Alternatives To Manure Management Problems

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One of the least popular areas to discuss with dairy producers is manure management. Yet, herd expansions and survivability may well depend on adequate manure management. Large dairy herds translate to large amounts of manure nutrients to be managed in a timely basis. The definition of proper management will vary if identified by an operator, a neighbor, an environmentalist, or a regulatory staff person. Adequate manure management will minimize complaints associated with flies and odor. Also, it will minimize contamination of natural resources.

Manure management on large dairies must incorporate nutrient and solids collection, treatment, storage, and utilization. Management tools include dietary manipulation to reduce nutrient intake and/or improve nutrient utilization, relocation of manure off site, solid liquid separation, seasonal scraping instead of flushing, agronomic application of manure nutrients and reduction of imported bedding material. Site specific conditions must be considered to accomplish adequate manure management in a cost effective manner.

Reducing Excessive Nutrients

Often, and increase in herd size comes with no additional increase in crop land. Also, land is taken out of production to accommodate the new animals. The net result is much less crop land available for manure nutrient utilization. If large amounts of crop land were available before the expansion, the additional growth and reduction in crop land may not be a problem. A different scenario will exist if land was adequate or a bit short for manure nutrient utilization prior to the expansion.

Numerous creative techniques can reduce the quantity of manure nutrients that must be managed. The first is to reduce the amount of nutrients excreted. The second is to reduce the amount of excreted nutrients that need to be managed. Both of these alternatives will be discussed.

Dietary Manipulation

Much discussion has occurred during the last decade to utilize dietary manipulation to alter manure nutrients. If you don't put the nutrients in the front end of the animal, they can't come out the rear end of the animal. Dietary manipulation can be effective if nutrients are fed in excess of dietary needs. Plenty of data exist to indicate that dietary manipulation can reduce excretion of nitrogen (N) or phosphorus (P). Concerns related to excess N application are often associated with poor quality soils and shallow depth to groundwater (nitrate contamination) or fish kills in surface waters (high soluble ammonia). Phosphorus is usually carried in eroded soil and released in surface waters. Under normal conditions, P is usually in low concentrations in surface waters. The addition of P to surface waters can result in algal blooms and subsequent eutrophication of waters.

Dietary manipulation of nutrients can alter nutrient excretion (Tamminga, 1992; Wholt et al., 1991). Cows need a particular amount of a nutrient. The quantity needed depends on the cow's production level, age, stage of gestation, and body condition. Diets are formulated that provide the appropriate nutrients to cows assuming a given dry matter intake.

Formulating feed for cattle based on undegradable intake protein (UIP) and degradable intake protein (DIP) can be challenging. The need to have consistent feedstuff product quality and to be able to accomplish testing for UIP and DIP with a reliable test that has a quick turn around time are particularly important. Also, depending on local situations, a least cost diet may be one of higher protein content. Such circumstances would increase the cost of feeding diets with lower CP concentrations. Whole farm costs must be evaluated and not merely the cost of feed per unit milk produced. One must evaluate whole farm costs to include feed per unit production as well as nutrient management costs. It may be less expensive to minimize N excretion and potential ammonia volatilization than to increase costs associated with manure management to reduce ammonia volatilization.

Fecal and urinary losses of N can be minimized by feeding N relative to energy needs. Feeding of N to meet energy needs, and not as a source of N for protein synthesis, will result in excess excretion of N by the animal.

Further reductions in N excretion can result when rumen N and energy concentrations are synchronized; and by shifting the site of digestion of protein and starch from the rumen to the small intestine (Tamminga, 1992). Tomlinson et al. (1997) used data from a nutrition experiment to predict urinary and fecal excretions of N as:

Urine N (g) = 80.07 + .624*(N intake grams) -11.32*(DMI kg)
Fecal N (g) = 33.21 + .125*(N intake grams) + 4.877*(DMI kg)

Milk yield was not included in these calculations, since dry matter intake was highly correlated to milk yield and milk yield was not significant. A summary of N utilization by animals is presented in Table 1.

