BRITISH COLUMBIA | Ministry of Agriculture

Summary of Manure Handling Systems in the Context of Hullcar

A part of the Hullcar Situation Review
Nutrient Management Practices - Technical Report

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EXECUTIVE SUMMARY

The consistency of dairy manure will vary and is dependent on the type of management and animal housing in place. Based on its consistency, manure is handled as a solid, semisolid, slurry or liquid. There are various factors that influence the type of manure handling system used on-farm such as herd management, housing, bedding type, and topography. These systems have evolved primarily based on animal comfort and increased labour efficiency. Both flush and scrape manure handling systems have their merits, but the design and success of the system ultimately depends on the producer.

Regardless of manure handling system (scrape, flush, etc.), the amount of nutrients in the total volume remains the same. There is no scientific basis to suggest that using a scrape system instead of a flush system for manure handing will reduce the risk of nitrate leaching from manure applications.

This review highlights the following:

- Flush systems increase the overall liquid manure volume compared to that of a scrape system.
- Switching from a flush system to a scrape system would not significantly affect the total amount of nutrients, including nitrogen, in the manure.
- Switching from a flush system to a scrape system would not affect the forms of nitrogen present in the manure, which has no appreciable nitrate content (nitrate forms through mineralization in the soil after application).
- Thus, the choice of a scrape system or a flush system has no significant effect on the nitrogen balance for a cropped area receiving manure.
- Application of liquid manure would only leach nitrate in the soil to a depth below the crop root zone if the manure has so much water that the soil's water holding capacity is exceeded, causing water to move below the root zone.
- Based on a case study review of the H.S. Jansen Dairy's 2017 manure application plan and soil types, it was unlikely there was enough water in any manure application to exceed the soil's water holding capacity, despite the water added by the flush system during manure handling.

B.C. AGRI’s Jurisdictional scan of regulations and BMPs related to nutrient management found no available evidence from other jurisdictions that scrape systems are a recommended management tool to improve nutrient management over flush systems. Additionally, no jurisdictions have been identified to restrict or ban in-barn manure handling systems, such as flush systems, to address agricultural nitrate leaching risks.

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1. CHARACTERISTICS OF FRESH DAIRY MANURE

Fresh manure in a dairy production system is a combination of both urine and feces. It is not practically feasible to manage dairy cattle waste excretions as separate waste streams and as such the combined waste output has a solids content ranging from 12 – 14%. The actual volume and solids content of fresh manure will vary and is dependent upon factors such as feed, age of the animal and milk production.

Table 1: Average Daily Livestock Waste Production* (Excerpt of Table 3.4 of the BC EFP reference Guide)

Stage of Production	Age or Weight	Waste Production (L/day)	Liquid Manure Storage (L/day)	Solid Manure Storage (L/day)
Calves	0 – 3 months	6	6	
	3 – 6 months	8	11	
Heifers	6 – 15 months	16	22	19
	15 – 26 months	24	35	25
Milking Cow	640 kg free stall	60	75	63
	640 kg tie stall	60	67	65
	640 kg loose	60		75

* Values are approximate. The total volume of manure can be much larger than the table values depending on manure handling, i.e., the addition of water, bedding, etc.

2. EXTERNAL CONTRIBUTIONS TO FRESH MANURE

After fresh manure is excreted from the animal, there are a number of external contributions that are combined with the fresh manure that influence the end consistency and total volume of the product. These contributions are a result of the type of feed, bedding, water used for cleaning, manure handling and on-farm precipitation management system that are all part of standard dairy production practices.

Contributions to fresh manure may include:

- spilled feed (e.g. silage, hay)
- spilled drinking water
- bedding (e.g. sawdust, straw, sand)
- barn wash water (for sanitization and manure management)
- milking center wash water (for sanitization)
- precipitation (e.g. collection from roof water, storm water collection, open manure storages),

$$\text{Total Volume} = \begin{Bmatrix} \text{Manure} \\ \text{Produced} \end{Bmatrix} + \{Bedding\} + \begin{Bmatrix} \text{Barn Wash} \\ \text{Water} \end{Bmatrix} + \begin{Bmatrix} Milking\ Center \\ Wash\ Water \end{Bmatrix} + \begin{Bmatrix} Open\ Storage \\ Precipitation \end{Bmatrix} - \{\text{Evaporation}\}$$

