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Approved VCS Methodology Revision VMR0003

Version 1.0, 18 January 2013

Sectoral Scope 13

Revisions to AMS-III.Y to Include Use of Organic Bedding Material

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Table of Contents

1 SOURCES

This methodology revision applies to CDM small-scale methodology AMS-III.Y, *Methane avoidance through separation of solids from wastewater or manure treatment systems*. Project proponents must apply this methodology revision in conjunction with the latest version of AMS-III.Y.

2 SUMMARY DESCRIPTION OF THE METHODOLOGY REVISION

AMS-III.Y, *Methane avoidance through separation of solids from wastewater or manure treatment systems*, a small-scale UNFCCC Clean Development Mechanism (CDM) methodology, incorporates an applicability condition that makes manure treatment projects ineligible if the livestock farm uses organic bedding material in its barns, or intentionally adds organic material to the manure stream. Given the prevalence of the use of sawdust for bedding[1] and recent price increases and supply uncertainty associated with this material[2], many farmers are seeking alternative materials for bedding livestock stalls. One material of growing interest[3] is the use of separated manure solids for bedding. However, while separation of solids from manure prior to its transfer to anaerobic manure treatment systems results in GHG emission reductions, the use of solids in the barns for bedding renders those farms ineligible under AMS-III.Y, which in other respects is the most directly applicable methodology for this type of project activity. This methodology revision presents technically sound and relatively minor adjustments to AMS-III.Y that will broaden its applicability and make possible a greater number of project activities without compromising the accuracy or conservatism of the underlying methodology.

The principal methodology revision is to remove the applicability condition that prohibits the use of organic bedding material in the project barns and modify the means for measuring and quantifying baseline emissions such that this change does not impact the technical soundness of the underlying methodology. The methodology also includes minor revisions for improving the accuracy of emission calculations for U.S. projects.

3 DEFINITIONS

The definitions provided in the CDM methodology AMS-III.Y apply for this revision.

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[1] For information about bedding options and the prevalence of sawdust, see: http://extension.umass.edu/cdle/fact-sheets/bedding-options-dairy-cows

[2] The effect of recent economic conditions on the availability of sawdust for bedding is described in a Wall Street Journal article, *Sawdust Shock: A Shortage Looms as Economy Slows, March 3, 2008*

[3] For information on the increasing use of separated manure solids for bedding, see: http://www.progressivedairy.com/index.php?option=com_content&view=article&id=5367:use-of-dried-manure-solids-as-bedding-for-dairy-cows&catid=51:cow-comfort&Itemid=77

4 APPLICABILITY CONDITIONS

Projects must comply with all applicability conditions set out in CDM methodology AMS-III.Y, except the condition that no organic bedding material is used in the animal barns or intentionally added to the manure stream (specified as condition 6(b) in AMS-III.Y version 3.0, issued 2 March 2012, the version of the methodology current on the issuance date of this methodology revision).

5 PROJECT BOUNDARY

The project boundary must be determined following the procedure provided in CDM methodology AMS-III.Y.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

The baseline scenario must be determined following the procedure provided in CDM methodology AMS-III.Y.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

Additionality must be demonstrated following the procedure provided in CDM methodology AMS-III.Y.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

Baseline emissions must be determined following the procedure provided in CDM methodology AMS-III.Y, modified as set out in this section. These revisions describe a key methodological change, which is the means of quantifying and measuring the mass of separated solids (M_{ss}) produced by the separation system.

In lieu of the requirement for direct weighing of solids, this revision requires that M_{ss} be determined by an accounting of the amount of livestock manure processed through the separation system and the monitored efficiency of that system in removing solids from the manure stream. This change is required to ensure that the broadening of the applicability conditions to allow the use of organic bedding material in the barns does not result in the potential over-statement of M_{ss} from weighing separated solids (which may include some organic bedding). This revision requires that the amount of manure processed by the separator be based on an accounting of the number of animals by type confined in the barns, the excretion rates of such animal types, and the fraction of manure by animal type that is collected for processing. In recognition of the CDM Executive Board guidance on the preferred use of country- and/or project-specific data where available,[4] this revision allows for the calculation of excretion rates based on

