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The authors are grateful for funding from the Oregon Dairy Farmers Association, individual dairy producers participating in this study, and the Marion Soil and Water Conservation District.

ANALYSIS OF SEPARATED MANURE SOLIDS FROM SELECTED MANURE SEPARATORS in Willamette Valley, Oregon Dairy Facilities

by Mike Gangwer, OSU Extension Service
and Monte Graham, Natural Resources Conservation Service

INTRODUCTION

A common component of many recycle-flush manure systems is the mechanical manure separator. The primary purpose of a separator is removing manure solids from the flush volume. This serves two purposes: 1) storage ponds are less likely to be overloaded with organic material if manure solids are removed and 2) a product is created that can be used for several purposes.

The overloading of these manure ponds increases Biochemical Oxygen Demand concentration, or BOD. If the BOD concentration increases (thus reducing the concentration of dissolved oxygen, which in turn alters the bacterial flora of the pond towards facultative and anaerobic instead of aerobic), mineralization is slowed and the organic content accumulates. A very significant by-product of these overloaded ponds is undesirable odors (brought about by the insufficient availability of dissolved oxygen) caused by the anaerobic fermentation of organic matter into gasses that are volatilized into the atmosphere.

Manure separators can provide a source of organic bedding for free stall housing. When separated manure solids are stored at temperatures of 140 degrees or more, almost all of the potential pathogens are killed, and the material can be used as bedding. Another option is selling the manure solids to a nursery or neighboring non-livestock grower (serving the purpose of removing nutrients from the farm system if land is limited for manure distribution). Non-dairy farmers recognize the benefit of the organic matter in these solids and are willing to buy it. One other option is to distribute manure solids onto dairy land that needs organic matter supplementation, yet cannot easily be reached with irrigation using the manure pond volume as a source of nutrients.

Manure separators represent a significant initial investment and require daily management. However, many dairy producers find them to be an integral part of their animal manure systems, as the separator reduces the organic matter loading rate and supplies a source of organic material for on-farm or off-farm use.

There are two primary types of manure separators. The sidehill design has no moving parts. The flush volume cascades over a screen as the water falls thru by gravity. The larger particles of organic material slide off the surface of the screen and accumulate beneath the separator. The second type is a dragchain separator. In this design, a moving chain with flights moves the flush volume over a screen; the water falls thru but the larger particles of manure solids are raked over the screen until they fall off the end of the dragchain, accumulating in a pile beneath the separator. There are variations of these designs, but all are similar to one of the two categories.

A recently developed FAN separator is a model that was not included in this study. There will be other designs in the future as the technology of separating manure solids from the liquid develops.

PURPOSES AND GOALS

Several purposes and goals were formulated for this applied research study:

1. Identify 51 manure systems in the Willamette Valley, Oregon that have manure separators.
2. Secure two samples, taken approximately 6 months apart, from each of these facilities.
3. Collect 3-4 pounds of fresh manure solids beneath the separator for analysis. The analysis consists of total kjeldahl nitrogen (TKN), total phosphorus, total potassium, organic matter and dry matter. Determine standard deviation* as a measure of variability.
4. Determine of separator output expressed as cubic feet/cow/day .
5. Determine C:N ratio.
6. Compare the analysis of the manure solids with regard to season, herd size, separator type, and bedding type.
7. Determine separator efficiency at removing manure solids from the total flush volume.
8. Determine if a "best separator" can be identified.
9. Provide nutrient analysis of manure solids for each cooperating dairy producer.

METHODS

Beginning in May 1993, and ending in April 1994, 51 dairy facilities with manure separators were identified and sampled. A total of 102 manure solid samples were analyzed at Coffey Laboratories Inc. [12423 N. E. Whitaker Way, Portland, Oregon 97230]. Each sample was collected at, or as near as possible to, the peak of the pile. The sample, about 3-4 pounds, was sealed in a plastic baggie, refrigerated immediately, and delivered to the lab.

The volume of separated manure solids was measured or estimated. In some cases the dairy operator provided this measurement. A container of manure solids was weighed at each facility on a balance beam scale. From this weight and known container volume, the density was calculated and output per cow on a daily basis was determined.

A determination of waste material, bedding, discarded feed, and other material contributing to the separated solid volume was not made. The flush volume contains manure and these waste products as well. The nutrient analysis of manure solids therefore includes both sources of solids - manure and waste products.

VARIABLES - FACILITIES DESCRIPTION

The following variables for each facility were examined:

1. **Season.** Dry refers to the sampling months of June, July, August, September, October, and November. Wet refers to December, January, February, March, April, and May.