2.1. Milking Center Wash Water

A common contribution to liquid dairy manure systems is wash water that is produced from the sanitization practices in the milking parlor. Milking centre wash water adds very little fertility value to the manure and can be applied to the land. The volume of milking center wash water generated will vary greatly depending on the type of cleaning methods used for floors and udders, and the type of milking system used. Milking systems have made many advances over time, resulting in management practices and technologies that reduce the volume of milking center wash water produced. These management practices include recirculating plate cooler water, recycling of wash water, choosing appropriate floor cleaning methods, preparing cows before milking and many other factors.

Table 2: Milking Center Wash Water Production

Milking System Type	Wash Water Production (L/cow/day)
Tie Stall (no pipeline/bucket milking)	7
Tie Stall (pipeline)	14
Free Stall (parlour)	17
Robotic (brush teat cleaning)	11
Robotic (water teat cleaning)	20

2.2. Precipitation

On-farm management of precipitation will have an impact on the end volume and consistency of manure. Agricultural producers should ensure that they have environmentally sustainable storm water management systems in place on their farm operation. Agricultural producers may choose to collect precipitation that falls on impervious yard or roof surfaces and manage it with their liquid manure systems. This is a commonly recognized management practice. Precipitation may also contribute to the volume and consistency of liquid manure by directly entering the manure storage area from the sky. Producers may choose to reduce precipitation contributions to their liquid manure by building a cover over their liquid manure storage.

2.3. Barn Wash Water

In addition to the water used in sanitizing the milking center, water can also be used as mechanism to sanitize and manage manure within the barn. This is commonly referred to as a flush system. Flush systems are expanded upon below.

3. MANURE CONSISTENCY / CATEGORY

Based upon the type and volume of external contributions the consistency of the manure is typically stated in terms of the solids content (wet basis) and is often categorised into the following four types of manure:

- Solid
- Semi-solid
- Slurry
- Liquid

The manure consistency/type is the primary factor that determines the methods used to collect, transfer, store and apply manure. Solid, semi-solid, slurry, and liquid manures are handled differently in barns. Solid manure is typically handled and stored separately from semi solid or liquid manure on farm. Handling of semi-solid, slurry, and liquid dairy manure is included in this review.

Table 3: Manure Category and Associated Manure Management & Handling Systems

Manure Category	Example of Housing and Manure Management System	Handling System
Solid (solids content of 18% or more)	• bedding mixed in manure stream • no milking centre wastewater or precipitation added • about 12 pounds of bedding needs to be added per 100 pounds of fresh manure to handle dairy manure as a solid	• solid manure can be handled using front-end loaders, tractor-mounted blades, or mechanical scrapers
Semi-solid (solids content ranging from 10 to 17%)	• fresh dairy manure is about 12% • limited bedding mixed in • no milking centre wastewater or precipitation added	• may be pumped with a piston pump, or unloaded using an auger • handled with scraping systems • gravity flow channels with additional water
Slurry (solids content ranging from 4 to 10%)	• no bedding mixed in (or bedding mixed and more water added) • adding water from precipitation, barn cleaning, or milking center effluent • adding 30 gallons of dilution per 100 gallons of fresh manure	• slurry can be handled with manure pumps • direct scraping • gravity flow channels
Liquid (solids content of less than 4%)	• liquid manure is typically the effluent from liquid-solid separation equipment • all water added from milking centre wastewater, precipitation, or flush system • about 250 gallons of dilution water must be added per 100 gallons of fresh manure to reduce the solids content to less than 4%	• liquid manure can be handled with liquid pumps • direct scraping • gravity flow channels

4. MANURE HANDLING SYSTEMS IN BARNS

Manure handling systems include scrape systems (tractor or mechanical), flush systems, and gravity-flow channels. All systems collect and transfer manure, but each result in significantly different end products. Each system has its advantages, challenges, and costs from an operational and processing standpoint.