[4] CDM Executive Board 25th Meeting Report dated July 2006, page 11. Paragraph 59. Meeting Report is available at: http://cdm.unfccc.int/EB/025/eb25rep.pdf

animal rations (when site-specific data are available) for U.S. projects, in lieu of the use of default data. Projects outside of the U.S. must seek project- and/or country-specific data from data sources that are appropriate for the country location of the project for calculation of manure solids quantities. In the absence of such data, project proponents must use relevant default values for VS excretion by animal type from IPCC 2006 Guidelines (see equation for baseline emissions (BEy) below). Finally, this methodology revision modifies the calculation method for determining baseline emissions (in cases where manure solids bedding is used in the barns) to account for the possible bypass of solids through the separation system after some previously separated solids are recycled from the barns. These changes are described in more detail below.

Two adjustments relative to the mass of separated solids (M_{ss}) used in equation (1) in AMS-III.Y are as follows:

1) Change how M_{ss} is quantified; and

2) Adjust M_{ss} to account for the possibility of recycled solids bypassing the separation system.

Quantification of M_{ss}

The method of calculating M_{ss} is as follows:

$$M_{ss,y} = \sum_{LT} N_{LT,y} \times TS_{LT,y} \times P_{LT,y} \times EFF_{ss,p} \quad [1]$$

Where:

$TS_{LT,y}$ = Annual amount of total solids excreted by one animal of livestock type LT managed by the management system in year *y* (kg);

P_{LT} = Average percent of manure from animal type LT that is delivered to the separation process (%) in year y; and

$EFF_{ss,p}$ = Separation efficiency of the project solids/liquid separation system in removing solids from the influent manure stream (kg separated solids/kg influent solids) (dry matter basis).

$N_{LT,y}$ = Number of animals of livestock type LT in year y (number).

For U.S. project activities where herd-specific ration data are available, such data must be used to calculate $TS_{LT,y}$, as follows[5]:

For lactating cows:

$$TS_{LT,y} = [(DMI_{milk} \times 0.35) + 1.017] \times 365; \quad [2]$$

[5] These data are derived from the American Society of Agricultural Engineers (ASAE), Manure Production and Characteristics, D.384-2, 2005, pp 4 -8, regression equations for deriving dry matter excretion rates by animal type, http://evo31.ae.iastate.edu/ifafs/doc/pdf/ASAE_D384.2.pdf

For dry cows:

$TS_{LT,y}$ = [(DMI_{dry} x 0.178)+ 2.773] x 365; [3]

For heifer cows:

$TS_{LT,y}$ = [(DMI_{heifer} x 3.886) – (BW_{heifer} x 0.029) + 5.641] x 0.17 x 365; and [4]

For beef cows:

$TS_{LT,y}$ = [DMI_{beef} x (1 – DMD_{beef}/100) + 20.3 x (0.06 x BW_{AVG})] x 365 [5]

Where:

DMI_{LT} = Dry matter intake by animal type (lactating, dry, heifer or beef cows) (kg/day/animal);

BW_{heifer} = Average body weight for heifer cows (kg/animal)[6]

DMD_{beef}= Dry mater digestibility of total ration (% of DMI); and

BW_{AVG} = Average live body weight for feeding period for beef cows (kg)

For U.S. projects without specific herd ration data, $TS_{LT,y}$ will be set according to the latest available default values for total solids excretion rates as reported by the ASAE.

The separation efficiency of the project separation system ($EFF_{ss,p}$) is determined at the time of commissioning (and annually thereafter) by a combination of on-site measurements of flow rates and lab analysis for solids content of the influent manure and liquid effluent streams, and calculated as follows:

$$EFF_{ss,p} = \left(m_{Infl} \times \%TS_{Infl} - m_{LEffl} \times \%TS_{LEffl}\right)/\left(m_{Infl} \times \%TS_{Infl}\right) \quad [6]$$

Where:

$EFF_{ss,p}$ = Measured separation efficiency of the project separation system

m_{Infl} = Mass of manure influent (kg)

$\%TS_{Infl}$ = Percent total solids of influent (dry basis)

m_{LEffl} = Mass of liquid manure effluent (kg)

$\%TS_{LEffl}$ = Percent total solids of liquid effluent (dry basis)

[6] Where weight records are not available, use a default value of 440 kg for heifer cows for U.S. projects, as reported by ASAE.