2. **Herd size.** There were 9 herds of less than 200 cows (milking and dry) and 42 herds of more than 200 cows. While in most cases some heifers contributed manure to the manure volume, we

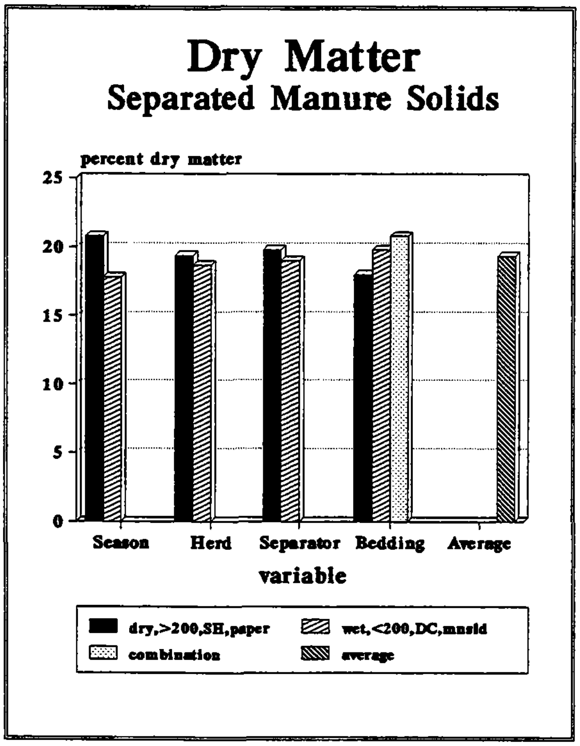
chose to use 200 cows as the variable, largely because that is about the average herd size in the Willamette Valley.

3. **Separator type.** Sidehill and dragchain are the two variables used because all separators can be put into one or another of these categories. There were 30 sidehills and 21 dragchain separators in this study.

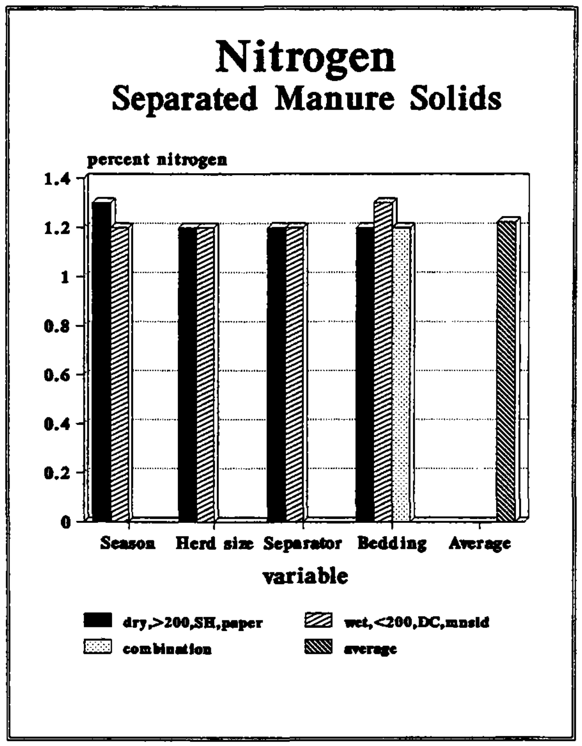
4. **Bedding types.** Three variables were used: 1) paper sludge, a common bedding material that is a by-product of Smurfit Paper Company [Newberg and Oregon City, Oregon]; 2) separated manure solids recycled back into the system as bedding material; and 3) a combination of bedding types, such as wood products and manure solids, or paper sludge and manure solids. There were 18 dairies that used paper sludge, 19 used recycled manure solids, and 14 used a combination of bedding types.

NUTRIENT ANALYSIS

Dry Matter



Nitrogen [TKN]



Dry matter and nitrogen content of separated manure solids are shown in the above graphs.

The dry matter content of separated solids is slightly drier in the dry period, 20.8 percent compared to 17.8 percent. This trend may be explained by evaporation of moisture from the solids pile during the dry months, and that some samples were collected during rainfall, increasing the moisture content. The average **dry matter** content for all samples is **19.34 percent** with a standard deviation of 3.95 percent.

