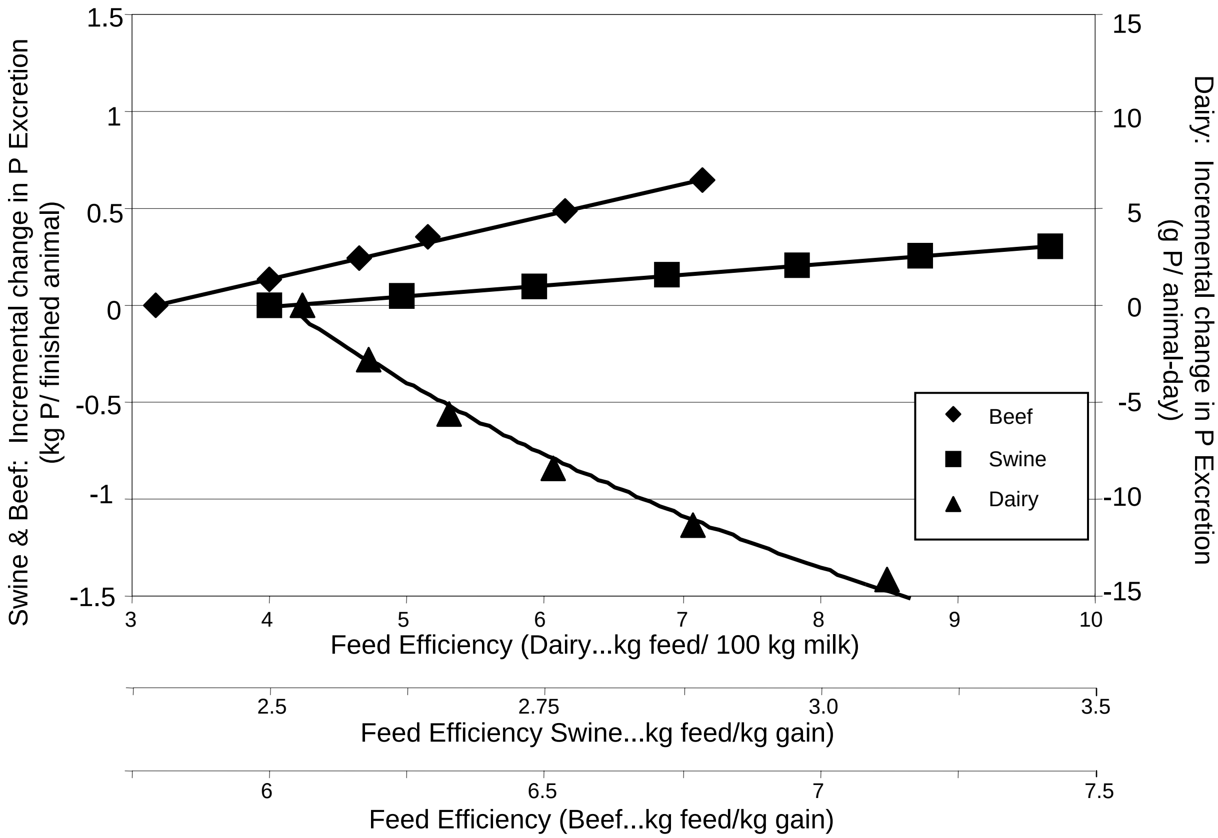


[1] Ratio of units (e.g. kg) increased P excretion for every unit increase in P dietary intake.

Equation Response to Performance Changes

Changes in animal performance should also impact excretion. Declining efficiency in feed utilization for growth or milk production should result in increased nutrient excretion if nutrient intake remains constant. Less nutrient would be deposited in animal products (body weight gain or milk) leaving more to be excreted by the animal. Figure 4 illustrates in beef cattle that a decline in feed use efficiency from 5.75 to 6.75 kg of feed per kg of gain would result in increased excretion of about 0.7 kg of P per finished animal. Similar increases in excretion are observed for reduced feed efficiency for swine. However, the equations used for dairy suggest an opposite trend. The swine and beef equations follow a predictable trend for changes in animal performance when all other factors are constant. However, the regression equations for dairy did not follow this predicted trend.

Figure 4. Change in excretion resulting from changes in feed efficiency when all other factors are held constant.



Applications of New ASAE Standard

From the previous section, the range in anticipated excretion levels for typical variations in diet and animal performance supports the value of an equation-based estimate of excretion based upon farm-specific feed program and performance considerations. Most planning processes follow a step-wise procedure similar to that illustrated in Figure 5. At this time, the equation-based estimates of solids and nutrients will have their greatest utility in the strategic or long-term planning estimates that are commonly made by livestock and poultry farms. These strategic or long-term planning procedures are typically the planning estimates made when:

1) A new or expanded facility is proposed;
2) An animal facility is developing a Nutrient Management Plan (NMP) for a regulatory permit such as a National Pollution Discharge Elimination System permit;
3) When an animal facility is developing a proposal for cost share funding under U.S. Department of Agriculture environmental incentive programs such as Environmental Quality Incentives Program.