In the case where solids separation exists in the baseline scenario and the project activity involves the addition of new more efficient or additional separation equipment, the calculation of $EFF_{ss,p}$ for project activities must be adjusted to account for the removal of a portion of the mass of separated solids by the baseline separation equipment. In this case, the solids separation efficiency is adjusted as follows:

$$EFF_{ss,} = (1\text{-}EFF_{ss,b}) \times EFF_{ss,p}, \quad [7]$$

Where:

EFF_{ss} = Adjusted separation efficiency of the project separation system; and

$EFF_{ss,b}$ = Measured separation efficiency of the baseline separation system.

This will require measurement of the portion of total solids being removed by the baseline separator using the above equation [6] for $EFF_{ss,,p}$ with the appropriate input values. The adjusted separation efficiency (EFF_{ss}) must then be substituted for $EFF_{ss.p}$ for calculation of $M_{ss,y}$ using equation [1] set out above.

Adjustment of Mss Quantification

To account for the possibility of a portion of recycled separated solids bypassing the separation system in cases where separated manure solids are used in the barns, equation (1) in AMS.III-Y is modified to include adjustment factors as follows (emphasis in red added):

$$BEy = \left(B_{o,w,y} \times M_{ss,y} \times (1 - (SS_{\text{bypass,y}} \times SS_{bedding,y})) \times VS_{ss,y} \times UF_b \times GWP_{CH4} \times D_{CH4}/1000\right) \times \sum_{Bl,i}\left(MS_{Bl,i} \times MCF_{b,i}\right); \text{ where,} \quad [8]$$

BE_y = Baseline emissions in year *y* (tCO_2e);

$B_{o,w,y}$ = Weighted methane-producing potential of the volatile solids separated by the project in year *y* (m^3 CH_4 per kg of VS);

$M_{ss,y}$ = Mass (dry matter basis) of total separated solids in year *y* (kg);

$SS_{bypass,y}$ = Fraction of separated solids in year y that bypass separation system as a result of recycling and particle-size reduction. The default values for $SS_{bypass,y}$ are 5% in cases where separated manure solids are used in the barn, and 0% otherwise;

$SS_{bedding,y}$ = Fraction of separated solids in year y that are used in the project barns for bedding, which is equal to ($V_{ss,bedding,y}$ x $D_{bedding,y}$)/$M_{ss,y,}$; where,

$V_{ss,bedding,y}$ = Volume of separated solids used as bedding in the barns; and

$D_{bedding,y}$ = Bulk density of separated solids[7];

$VS_{ss,y}$ = Volatile solids content of the separated solids in year *y* on a dry matter basis (kg/kg);

UF_b = Model correction factor to account for model uncertainties (0.94);

GWP_{CH4} = Global Warming Potential of methane (value of 21);

D_{CH4} = Conversion factor of m^3 CH_4 to kilograms (0.67 kg per m^3 at 20°C and 1 atm pressure);

i = Index for baseline anaerobic manure management system

$MS_{Bl,i}$ = Fraction of manure handled in the baseline anaerobic manure management system *i* (fraction, mass basis); and

$MCF_{b,i}$ = Methane conversion factor for the baseline anaerobic manure management system *i* as per 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 10.

In cases where organic bedding material other than separated solids is used in the barns, the equation for quantifying baseline emissions will not include the factors $SS_{bypass,y}$ or $SS_{bedding,y}$. However, the method for quantification of $M_{ss,y}$ will be as set out in this section in equation [1]. To ensure that the quantification of baseline emissions is conservative, no emissions associated with diverting organic bedding material other than manure solids (e.g. sawdust) from anaerobic manure management systems shall be included.

Projects developed outside of the U.S. relying on default values for volatile solids by livestock type ($VS_{LT,y}$) from IPCC Guidelines must substitute $VS_{LT,y}$ x $EFF_{ss,p}$ for the terms $M_{ss,y}$ x $VS_{ss,y}$ when calculating baseline emissions (BE_y) using equation [8]. Also, for *ex-ante* calculations of BE_y, projects relying on default values must substitute and $VS_{LT,y}$ / 0.80 for $M_{ss,y}$, in calculating $SS_{bedding,y}$, where the 0.80 factor is a conservative default value for the fraction of total manure solids that are volatile solids.[8] However, *ex-post* calculations of BE_y must rely on measured values of $VS_{ss,y}$ from project monitoring data.