Theoretically, increases in ruminal ammonia would increase absorption of ammonia across the rumen wall, and potentially increase circulating blood urea N. Urea clearance would be via kidneys and could explain the increases observed in urinary N excretion. Additionally, the increased circulating urea N concentrations could increase milk urea N concentrations.

The association relationship between milk urea nitrogen (MUN) and nitrogen utilization in the lactating dairy cows in unknown. However, some have suggested that it might be possible to use MUN to evaluated nutrition programs of lactating cows in regard to nitrogen metabolism (Baker et al., 1992; Ferguson, 1996). Reducing nitrogen losses in the urine and feces from lactating cows would help to prevent environmental contamination (Anonymous, 1996; Baker et al., 1992; Nelson, 1995).

Milk urea N does offer potential as an indicator of dietary N utilization in regard to N excretion in milk and urine. However, it is unlikely that MUN will be used alone without additional parameters. Further research is required to define the parameters needed to use MUN as a monitor of N excretion by the lactating dairy cow.

The proportion of N excreted in urine and feces is receiving greater focus as a result of air quality concerns. As an example, diet A results in an excretion of 500 g of N/d and the N is excreted equally in feces and urine (250 g each). If diet B results in a reduction of N excretion by 10% and does not alter pathway of excretion, total excretion would be 450 g/d and the urinary component would be 225 g/d (a 10% reduction in urinary N). Diet C reduces N excretion by 5% but alters urinary N to contain only 40% of N excreted, for an excretion of 190 g/d (a 24% reduction in urinary N). Given that the predominant form of N in urine is urea and that this is readily cleaved to ammonia and potentially volatilized, diet C provides the greatest potential for reduced ammonia volatilization. Reduced ruminal ammonia concentrations should also reduce urinary N excretion. This may be accomplished by using UIP/DIP formulations instead of the traditional CP formulations.

Table 1: Summarization of nitrogen excretion studies.

source	animal (n)	body weight	N intake	Nmilk+ retained	N feces	N urine
Crooker et al 1990	calves (F 6)	104 kg	99		30*	
Cummins et al. 1982	cCalves (M 54)	110 kg	66.8	+20.1	29.2	17.7
Sechen et al. 1989	3.6 yr (6)	603+52	585	171-1	172	241
	62d pp	BST	579	189	170	213
Wohlt et al. 1991	multiparous	12% CP	387	144+30	136	77
	(40) 21d pp	16% SBM	621	185+78	164	194
		16% FM	580	179+86	150	165
		16% CGM	515	155+39	156	165
Tyrrell et al. 1988	multiparous	588 C	429	136-21	145	164
		602 BST	410	144-35	142	155
Tomlinson et al. 1996	(34)	SBM		100+38	179	195
		BM		100+?	208	183
		FM			162	112
		12% CP		+16	158	99
		15% CP		+43	179	138
		18% CP		+55	199	228

**: fecal N excretion is total N excretion; pp=post partum; F=female; M=male; BST= bovine somatotropin; C=control; SBM=soybean meal; CGM=corn gluten meal; BM=blood meal; FM=fish meal; CP=crude protein.*

Most locations in the west are not immediately concerned about P contamination. Certainly the possibility exists that over time the maximum P adsorption to soil will be reached. Environmental problems associated with P and surface waters have occurred in the Northeastern US (including the Chesapeake Bay Region) and in Florida dairies. In both areas, legislation was promulgated to reduce surface water contamination by P from dairy areas. Phosphorus is not found in its elemental form. It readily adsorbs to soil particles or other particulate matter, but can contaminate surface waters when soil or organic compounds are eroded.

The primary production concern related to P concentration is reproduction. Effects of P deficiency on efficiency of reproduction have been inconsistent. Observations from areas where soils were deficient in P indicated that there was reduced efficiency of reproduction due to frequent anestrus and reduced conception rates. In some cases, deficiency of P was confounded with poor quality and/or low quantity of feeds. This resulted in other nutrient deficiencies such as energy, protein, and minerals. Other researchers reported that reduced intake of dietary P did not alter reproductive performance.