Figure 5 illustrates a second critical planning phase, the Annual Plan. For some activities such as cropping system nutrient planning, annual decisions for manure application rates, timing, and placement must recognize constantly changing conditions such as weather dependent variables and residual soil nutrients. On-farm data such as manure samples will likely be of greater value to annual planning processes than the predictions made by the new ASAE equations. However, in some situations, the equations have the potential for estimating nutrient concentration in manure as an alternative to a manure sample. Currently, this is an unproven application of the equations. The most immediate application of the ASAE equations for nutrient and solids excretion is for strategic planning procedures such as developing site specific plans for total manure volume and mass of manure nutrients produced relative to farm specific dietary programs. Those estimates will impact necessary storage volume and land requirements.

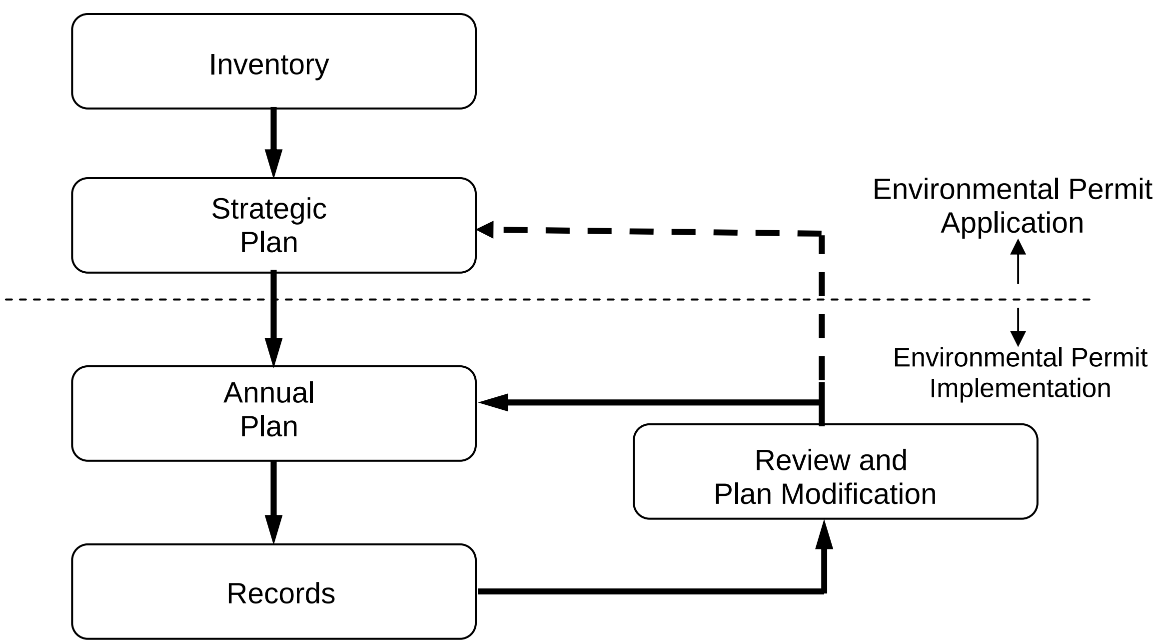


Figure 5. Common planning procedure used for nutrient management planning.

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

- *Land requirements for managing N and P*. The equations will provide a better starting point for the calculations used to estimate land requirements for manure application. Nitrogen volatilization and availability estimates will remain a weak point for this planning process, but a more accurate initial estimate of excretion should reduce some of the inaccuracies of past planning procedures.
- *Cost of manure application*. The value as a fertilizer resource for crop production, and the time, equipment, and labor requirements for handling manure requires accurate estimates of manure nutrients and volumes. The ASAE equations have recently been used to estimate the benefits and cost of managing feedlot manure when increasing rates of distillers grains are fed to finishing cattle (Kissinger et al., 2005).
- *Ammonia emissions*. Ammonia emissions from animal facilities are increasingly being scrutinized by regulators and researchers for representative farms. Current ammonia measurement strategies for identifying representative farms do not attempt to measure variations resulting from differences in animal performance or dietary strategies. The equations should provide a mechanism for adjusting farm emissions based upon these farm-specific factors.

The equations also allow a prediction of dry matter excretion and possibly organic matter (or 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 gas production*,
- *Storage sizing* if solids estimates are combined with known moisture contents resulting from specific manure handling systems,
- *Handling and land application equipment needs* based upon volumes or mass of manure produced. Again knowledge of moisture contents would need to supplement the improved estimates of solids excretion.

Using the proposed ASAE equations will 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 requirements for site-specific dietary and animal performance information. One tool nearing completion is a spreadsheet product illustrated in Figure 6. It provides a base set of worksheets for estimating and reporting excretion based upon the ASAE equations for all targeted species. This base tool could serve as a building block for each of the planning procedures identified previously. The authors are aware of this tool currently serving as a building block for planning tools to estimate 1) the land requirements for manure application and 2) economic cost and benefits for alternative application rates. Planners interested in using this spreadsheet as a building block for other planning tools should contact the lead author.