[7] $D_{bedding,y}$ is determined by direct weighing of samples of known volume. A reference for developing ex-ante estimates of manure solids bulk density is *Physical and flow properties of solid and semi-solid manure as related to the design of handling and land application equipment,* Landry et al, Department of Agricultural and Bioresource Engineering, University of Saskatchewan, 2002, available at: http://www.engr.usask.ca/societies/csae/PapersAIC2002/CSAE02-214.pdf

[8] Numerous sources report the VS content of livestock manure, which typically ranges from 77% - 85% of total solids. An example reference from an international study, *Effluent and Manure Management Data Base for the Dairy Industry,* Chapter 1.1, Physical, biological and chemical components of effluent and manure, pg 2, reports a VS content for dairy manure of 80 – 86%, and is available at: http://www.dairyingfortomorrow.com/uploads/documents/file/effluent%20management%20database/chapters/physical%20biological%20and%20chemical%20components%20of%20effluent%20and%20manure.pdf

8.2 Project Emissions

Project emissions must be determined following the procedure provided in CDM methodology AMS-III.Y.

8.3 Summary of GHG Emission Reduction and/or Removals

The summary of GHG emission reductions and/or removals must be reported following the procedure provided in CDM methodology AMS-III.Y.

9 MONITORING

Project proponents must follow the monitoring procedures provided in CDM methodology AMS-III.Y, noting the revisions set out in Sections 9.1, 9.2 and 9.3 below.

9.1 Data and Parameters Available at Validation

The monitoring requirement in AMS-III.Y that no organic bedding material is used in the barns or intentionally added to the manure stream (specified under paragraph 33, sub-paragraph 33(a) in AMS-III.Y version 3.0, issued 2 March 2012, the version of the methodology current on the issuance date of this methodology revision) is removed.

In addition to the data and parameters relevant to AMS-III.Y, the following additional data and parameters must be available at validation for this revised methodology.

Data Unit / Parameter:	$SS_{bypass,y}$
Data unit:	Percent
Description:	Fraction of separated solids used as bedding that bypasses separation system due to particle size reductions and recycling.
Source of data:	Default value from revised methodology (5%).
Justification of choice of data or description of measurement methods and procedures applied:	Bypass estimate is conservative. See discussion under Section 10 below.
Any comment:	Applicable only in cases where separated solids are used in the barns.

9.2 Data and Parameters Monitored

In addition to other information required to meet the monitoring requirements of AMS-III.Y, the following data and parameters must be available at monitoring for this revised methodology.

Data Unit / Parameter:	$P_{LT,y}$
Data unit:	Percent

Description:	Average percent of manure from animal type LT that is delivered to the separation process in year y.
Source of data:	Configuration of manure management systems.
Description of measurement methods and procedures to be applied:	Average percent of total number of animals by type confined in facilities from which manure is being sent through the separator.
Frequency of monitoring/recording:	Daily records of animal numbers by type.
QA/QC procedures to be applied:	Review of project records of electricity use by separation system to verify hours of operation are consistent with validated value of $P_{LT,y}$.
Any comment:	n/a

Data Unit / Parameter:	$TS_{LT,y}$
Data unit:	kg/yr
Description:	Total dry solids excreted by animal type LT (lactating, dry, heifer, beef cows) in year y.
Source of data:	Records of animal rations or default values reported by ASAE.
Description of measurement methods and procedures to be applied:	See calculation procedure in section 8.1 of this methodology revision.
Frequency of monitoring/recording:	Annually or when animal rations are changed, if more frequent.
QA/QC procedures to be applied:	Comparison of daily animal ration sheets and annual animal inventories to records of total rations fed annually.
Any comment:	n/a

Data Unit **/** Parameter**:**	$BW_{heifer,y}$
Data unit:	kg
Description:	Average weight of heifer cows.
Source of data:	Farm records or default values reported by