As with N, P excretion can be minimized through balanced diets. First, it is important to realize that P bound to phytic acid is readily available to ruminants (Morse et al., 1992b). Second, it is recommended to feed adequate P. Current NRC recommendations are not being questioned at this time. Data from Morse et. al (1992a) indicated a potential reduction of P excretion by reducing intake. Reductions in amount of P fed will reduce P concentration in feces. This is beneficial to land receiving manures. When manure is applied to meet N requirements of plants, P and K are inevitably over applied and will build up in soil over time.

Relocation Of Manure

Housing design dictates manure collection and storage forms. Manure nutrients are collected in solid, semi-solid, slurry or liquid forms. Liquid forms of manure are utilized through irrigation techniques. Solid manures require field spreading. The more dry matter that is in manure, the greater the opportunity there is for manure to be hauled any great distance. Relocation of manure off of farms is one method to reduce the amount of manure and nutrients remaining for land application. Certainly, solid manure lends itself to be transported off farm much easier and less expensive than does liquid manure. The amount of water in liquid manure makes it costly to transport any great distance. Densification of nutrients is required to allow more feasible transportation of liquid manures.

Efficiency Of Solid Liquid Separators

People are under the impression that many dairies use solid liquid separators. A 1995 survey in California indicated that 54.1% of dairies accomplished some type of solids separation with only 14.9% of dairies utilizing mechanical solid liquid separators (Meyer et al., 1997). Each operator must identify the objectives of having a separator on their property. Possible reasons include: reduce solids loading rate to the storage pond, reduce frequency of clean out of storage pond, allow exportation of solids (nutrients), improve the ease of handling liquid with standard pumping and piping equipment for irrigation, reduce odors and flies, reduce water use by recycling separated liquid as flush water, or reduce the need to purchase other solid materials for bedding (reuse solids as bedding). A separator can provide positive benefits in many of the above mentioned categories. The question an operator should ask is what is the primary reason for installing a separator and will the separator perform as needed?

Typically, separators are selected based on their initial cost, estimated operating and maintenance costs, management required to deal with solids (regular or intermittent solids removal), adequate capacity to handle peak manure flow, and location. The concept of efficiency of solids removal doesn't usually make the list. How well does the particular separator work? Unfortunately, few data are available to identify the efficiency of separation---especially with dilute (0.5 to 2.5% total solids) solutions.

Solid liquid separators have long been promoted as useful tools to remove solids from liquid waste streams. Few studies have evaluated the efficiency of solid liquid separators with dilute dairy manure. Most studies available in the literature report information on swine manure and on dairy manures with higher solids concentrations. Pain and Hepherd (1980) evaluated the benefits of mechanical separation in the United Kingdom. They utilized a roller press machine fitted with a screen with 1 mm diameter perforation. The influent material ranged between 3 and 14% total solids (dry matter). The solids removal efficiency ranged from 22 to 65%. A linear relationship existed between the 3 and 10% total solids and percent removal. The greater the input solids percent the greater the removal. Extrapolation of their results to a more dilute solution would suggest an anticipated 10 to 20% removal of solids from a 1 to 3% influent solids material.

Auverman and Sweeten (1992) summarized results obtained from sampling

six different solid liquid separators during a Southwest Dairy Field Day. Three influent and effluent samples were obtained from each separator. Influent samples ranged in total solids from 0.6 to 1.5%. The separator types were from Dairyland Automation, Innovative Resources, Agpro, Agkone, American Environmental Systems and Environmental Protection Technologies International. The percent reduction in total solids ranged from (-)12.0 to (+)19.4%. No data were reported for the Environmental Protection Technologies International separator.

Recently, research has been conducted on California dairies to evaluate the efficiency of solid liquid separators. Seven different separators were evaluated: two moderately inclined conveyor scrapers, two slightly inclined conveyor scrapers, and four stationary inclined screens. Between five and 15 paired influent and effluent samples were taken. Separator efficiency for removal of total solids from the influent stream ranged from 0 to 15.9%. The influent stream to most separators was flushwater on its way to a storage pond. The lower values were obtained from separators where water from a storage pond was used as the influent stream. All dairies used recycled wastewater for flushwater. The colored water component of the flush water (previously unfiltered solids) consisted of fine suspended solids. Samples from four of these dairies are being evaluated for particle size. The size of the particle will provide the greatest insight to the potential efficiency of the separator.