The handling system will influence the moisture content of manure, but will not significantly affect the total amount of nutrients, including nitrogen, in the manure. With the exception of composted manure, manure nitrogen is present in organic and ammonium forms, with nitrate only being produced once mineralization is mediated by soil organisms. The mineralization process which transforms organic and ammonium forms for nitrogen into nitrate occurs after manure is applied to the soil. A flush system or scrape system would not affect the forms of mineral nitrogen present in the manure.

4.1. Scrape Systems

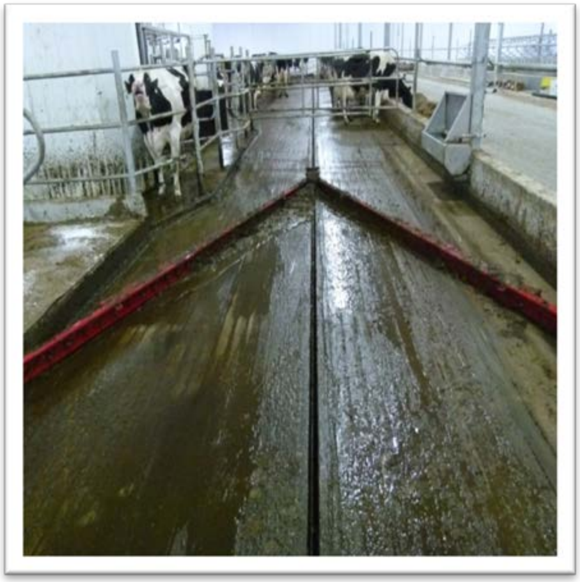

Figure 1: Alley Scraper

In British Columbia, one of the most common methods of manure collection from freestall alleys is scraping with a tractor or a mechanical scraper. In a barn with a scrape system, manure is scraped off the alley floor towards the middle or end of the barn into the manure pit or to a manure transfer system.

Manure is then usually transferred using a flush system in gravity flow channels or a mechanical cross gutter system to move the collected manure to the manure pit. If a flush system in gravity flow channels is used, the solids content is expected to vary between 4 – 9%, whereas if a mechanical cross gutter system is used, or the manure is scraped directly to the pit, the solids content is expected to vary between 8 – 18%.

Manure Transfer System - Gravity-Flow Channels

Gravity flow slurry channels are popular in new barns as a means by which to transfer liquid manure from the barn to storage after scraping the manure into the channels. The manure continuously flows to a reception pit, cross channel, or discharge pipe so minimal labour is required to transfer manure to storage.

The manure that is deposited into the channel must be wet enough to be able to flow. Wash water, wastewater, or fresh water can be added upstream to assist in manure flow. During the initial scraping operation, the water is mixed to produce uniform, liquid slurry. Gravity flow channels allow for the reduction or elimination of mechanical manure handling systems required for transfer of manure from the barn to a storage structure. This type of system can only be used on manure with a solid content of slurry or lower, and will require water to be added to ensure adequate flow

Advantages of scrape systems
- Provide rapid removal of manure
- Frequent cleaning results in less manure being dragged into the stalls and, therefore, cleaner cows
- Effective in pushing manure through slats

Disadvantages of scrape systems
- During cold weather the scrapers have to run more often to prevent manure from freezing to the alley floors
- Over time, they will cause wear to the alley floors, making them slippery
- Though these systems can be used with sand, the sand will increase the wear on the equipment and on the floor
- Cannot remove manure from cross-overs and holding areas

4.2. Flush System

Most dairy barns with flush manure systems follow a standard process. The flush water is collected in a storage tank. From the storage tank the manure rich water passes through a mechanical separator, the solids go to a storage pile and the liquid to a lagoon. The liquid manure is allowed to settle and then is reused to flush the barn again. The amount of fresh water required for alley flushing can be greatly reduced by recycling the water used for flushing.

Flush systems can be used to clean holding and cow traffic areas which require a large volume of water for proper cleaning.

The alleys in flush barns are sloped from 1.5 – 4% for efficient manure removal. The flushing volume depends on the number of cows, alley slope and alley width. In most cases, the actual water volumes used and the frequency of flushing is determined by trial and error on a farm to farm basis. Due to the large volumes of water used in a flush system, the final solids content is typically below 2%.