	ASAE.
Description of measurement methods and procedures to be applied:	Farm estimate of weights of livestock groups, if applicable, or application of default values.
Frequency of monitoring/recording:	When animal rations are changed.
QA/QC procedures to be applied:	Comparison to cattle industry typical averages.
Calculation method:	n/a
Any comment:	n/a

Data Unit / Parameter:	BW_{avg}
Data unit:	kg
Description:	Average weight of beef cows during feeding period.
Source of data:	Farm records of animal weights.
Description of measurement methods and procedures to be applied:	Beef cows are weighed-in when delivered to farm and weight-out when shipped out of farm.
Frequency of monitoring/recording:	As beef cows arrive on farm and are shipped out.
QA/QC procedures to be applied:	Comparison to cattle industry typical averages.
Any comment:	n/a

Data Unit / Parameter:	$EFF_{ss,p}$
Data unit:	Percent (kg separated solids/kg influent manure solids).
Description:	Efficiency of project separation system in removing solids contained in influent manure stream in year *y*.
Source of data:	Testing by qualified personnel.
Description of measurement methods and procedures to be applied:	Measurement of flow rates of influent (m_{Infl}) and liquid effluent (m_{Leffl}). Accredited lab tests for total

	solids ($\%TS_{Infl}$) of influent, liquid effluent ($\%TS_{Leffl}$) and separated solids streams.[9]
Frequency of monitoring/recording:	At commissioning of each project activity and annually thereafter.
QA/QC procedures to be applied:	Use of accredited testing service with internal QA/QC procedures. Annual re-testing separation efficiency confirms on-going performance of separator. Review for reasonableness by comparison to industry averages.[10]
Any comment:	n/a

Data Unit / Parameter:	m_{Infl}
Data unit:	kg
Description:	Mass of manure influent.
Source of data:	Measured during field testing of separation efficiency.
Description of measurement methods and procedures to be applied:	Influent flow rate (kg/min) determined by observed rate of intake of known volume (e.g. from manure reception tank), multiplied by minutes of test duration and appropriate mass density values.
Frequency of monitoring/recording:	At commissioning of each project activity and annually thereafter.
QA/QC procedures to be applied:	Multiple observations and averaging of measurements.
Any comment:	n/a

Data Unit / Parameter:	$\%TS_{Infl}$

[9] Laboratories providing testing of manure samples must be accredited in accordance with ISO 17025:2005. Required on-site samples and measurements will be done in accordance with procedures set forth by the testing lab and will be designed to achieve an overall outcome with 90%/10% confidence/precision.

[10] An example reference for industry averages is *"Mechanical Liquid-Solid Separation of Livestock Manure, A Literature Review" (Ford and Fleming, 2002)*

Data unit:	Percent
Description:	Percent total solids of influent (dry basis).
Source of data:	Testing of influent manure samples by accredited testing service.
Description of measurement methods and procedures to be applied:	Sampling procedures per instructions from accredited testing service.
Frequency of monitoring/recording:	At commissioning of each project activity and annually thereafter.
QA/QC procedures to be applied:	Use of accredited testing service with internal QC/QA procedures.
Any comment:	n/a

Data Unit / Parameter:	m_{LEffl}
Data unit:	kg
Description:	Mass of liquid manure effluent (kg).
Source of data:	Measured during field testing of separation efficiency.
Description of measurement methods and procedures to be applied:	Effluent flow rate (kg/min) determined by observed rate of output of known volume (e.g. into bucket/vessel), multiplied by minutes of test duration and appropriate mass density.
Frequency of monitoring/recording:	At commissioning of each project activity and annually thereafter.
QA/QC procedures to be applied:	Multiple measurements and averaging of results.
Any comment:	n/a

Data Unit / Parameter:	$\%TS_{LEffl}$
Data unit:	Percent
Description:	Percent total solids of influent (dry basis).
Source of data:	Testing of effluent manure samples by accredited testing service.