An Alternative Method

If the main goal of installing a separator is to reduce the solids loading rate to the storage pond, maybe an alternative method should be evaluated. Historically, flush systems were installed on dairies to reduce labor costs associated with scraping freestall and feed lanes. This was identified as the solution to labor costs. The ramifications of the solution to labor costs were an increase use of water and the subsequent need to store larger volumes of manured water. Although ponds may have been designed to hold the capacity of water, they may not have been designed to hold the additional total solids in the water. Also, increases in herd size may not have been coupled with increases in pond capacity to store additional total solids. An alternative method to reduce the amount of solids collected through the flush system is to discontinue flushing and revert to scraping of corrals. This need not occur during all months of the year.

A comparison of manure collection systems provides food for thought. For the sake of discussion, the following assumptions are used for a freestall facility where cows have access to corrals. Winter conditions exist for 4 months (no access to corrals). Two months exist in transition when cattle utilize corrals on the average of 8 hours daily. The remainder of the year (6 months) cattle use corrals 13 hours and freestalls 8 hours, daily. Cattle

Table 2: Calculation of annual manure collection based on daily manure deposition locations and manure collection systems.

					no separator		separator	
season	nonths	milking	freestall	corral	noscr	scrape	noscr	scrape
		--------------hr/day-------------			-------------% solids collected-------------			
separator efficiency assumed to be 15%								
winter	4	3	21	0	0.0	0.0	15.0	15.0
transition	2	3	13	8	33.3	33.3	43.3	43.3
summer	6	3	8	13	54.2	87.5	61.0	89.4
annual percent of manure solids collected					***32.6***	***49.3***	***42.7***	***56.9***
separator efficiency assumed to be 7.5%								
winter	4	3	21	0	0.0	0.0	7.5	7.5.
transition	2	3	13	8	33.3	33.3	38.3	38.3
summer	6	3	8	13	54.2	87.5	57.6	88.4
annual percent of manure solids collected					***32.6***	***49.3***	***37.7***	***53.1***

spend 3 hours daily in the milking mode. This includes transportation to and from the parlor, time in the holding pen, and time in the parlor. Manure is distributed proportionally to where cattle spend their time. As an example, if 3 hours in 24 are spent in the milking mode, 12.5% (3/24*100) of the manure occurs. All milking and freestall manures are collected through a flush system. Corral manure is scraped (collected as a solid). Estimations of the amount of solid manure collection are calculated for 1) no separator, no additional scraping; 2) with a separator that separates solids at 15% or 7.5% efficiency, no additional scraping; 3) no separator, summer scraping of freestalls instead of flushing; 4) with a separator that separates solids at 15% or 7.5% efficiency, summer scraping of freestalls instead of flushing (Table 2). The traditional corral scraped manure only, collects 32.6% of solid manure. Addition of a separator would improve the collection to 37.7 (separator efficiency of 7.5%) or 42.7% (separator efficiency of 15%). Scraping of freestall/feed alley lanes during 6 months of the year with no use of a separator would improve collection from 32.6 to 49.3%. An additional 3.8 or 7.6% can be recovered if a separator was used with the liquid portion of the scraped scenario. The differences are due to the efficiency of separation.

The economics associated with the various options must also consider available labor, equipment, storage capacity, farming practices, market for solids, water needs, and nutrient concentration of remaining water. There is no universal answer for a producer to adopt. Many avenues must be considered prior to altering manure collection and treatment systems.

Manure Nutrient Management

Solid and liquid manure should be managed. The cumbersome task to apply nutrients at agronomic rates must utilize information from soil nutrient availability, plant nutrient needs, irrigation water management and manure nutrient concentrations. Some amount of record keeping is required to accomplish nutrient management.