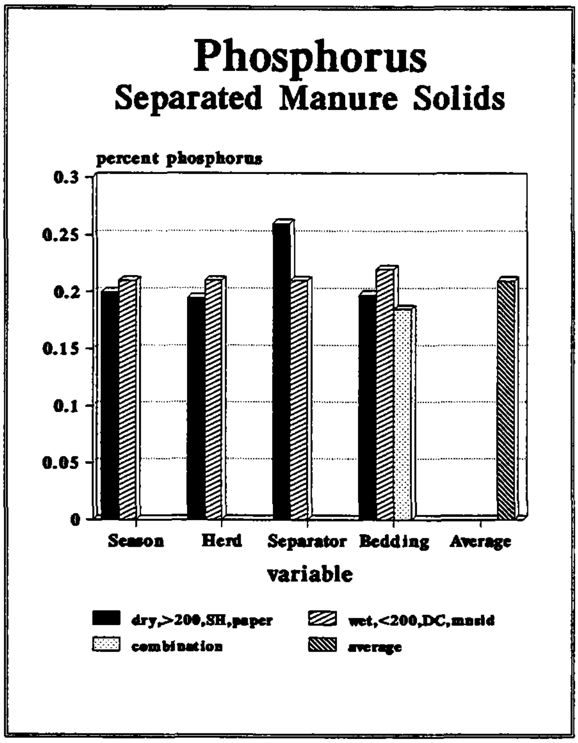
The nitrogen content of these separated solids, measured as total kjeldahl nitrogen, is similar across all variables. TKN is a measure of the organic nitrogen and the inorganic ammonium form.

The TKN analysis accounts for all of the nitrogen in the sample except that portion nitrified into nitrate, and this amount is insignificant.

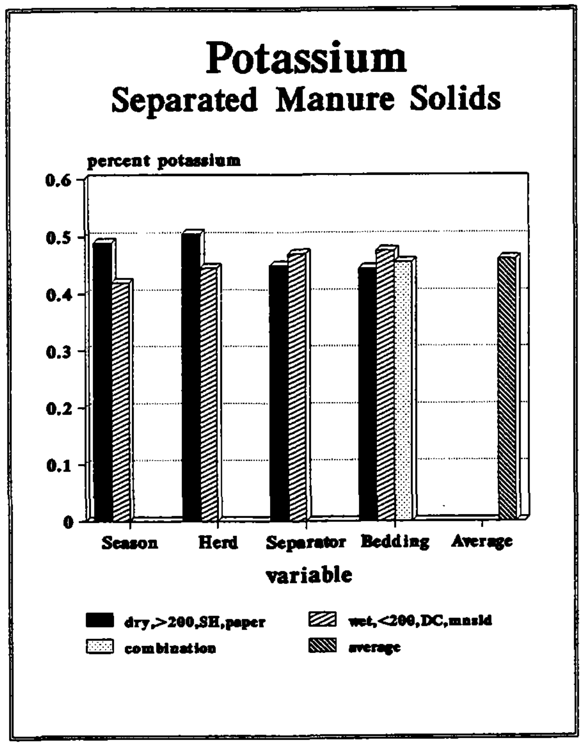
The average **nitrogen** concentration is **1.22 percent** with a standard deviation of 0.28 percent (dry matter basis).

** Standard deviation measures the distribution of results around the mean. The lower the standard deviation, the closer the results are to the mean. A wide standard deviation indicates a higher degree of variability.*

Phosphorus



Potassium

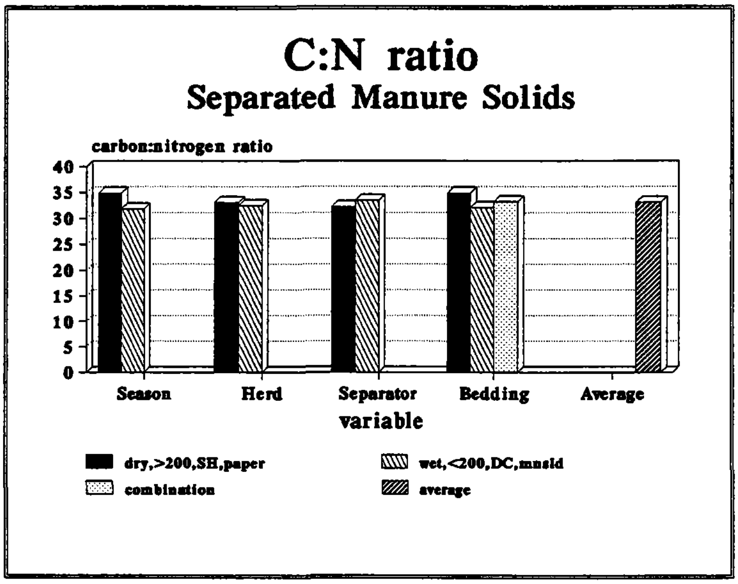


The total phosphorus appears slightly higher in separated solids taken from sidehill separators. The average **phosphorus** content, which includes organic and inorganic forms, is **0.21 percent**, with a standard deviation of 0.11 percent (dry matter basis). The wide standard deviation for total phosphorus may be explained by different feeding programs, including mineral supplementation, and the use of different types of free stall bedding.