Description of measurement methods and procedures to be applied:	Sampling procedures per instructions from accredited testing service.
Frequency of monitoring/recording:	At commissioning of each project activity and annually thereafter.
QA/QC procedures to be applied:	Use of accredited testing service with internal QC/QA procedures.
Any comment:	n/a

Data Unit / Parameter:	$DMI_{LT,y}$
Data unit:	kg/animal/day
Description:	Mass of dry matter intake by animal type (lactating, dry and beef cows) per day.
Source of data:	Farm's herd management software or records of animal rations.
Description of measurement methods and procedures to be applied:	Input by farm personnel into Farm's records system or ration analysis records.
Frequency of monitoring/recording:	Whenever animal rations are changed.
QA/QC procedures to be applied:	Reasonableness check against industry averages.[11]
Any comment:	n/a

Data Unit / Parameter:	$DMD_{beef,y}$
Data unit:	Percent of dry matter intake.
Description:	Dry matter digestibility of total ration fed to beef cows in year y.
Source of data:	Farm's herd management software or records of animal rations.
Description of measurement methods and procedures to be applied:	Input by farm personnel into Farm's records system or ration analysis records.

[11] An example reference for industry averages is *"Beef Cattle Nutrient Requirements" (University of Mississippi, 2009)*

Frequency of monitoring/recording:	Whenever animal rations are changed.
QA/QC procedures to be applied:	Reasonableness check against industry averages.[12]
Any comment:	n/a

Data Unit / Parameter:	$SS_{bedding,y}$
Data unit:	Percent
Description:	Fraction of separated solids ($M_{ss,y}$) that are used in the project barns as bedding material.
Source of data:	Farm records of volume of separated solids used for bedding and measured bulk density of separated solids.
Description of measurement methods and procedures to be applied:	Derived from $V_{ss,bedding,y}$, $D_{ss,bedding,y}$ and $M_{ss,y.}$
Frequency of monitoring/recording:	See monitoring frequency for input variables.
QA/QC procedures to be applied:	Reasonableness check against industry averages.[13]
Any comment:	Applicable only in cases where separated solids are used as bedding in the barns.

Data Unit / Parameter:	$V_{ss,bedding,y}$
Data unit:	cubic meters
Description:	Volume of separated solids used in the project barns in year y.
Source of data:	Farm records of bedding volume used.
Description of measurement methods and procedures to be applied:	Recording of number of loads of bedding conveyance vehicles with known payload volume that are moved to barns and/or commodity

[12] A representative resource for industry averages is *"Nutrient Requirements of Beef Cattle," (Oklahoma State University, Lalman, D.)*

[13] A relevant source of information on animal bedding requirements *is Chapter 4, Agricultural Waste Characteristics of the NRCS Agricultural Waste Field Handbook*

	storage.
Frequency of monitoring/recording:	Daily
QA/QC procedures to be applied:	Reasonableness check against industry averages.[14]
Any comment:	Applicable only for cases where separated solids are used as bedding in the barns.

Data Unit / Parameter:	$D_{ss,bedding,y}$
Data unit:	kg/cubic meter
Description:	Bulk density of separated solids.
Source of data:	Records of test data.
Description of measurement methods and procedures to be applied:	Weighing of known volume of separated solids.
Frequency of monitoring/recording:	Quarterly
QA/QC procedures to be applied:	Quarterly measurements with use of highest quarterly value for annual calculations.
Any comment:	Applicable only in cases where separated solids are used as bedding in the barns.

9.3 Description of the Monitoring Plan

The data and parameters required by this methodology revision set out in Section 9.2 must be monitored by the project proponent in addition to the data and parameters required by AMS-III.Y, and be made available during verification. Project proponents must establish a comprehensive monitoring plan for ensuring the collection, measurement, recording and QA/QC procedures for these data and parameters and this must be documented in the project description.

10 REFERENCES AND OTHER INFORMATION

The following discussion provides the rationale for the adjustment factor for the mass of separated solids ($SS_{bypass,y}$) to account for any fraction of the solids which may pass through the separation system due to recycling and particle-size reduction. The overall separation efficiency may vary from farm-to-farm due to differences in manure composition, but the $SS_{bypass,y}$ should

[14] A relevant source of information on animal bedding requirements is *Chapter 4, Agricultural Waste Characteristics of the NRCS Agricultural Waste Field Handbook*

not because it is a function of the composition of the solids already removed by the separator, as explained below.

In practice, separated volatile solids used in the project barns as bedding will either decompose aerobically over time or be inadvertently recycled through the separation system (e.g. bedding material kicked out of stalls into alley ways by livestock). Over time mechanical forces (e.g. from hooves, stall raking, recycling through the separator) will tend to breakdown the particle size of the previously separated solids so that a portion of the solids that are recycled through the separation process may eventually pass through the separator and go into the anaerobic manure management system.