Sampling Nutrient Sources

Samples of both solid and liquid sources should be obtained near the time of use. Solids should be analyzed for total N, ammoniacal-N, P, K, Ca, Mg, Na, Cl and EC. Also, moisture or dry matter (100%-Moisture%) should be determined. Dry manures are 10 to 20% moisture. Compost may have as much as 50% moisture. Solids straight from a separator can be 85% moisture. Table 3 lists average values for nutrient composition of solid manure samples taken in California.

Manure liquids should be evaluated for the same chemical elements as the solids. However, an evaluation of moisture would be quite difficult and not necessarily useful. Also, it is helpful to know the flow rate of the manure water. Then, the results of analytical analysis can be calculated in terms of pounds of nutrients applied per hour of manure water application. Table 4 is a summary of such data evaluated during the summer of 1996.

Determining Application Rate

Solid or liquid manures should be applied based on soil nutrient concentrations, crop needs and nutrient concentration in the manure. First, it is important to determine how much manure should be applied to a particular crop given the nutrients already present in the soil and the needs of the crop. Second, it is necessary to identify how the nutrients will be applied. Various application methods exist for different types of manures. As an example, a crop needs 250 lbs of N for its production. If soil nitrate levels indicate that there are already in excess of 250 lbs of nitrate N in the soil, maybe no manure is needed. Maybe manure is needed. That may in fact be the case if there is a potential for nitrate to leach beneath the crop root zone during the growing season. This can occur when excessive irrigation water is applied and nitrate (a very mobile nutrient) is leached.

It is important to consider the method of application when determining the application rate. For instance, if solid manure should be applied at 4 tons per acre. Can the manure spreader or truck apply that rate? Equipment used for spreading manure should be calibrated annually.

The method of application is important to consider. If the irrigation method is flood (versus sprinkler) then a non-uniform distribution of water and nutrients will occur. This is a particular concern in areas of poor soils and shallow water tables. Irrigation water management is very critical. It becomes increasingly important to manage irrigation water if the site has a shallow water table and poor quality soil.

Commonly, a single pump is available to pump manure water. Therefore, alterations in application rate require the ability to alter the amount of fresh water commingled (dilution rate). Can the irrigation piping system accommodate delivery of manure nutrients at the right time? Most operations only have one set of pipes or ditches and one or two pumps capable of pumping manure water to the appropriate field. Logistically, it is difficult to transport manure water great distances during the summer irrigation months.

Challenges In Using Manure

First and foremost, one must consider the nutrient content of the manure. Crops use much more N than P. As a result, if manure is applied to meet crop N needs, P and salts will be over applied. Will this affect the crop or the soil? Two methods can be used to overcome this poor N:P ratio. The first is N conservation once manure is excreted from the cow. Current research efforts are focusing on techniques to accomplish N conservation. A second method to enhance N:P ratio includes incorporation of fertilizer N.

A second consideration is distribution uniformity of nutrients. Spreaders that shoot out large clumps of manure may not distribute nutrients evenly. Is this acceptable in the particular farming scheme? Also, spreaders compact soil which can be detrimental to the cropping system. This practice may be undesirable in permanent crop systems. Although liquid manure does not compact soil, some producers have reported crop loss or damage, and poor water infiltration. Will water be able to infiltrate into the soil? This is an especially important consideration in orchards or vineyards where soil tillage is less than that of forage or row crops. Crop loss or damage can be associated with high salt, high ammoniacal N, or high organic content (which as it decomposes removes oxygen from the oil resulting in crop death due to lack of oxygen). Also, it has been suggested that fines in manure water (bacteria and small particles) seal the soil surface and prevent oxygen from entering and other gases from leaving the soil.

A third consideration is viable weed seeds. The inside of composted manure or stacked manure piles that has undergone static composting will be virtually weed-seed free. However, wind blown weed seeds can be embedded in the pile surface. Corral manure and manure liquids will contain viable weed seeds. Organic growers and others may choose to further analyze manure utilization potentials based on the risk of broadcasting weed seeds. Weed control around piled manure is important to minimize plant maturation. Solid liquid separators have not been evaluated on their ability to remove weed seeds.