In the total potassium data as graphed, samples taken during the dry period are slightly higher. These samples are slightly drier, and as moisture evaporates from the separated solid pile, potassium is left behind and may be slightly more concentrated than the wetter samples. Potassium (and phosphorus) is not volatilized like nitrogen; when moisture is removed, this mineral remains part of the drier sample. Samples taken from herds of more than 200 cows were slightly higher.

The average total **potassium** content is **0.46 percent** with a standard deviation of 0.22 percent (dry matter basis). The reasons for the wide standard deviation are the same as those listed for phosphorus.

C:N Ratio



The **carbon** content of separated manure solid samples was determined by multiplying the organic matter content by **44 percent**. This is based upon the molecular weight of typical organic manure, in that approximately 44 percent of the total atomic weight is carbon.

The carbon:nitrogen ratio can be calculated by taking the carbon as calculated and the nitrogen by TKN measurement. This ratio is used in determining the rate of organic decomposition. Organic decomposition is also called organic mineralization, in which organic matter is decomposed into its inorganic form.

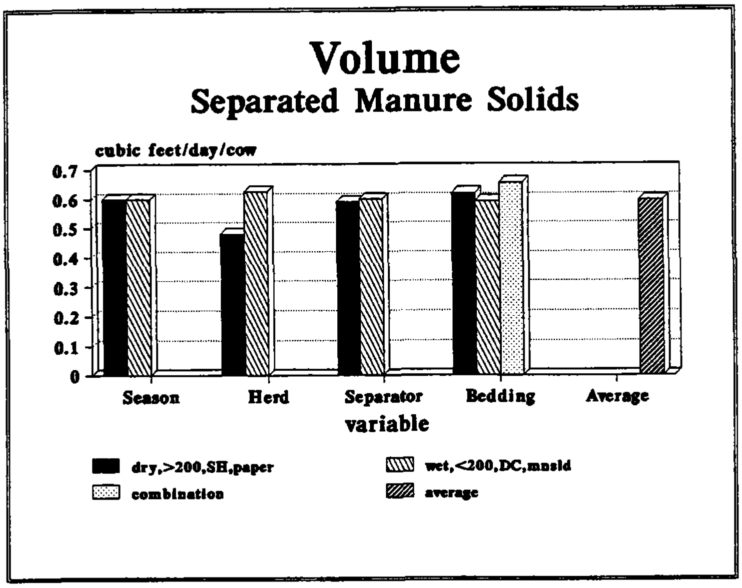
Generally, the higher the C:N ratio, the slower the rate of decomposition. Fresh manure from a dairy herd has a C:N ratio of about 20:1. In this study, the average **C:N ratio** is **33:1** with a standard deviation of 7. The higher C:N ratio (from fresh manure) is probably due to the contribution of other waste products entering the flush volume - discarded feed and in some cases bedding.

The pile of separated manure solids beneath the separator begins warming up very quickly. This warming is due to the aerobic biological decomposition of these solids because oxygen is present. This occurrence is similar to a compost pile, where the nutrients (nitrogen) are stabilized in the organic form. The portion of nitrogen that is fully oxidized into ammonia can escape into the atmosphere, resulting in a loss of total nitrogen from the pile.

Temperatures of 140 degrees or more are attained and are usually sufficient to kill the coliform, streptococci, and other potential environmental pathogenic bacteria. Killing these environmental bacteria will help reduce the potential for environmental mastitis if the separated manure solids are to be used for bedding material in free stall barns.

If the separated manure solids are used for composting material and sold off the farm, a storage period is required in which the pile is stirred two or three times. This allows oxygen to permeate the pile, converting any unstable inorganic nitrogen into ammonia gas. The remaining product is more stable, and when applied to the soil undergoes a slower mineralization process (than fresh manure), converting the stable organic nutrients into a plant-available inorganic form. The total compost volume is reduced as well, as the pile becomes drier and the organic material becomes more concentrated with nutrients.

Volume



In this study, volume is defined as the amount of wet basis separated manure solids that accumulated beneath the separator. The density of these solids was determined by measuring the weight per known volume, and averages **36 pounds per cubic foot.**

The average **volume per cow per day** is **0.6 cubic feet**, or **21.6 pounds** of wet basis separated manure solids per cow per day. The standard deviation for this measurement is .27 cubic feet, thus there is almost a 50 percent degree of variability in volume produced per dairy facility.