To estimate the amount of manure solids bedding material that is kicked out of stalls and recycled through the separation system, consideration is given to sand-bedded dairy barns, which are subject to cows kicking sand out of stalls, yet not subject to loss of bedding due to decomposition. Estimates of the amount of sand kicked out of sand-bedded stalls per day fall in the 30 – 50 lb/day range.[15] Using 40 lb/day and a bulk density for moist sand of 130 lb/cf[16] gives an estimated volume of 0.3 cf/day of sand, or about 112 cf/yr (4.2 cy/yr).

In the case of manure-solids bedding, bedding kicked out of the stalls will be recycled through the separation system. Results of a Cornell study on manure solids bedding show that particle-size distribution shifts to smaller particles for used compared to unused bedding. Specifically, used bedding has 10-15% less large particles (>2 mm) than unused bedding.[17] Thus, as a result of a greater fraction of smaller particles, one would expect a reduction in the amount of fiber removed from used bedding by a screen-based separation systems (e.g., screw press, rotary screen, etc.) when bedding is recycled through the system and a portion of the smaller, broken-down particles pass through the screens. Allowing for the fact that some of the manure fiber may in fact be recycled through the separation system multiple times, the conservative assumption is made that effectively double the amount of broken-down larger particles, or 25% of the recycled bedding material, eventually passes through the separation system and is deposited in the anaerobic manure management system.

Equating the solids bedding volume kicked out of stalls by the cows to the sand bedding estimates, we would expect 25% * 4.2 cy/yr, or approximately 1 cy/yr per cow of separated solids bedding used in the barn ends up passing through the separator into the farm's manure storage facilities.

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[15] See http://www.omafra.gov.on.ca/english/livestock/dairy/facts/info_sandbed.htm (20 - 25 kg/day) or http://www.ansci.cornell.edu/pdfs/pdsandbed.pdf (250 lb/week)

[16] See http://www.asiinstr.com/technical/Material_Bulk_Density_Chart_S.htm

[17] Harrison, Ellen et al, Cornell Waste Management Institute, *Using Manure Solids as Bedding, Final Report, 2008, compare values from tables 4-6 and 4-7, pp 4-6 – 4-7* available at: http://cwmi.css.cornell.edu/bedding.htm

A typical solids content of used manure bedding is 45%.[18] The bulk density of manure solids at 45% solids content is ~370 lb/cy.[19] Thus the 1 cy/yr per cow of recycled bedding material that passes into the manure storage facilities equates to 45% X 370 = 166 lb (dry basis) of manure solids. Using a typical VS/TS ratio of 85%, this represents about 140 lb of volatile solids per year.

A typical lactating dairy cow excretes 6200 lb/yr (dry basis) of volatile solids[20] and about 50% of these solids are removed by a typical separator.[21] Thus of the total mass of separated solids, about 140/3200 = 4% is expected to ultimately bypass the separation system. To be conservative, it is assumed that 5% of the mass of separated solids bypasses the system. Thus the default adjustment factor (SS_{bypass}) to account for the mass of separated solids bypassing the separation system is set to 5% in cases where manure solids are used as bedding material in the barns.

[18] Harrison, Ellen et al, see table 4-7, pg 4-7

[19] Landry, Hubert, et al, Physical and Flow Properties of Solid and Semi-solid Manure as Related to the Design of Handling and Land Application Equipment, University of Saskatchewan, 2002, Table 3 , pp 10 – 11, available at www.engr.usask.ca/socieites/csae/PapersAIC2002/CSAE02-214.pdf

[20] American Society of Agricultural Engineers, Manure Production and Characteristics, D.384-2, 2005, pg 2, table 1-b.

[21] *Gooch, Curt A. et al*, Mechanical Solid-Liquid Manure Separation: Performance Evaluation on Four New York State Dairy Farms-A Preliminary Report*, 2005, table 9, pg 12, available at* http://www.manuremanagement.cornell.edu/Pages/General_Docs/Papers/SLS_performance_eval_Gooch_etal_2005.pdf