Certain cropping systems are better suited to receive manure waters than others. Cropping systems that remove large amounts of N or that have deep roots are desirable. Deep rooted plants have a deeper root zone from which to remove nitrate. This may aid in reducing the amount of nitrate ultimately leached into underlying groundwater.

The nutrient availability of manure will depend on its chemical analysis, soil microbial activity (which depends on temperature) and the presence of cations and anions in the soil.

The solids in liquid manure can be a challenge. Most manure water is less than 1.5% solids. When thicker liquids are applied, solids will settle out of the liquid stream. Often, solids accumulate in the top 50 to 200 ft of a check. The deeper the solids, the greater the probability the solids will hinder cultivation practices. A 1' deep solid build-up immediately after an irrigation will dry down to 2 to 4" of material. The soil under such a thickness of solids takes longer to dry to allow equipment use without getting stuck. Solids settle as a result of their particle size and density and the reduced flow velocity that occurs as water exits the valve into a check. Flow rate can be increased or check width can be reduced in an attempt to distribute solids further. Alternatively, the first third or half of the irrigation can be with fresh water, with manure water added toward the middle of the irrigation. One-half as much time running manure water will reduce total solids applied to the field, thereby reducing solids settling

Table 4: Nutrients applied per (lbs.) hours of manure pump operation.

Concentration	Org-N	NH_4^+-N	P	K	Ca	Mg	Na	Cl
Low	9.0	7.9	1.7	10.8	8.5	1.8	4.8	2.3
High	99.7	115.5	33.2	202.3	90.7	39.9	69.4	98.3

Table 3: Nutrients applied from solid manures and compost.

source	moisture(%)	Org-N	NH_4^+-N	P	K	Ca	Mg	Na	Cl
		-------------------- lbs/ton applied --------------------							
Freshly separated solids (n=56)	85.0	4.5	0.4	1.0	1.1	3.6	0.8	0.4	0.3
Fresh manure (n=3)	84.2	7.5	0.3	2.0	1.9	5.8	1.7	0.4	1.1
Old dried manure (n=16)	38.8	25.6	0.4	7.8	15.3	32.1	7.6	3.4	5.0

at the top of the field. Solid liquid separators can be effective at removing larger sized fiber particles (>2mm). Unfortunately, this size particle makes up a small portion of the total solids in liquid manure. To date, settled solids at the head of a field have not been evaluated for particle length. Application of manure solids to fields where solids from manure water irrigations have settled should be done in consideration of the solid settling pattern (e.g. apply solids in the solid form to areas of the field that didn't receive considerable amounts of solids from the liquid form).

Manure As A Bedding Source

Most research has focused on the animal health ramifications of bacteria in bedding. Numerous waste products and byproducts have been identified as a potential source of bedding material. A more recent emphasis on food safety requires additional information. Pathogenic organisms responsible for food borne diseases have been weakly linked to cattle waste in popular press coverages. The objective of this study was to evaluate manure pile temperatures and moisture, coliforms, gram negative organisms, and absorbency in core samples.

Dried manure piles used for bedding freestalls were evaluated on twenty-five dairies located in the Central Valley of California. Piles consisted of solids from solid liquid separators, corral scrapings, or a combination of these materials. Piles were sampled four times during a two week period. Each sampling consisted of temperature measurements at 1, 2, and 3 ft depths and core sampling of manure for chemical and microbial analyses. Temperatures at 1 ft depth ranged from 33 to 59 C and from 38 to 64 C at the 3 ft depth. Percent moisture ranged from 16.3 to 85.2 and absorbency of material on an as used basis ranged from 62.2 to 216.2 percent. The combination of corral solids and separated solids was frequently used. Straight separated solids tended to have the disadvantage of being easily removed from stalls.

Summary:

Manure can be used on farm or relocated off farm. There are many options available to dairy producers to accomplish manure management. One of the keys is to identify the objectives for each component and then to periodically assess components to see if they meet objectives. Although it may be easier to remain status quo with respect to manure management, economics usually would benefit if evaluations were accomplished on an annual basis.

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Notes

Labor Management Roundtable:

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