Given the dry matter content of 19.3 percent, the yield of separated manure solids on a dry matter basis is **4.2 pounds** of manure solids.

A 1,400 pound cow excretes 20 pounds of manure solids (feces) per day. Excluding the contribution of waste products, such as discarded feed and organic bedding, separators removed **21 percent** (4.2 pounds/20 pounds) of the total solid concentration in the flush volume. If the waste products are included, then separators removed less than 21 percent.

This is apparently the case, given the C:N ratio of separated manure solids is higher (166 percent) than fresh manure, indicating the presence of waste products.

Summary Table

A summary table is presented below that includes the averages and standard deviations for each of the analyses measured in the separated manure solids on 51 dairies.

C:N ratio is reported as the average carbon number to one [33.14:1]. Cubic foot volume is reported as the output of wet basis manure solids from the separator per cow per day. Herd size includes all animals housed on the facility that contribute to the manure flush volume (milking and dry cows, replacement heifers).

Separated Manure Solids Analysis Table

	Dry matter	Nitrogen	Phosphorus	Potassium	C:N ratio	Cubic ft. vol	herd size
Average	19.34	1.22	0.21	0.46	33.14	0.60	466
standard dev.	3.95	0.28	0.11	0.22	7.02	0.27	327

Discussion and Conclusions

From this year-long study of separated manure solids on 51 dairy farms, the following conclusions can be drawn:

1. There is little difference between nitrogen, phosphorus, potassium, and C:N ratio with regard to season, herd size, separator type, or bedding type.

2. There are wide differences between volumes produced per cow per day. This is largely due to management techniques, quality of personnel, amount and consistency of flush volume, and the working condition of the equipment. Most separators require daily cleaning; if this is not done they tend to plug, which causes a wetter volume beneath the separator. One key factor in the proper operation of these systems is the consistency of the flush volume. The more the flush volume is diluted, the better all separators appear to remove solids.

3. In terms of efficiency, separators remove the large particles. In terms of total solids, they remove an average of 21 percent of the total solids from the flush volume. This figure is lower when other contributors are considered, such as waste products in the flush volume. This means most of the smaller particles, an average of 79 percent of the total solid load, ends up in the post-separator liquid volume piped into the manure pond. General observation of manure ponds support this finding. Most manure ponds in this study contained a greater volume of manure solids than the operator had originally planned or designed.

4. The primary purpose of a manure separator is two-fold: to remove the larger particles from the flush volume and to provide a source of bedding material or material for soil nutrient purposes. Installing a separator for the primary purpose of removing most or all of the total manure solid load is unwise given the performance of separators in this study.

Dairy farmers may need to rethink their options when deciding whether to install a manure separator, given the initial cost and day-to-day management that is required. Certainly if the flush volume cannot be diluted enough so that the separator can perform properly, then it should not be installed.

5. The following are calculations for inorganic fertilizer comparisons. They represent the fertilizer equivalent for N-P-K, but do not include a value for the carbon content.

All are based on dry matter basis.

Nitrogen:	1.22%(solids) = 4.88 lbs. N	[10.9 lbs. urea/wet ton of solids]
Phosphorus:	0.21%(solids) = 0.84 lbs. P	[1.9 lbs. P_2O_5/wet ton of solids]
Potassium:	0.46%(solids) = 1.84 lbs. K	[2.2 lbs. K_2O/wet ton of solids]

Example. If 20 tons of solids (wet basis) are land-applied, then the nutrient load is 218 pounds of urea, 38 pounds of phosphorus (as P_2O_5), and 44 pounds of potassium (as K_2O). Each of the above figures (inorganic fertilizer concentrations)are multiplied by 20. Also, approximately 44 percent of the dry matter is carbon, or 176 pounds of carbon per wet basis ton; in these 20 tons, 3,520 lbs. (1.76 tons) of carbon is land-applied.

6. Dairy operators should routinely sample their separated manure solids for analysis. However, these samples can be taken less frequently if no significant changes in flush volume content occur or if the management of the system is routine. Samples may be submitted to a certified lab that is capable of doing nutrition analysis.

7. Based on this study, we conclude there is not one "best separator." Dairy operators will match their ability to manage the system with what they can afford to pay for the components of the system.

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This publication concludes the second half of a three-year applied research project jointly conducted by the authors. The report: "Wastewater Volume and Nitrogen Concentrations in Willamette Valley, Oregon Dairy Ponds" [OSU Extension Special Report 939] was published in September, 1994, and represents the first half of the project.

We are especially indebted to the dairy producers participating in both projects. They have allowed us free access to their facilities.

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