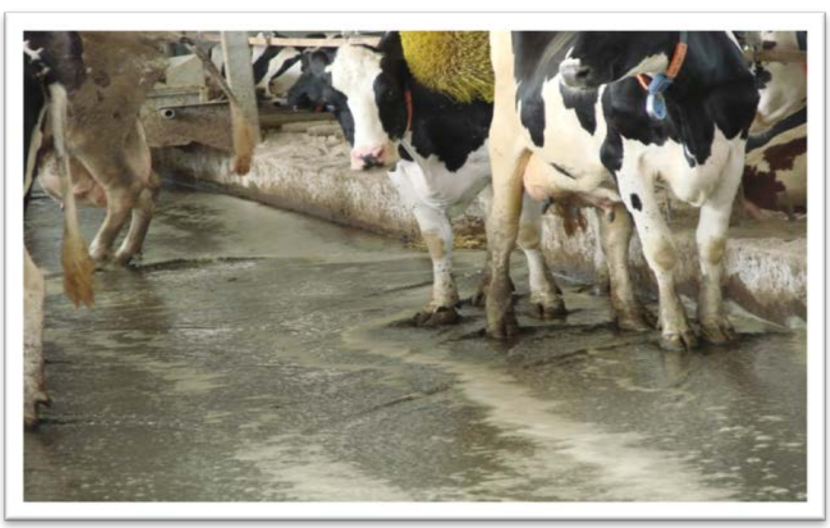

Figure 3: Alley Being Flushed

Advantages of flush systems

The following list includes some advantages of flushing dairy facilities, compared to a scrape system.

- Labor may be reduced
- Flush systems may be easily automated
- Frequent flushing may result in cleaner facilities and less odor
- Operating costs are lower
- Flush systems are suited to a low-labour system incorporating a lagoon and irrigation for storage/treatment and distribution of waste
- Better accommodates large facilities and cow numbers
- Floors dry out better because wet, residual manure is removed
- Sand bedding can be flushed into a settling lane and the sand can be removed
- Can be easily automated, reducing labour
- May result in cleaner facilities and less odour

Disadvantages of flush systems

- For optimum system, facilities should be designed with proper slopes and other features
- Large amounts of "water" are required and must be stored (up to 125 gallons per cow-day or more)
- Flush systems may not be feasible to operate in cold
- Optional system (scraping) required for cold weather operation, thus increasing total investment
- Installation of flush systems with associated recycle pump, piping, and flush devices may be relatively complicated and expensive
- Solids separation may be desirable to reduce system problems
- Require bigger manure storage facilities than non-flush operations

Table 4: Water Volume Differences between Manure Collection Systems

Manure Collection System	Water Volume Per Cow Per Day (US gallons)	Expected % Total Solids in Reception Pit
Flush System	60 -200	1-3
Scrape w/Gravity Flow Flush	30-50	4-9
Scrape w/Mechanical Cross Gutter	20	8-18 "As excreted"

5. CASE STUDY: MANURE APPLICATION CALCULATIONS REGARDING SOIL MOISTURE (H.S. JANSENS DAIRY - 2017)

Manure application can leach nitrate in the soil to a depth below the crop root zone **if** the manure has so much water that the soil's water holding capacity is exceeded, causing water to move below the root zone. Using the H.S. Jansen Dairy's 2017 manure application plan (2017 Hullcar NMP Jansen Worksheets) and soil types, the volume of liquid manure applied to an alfalfa and corn field is compared with the available water storage capacity in the calculations below.

Despite high water content of the manure from the flush system, it was unlikely there was enough water in any manure application to exceed the soil's water holding capacity.

5.1. Alfalfa Forage

The highest volume of liquid manure applied in 2017 to an alfalfa field was 29,933 imperial gallons (IG) per acre. This volume was applied in two equal applications. The applications were planned for June 15th and July 25th. The amount of dry matter contained in the liquid manure was only 0.6 percent, so for calculation purposes the entire volume will be used:

- Total volume/acre = 29,933 IG
- Application volumes = 29,933/2 = 14,967 IG
- One cubic foot = 6.23 IG
- Application volume = 14,967/6.23 = 2,402.4 FT^3
- One acre = 43,560 FT^2
- Depth applied = 2,402.4/43,560 = 0.05515 FT
- Depth applied = 0.05515 x 12 = 0.662 INCH

Each application of liquid manure applied a gross depth of 0.662 inches over one acre of land. This depth would have application efficiency loss due to evaporation, stream trajectory, wind drift, and runoff. The application efficiency has to be taken into account to calculate the net depth applied. Since the liquid was applied from a tanker wagon which would have medium trajectory, an application efficiency of 80 percent was used.