Figure 6. Sample input to spreadsheet that utilizes ASAE equations for estimating nutrient and solid excretion.

Manure Nutrient and Solids Excretion by Beef Feeder Cattle - Data Inputs

View Data Inputs | View N Comparison | View Calculations | Print Data Inputs | Print All
View Results | View P Comparison | Clear Data Inputs | Printout Setup | View Page Layout

Farm Name:

Producer's Name:

Step 1: Describe Farm or Conditions to be Evaluated:

Step 2: Enter animal performance characteristics

	Your Value	Default	Units
Feeder Cattle Group 1:		English	
Live Weight of Cattle....			
Entering Feedlot (lbs.):	750	660	lb
Exiting Feedlot (lbs.):	1,230	1210	lb
Targeted Grade for Marketed Beef:	Choice	Choice	
Number of Cattle (Single Turn):	5,000	1	beef feeder
Number of Cattle Finished per Year:	5,000	1	beef feeder
Average Days on Feed	145	150	days
Average Daily Gain	3.3		lb gain/day

Step 3. Enter ration information for each distinct feed program.

Feed Characteristics: Dry Basis

Ration ID	Days on Feed	Feed Intake (lb dry wt. /head /day)	No Input	Dry Matter Digestibility (% DB)	Organic Matter Digestibility[2] (% DB)	Ash[2] (% Dry Basis)	Dietary Crude Protein (% Dry Basis)	Dietary Phosphorus (% Dry Basis)
Receiving Diet								
Finishing Diet(s)								
Finisher	145	22.50		82.0%	80.0%	4.0%	13.0%	0.29%

Step 4. Enter Manure Management System Information

Step 5. Click on "View Results"

Facility Housing Animals? Home Feedlot

Total Solids (%)[1]: 70.0%

Liquid or Solid?

Two examples of sample output from spreadsheet summarizing results for two groups of fed cattle and illustrating impact of alternative diets on P excretion.

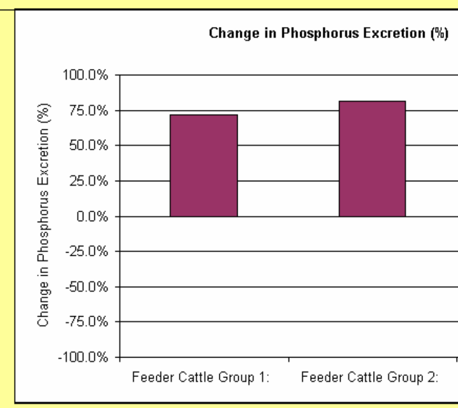
der Cattle - Results of Calculations

Producer's Name:

English Measurements

	Nitrogen	Phosphorus	Total Solids	Volatile Solids	Manure Mass[1]	Manure Volume[1,2] (ft³/yr)
	(lb/year)					
Feeder Cattle Group 1	294,758	36,449	3,810,470	3,864,105	5,443,528	-
Feeder Cattle Group 2	504,322	39,626	6,831,082	5,806,419	9,758,688	-
Feeder Cattle Group 3	-	-	-	-	-	-
TOTALS	799,081	76,076	10,641,551	9,670,524	15,202,216	-

	Current Diet: Dietary Phosphorus (% DB)	Current Diet: Phosphorus Excretion (lb P/year)	Modified Diet: Dietary Phosphorus (% DB)	Modified Diet: Phosphorus Intake (lb P/year)	Modified Diet: Phosphorus Excretion (lb P/year)	Increase (Decrease) In Excretion
Feeder Cattle Group 1: Receiving Diet			0.35%			
Finishing Diet(s)	0.29%	36,449	0.45%	73,406	62,549	72%
			0.35%			
			0.35%			
			0.35%			
			0.35%			
			0.35%			
			0.35%			
Feeder Cattle Group 2: Receiving Diet			0.35%			
Finishing Diet(s)	0.29%	39,626	0.46%	87,228	71,863	81%
			0.35%			
			0.35%			
			0.35%			
			0.35%			
			0.35%			
			0.35%			



Conclusions

A new ASAE standard has been released for estimating nutrient excretion based upon animal performance and feeding program. This biologically based approach should improve the accuracy of estimating nutrient and solids excretion and allow farm specific planning adjustments. Based upon current variation in animal performance and dietary strategies, significant variation in excretion of nutrients is likely to occur between farms. This variation is likely to increase as emerging feeding strategies are implemented for reducing excretion and additional by-products of food and ethanol processing are utilized for animal feed.

An evaluation of the performance of these equation based estimates reveals some challenges in applying regression based procedures for making situation-specific excretion estimates where only one factor is likely to change. ASAE should continue its interaction with the animal science community to encourage additional review and evaluation of these biologically based equations to further validate or improve their accuracy.

In the interim, the new ASAE standard provides a critical tool for integrating feed program and animal performance into a wide range of nutrient planning processes. Because of the equation's ability to respond to feed and performance factors that commonly vary between farms, this standard provides a fundamental building block for improving the accuracy of farm-specific nutrient management plans.

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