- Net depth applied = 0.662 x 0.8 = 0.53 INCH

Next, the ability of the soil to store water has to be calculated. For a forage alfalfa crop the effective rooting depth is 4 feet (B.C. Sprinkler Irrigation Manual). From the soil survey for the area of interest (Wittneben 1986), the soil type was sandy loam for the top three feet and loamy sand for the next foot. The total available water storage capacity (AWSC) of the soil is calculated below:

- AWSC (Sandy Loam - 3 FT) = 1.5 IN/FT
- AWSC (Loamy Sand - 1 FT) = 1.2 IN/FT
- Total AWSC = (1.5 x 3) +(1.2 x 1) = 5.7 IN/FT

The total water storage of a dry soil on this site is 5.7 inches. For agricultural irrigation practices the soil should only be allowed to dry to 50 percent of this storage. This amount is called the Maximum Soil Water Deficit (MSWD).

- MSWD = 5.7 x 0.50 = 2.9 IN

For the alfalfa crop the first application was planned for June 14th. Most of the initial soil moisture in the ground from winter would have been consumed by the crop. The storage capacity of the soil would have been more than adequate to hold the 0.53 inch application of liquid manure. There should have been no deep percolation from these applications.

5.2. Silage Corn

The highest volume of liquid manure applied in 2017 to a silage corn field was 17,960 imperial gallons (IG) per acre. This was volume was planned to be applied on April 14th, but was not applied until May 1st due to the late spring. Soil moisture conditions were taken into account as part of the manure application decision making process. The amount of dry matter contained in the liquid manure was only 0.6 percent so for calculation purposes the entire volume will be used.

- Total volume/acre = 17,960 IG
- Application volumes = 17,960 IG
- One cubic foot = 6.23 IG
- Application volume = 17,960/6.23 = 2,883 FT^3
- One acre = 43,560 FT^2
- Depth applied = 2,883/43,560 = 0.0662 FT
- Depth applied = 0.0662 x 12 = 0.794 INCH

The application of liquid manure applied a gross depth of 0.794 inches over one acre of land. This depth would have application efficiency losses similar to irrigation. Since the liquid was applied from a tanker wagon an application efficiency of 80 percent was used.

- Net depth applied = 0.794 x 0.8 = 0.64 INCH

Next, the ability of the soil to store water has to be calculated. For silage corn crop the effective rooting depth is 4 feet. From the soil survey (Wittneben 1986), the soil type was sandy loam, loam, and clay loam. The total available water storage capacity (AWSC) of the soil is calculated below:

- AWSC (Sandy loam – 0.5 FT) = 1.5 IN/FT
- AWSC (Loam – 1.0 FT) = 2.1 IN/FT
- AWSC (Clay loam – 0.75 FT) = 2.4 IN/FT
- AWSC (Loam – 1.75 FT) = 2.1 IN/FT
- Total AWSC = (1.5 x 0.5) +(2.1 x 1)+(2.4 x 0.75) +(2.1 x 1.75) = 8.3 IN/FT

The total water storage of a dry soil on this site is 8.3 inches. The Maximum Soil Water Deficit (MSWD) for a silage corn crop is calculated with a 50 percent coefficient.

- MSWD = 8.3 x 0.50 = 4.1 IN

The water storage capacity of the soil rooting zone is quite large and should have been more than adequate to hold the water from the liquid manure application. The crop would not be planted and the farm practice would be to spread the liquid manure, till field and then seed. For the silage corn crop, the application was applied May 1st. Evapotranspiration numbers from the Farmwest website at Deep Creek show that from April 1st to May 1st the moisture deficit was 61 mm or 2.4 inches. When comparing this to the calculated net depth applied of 0.64 inches there was enough evapotranspiration to dry the soil and compensate for the liquid manure application.

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