Best Management Practices For Manure Utilization

Colorado State University Cooperative Extension

August 1994

Bulletin #XCM-174

Principal author: Reagan M. Waskom
Extension Water Quality Specialist
Colorado State University Cooperative Extension

In association with: Colorado Department of Agriculture and the
Agricultural Chemicals and Groundwater Protection
Advisory Committee

The author and the Colorado Department of Agriculture gratefully acknowledge the extensive input and leadership of the Agricultural Chemical and Groundwater Protection Advisory Committee, representing production agriculture, agricultural chemical dealers and applicators, the green industry and the general public.

With cooperation from: Colorado Department of Health and Environment
USDA Soil Conservation Service – Colorado State Office
Colorado State University Department of Soil and Crop Sciences
Colorado State University Department of Ag and Chemical Engineering

Special Acknowledgments to
BMP Technical Review Team: G.E. Cardon, Assistant Professor of Agronomy
R.L. Croissant, Professor of Agronomy
J.J. Mortvedt, Extension Agronomist
G.A. Peterson, Professor of Agronomy
L.R. Walker, Extension Agricultural Engineer
D.G. Westfall, Professor of Agronomy

Layout and Design by: Colorado State University Publications and Creative Services

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Milan A. Rewerts, interim director of Cooperative Extension, Colorado State University, Fort Collins, Colorado. Cooperative Extension programs are available to all without discrimination. To simplify technical terminology, trade names of products and equipment occasionally will be used. No endorsement of products named is intended nor is criticism implied of products not mentioned.

Published by Colorado State University Cooperative Extension in cooperation with Colorado Department of Agriculture.

Best Management Practices for Manure Utilization

Livestock manure is rich in plant available nutrients which can be valuable assets to crop producers. However, it also can be a source of both ground and surface water contamination if improperly handled. Livestock manure contains significant quantities of N, P, and K, and smaller amounts of nutrients such as Ca, Mg, Mn, Zn, Cu, and S. Manure properly applied to cropland increases soil fertility, improves soil physical properties, and saves producers' fertilizer costs.

The primary constituents of manure or products released during manure decomposition that may cause water quality problems include pathogenic organisms, nitrate, ammonia, phosphorous, salts, and organic solids. Nitrate (NO_3) is the most common groundwater pollutant from fields that receive manure. Recent groundwater monitoring data and computer modeling efforts indicate that NO_3 contamination of groundwater can be a problem in the vicinity of confined livestock feeding operations. Runoff from feedlots or manured fields may also degrade the quality of surface water.

Regulatory Controls

The Agricultural Chemicals and Groundwater Protection Act (SB 90-126) does not directly address the use of manure because it is not classified as a commercial fertilizer. However, the proper management of N fertilizer requires accounting for all N sources, including manure. Best Management Practices (BMPs) prescribed under SB 90-126 will address manure management as a component of proper N fertilizer management to reduce NO_3 leaching. Sewage sludge application is regulated separately under Colorado law (5 CCR 1003-7), and is not directly addressed by these BMPs.

In Colorado, state law (5 CCR 1002-19) prohibits any direct discharge of manures or animal wastewater to either ground or surface water. The Confined Animal Feeding Operations Control Regulation mandates that producers who confine and feed an average of 1,000 or more "animal units" for 45 days per year ensure that no water quality impacts occur by collecting and properly disposing of all animal manures, as well as stormwater runoff. Smaller feeding operations that directly discharge into state waters or are located in hydrologically sensitive areas may also fall under this regulation. Animal feeding operations are directed to employ prescribed BMPs as appropriate to protect state waters.

Possible Sources of Water Contamination

Improper handling, storage, and land application of manure presents multiple opportunities for both ground and surface water contamination. Water moving across the land surface or through the soil profile can transport salts, pathogenic organisms, nitrate, and organic solids, which can degrade drinking water sources from both underground and surface water supplies.

Livestock feedlots, manure stockpiles, and storage lagoons represent potential point sources of groundwater contamination. Research has shown that active feedlots develop a compacted manure/soil layer, which acts as a seal to prevent leaching. Compacted layers of manure and soil usually limit water infiltration to less than 0.05 inches per day. It is very important to avoid disturbing this seal when cleaning pens. Workers need to be trained to correctly use manure loading machinery to leave an undisturbed manure pack on the surface. Abandoned feedlots have a large potential to cause NO_3 leaching as the surface seal cracks and deteriorates. For this reason, pens need to be thoroughly cleaned and scraped down to bare earth prior to abandonment. Revegetation of the old pens is also important to help absorb excess soil nutrients and prevent erosion.

Stormwater and wastewater runoff from feedlots can contain high concentrations of nutrients, salts, pathogens, and oxygen-demanding organic matter. Preventing stormwater from passing across the feedlot surface by installing upgradient ditches or berms is a BMP that can significantly reduce the volume of wastewater. Decreasing your total lot area when animal numbers are low can also help decrease the total stormwater runoff. Storage lagoons and holding ponds are necessary in many cases to contain excess wastewater until it can be land applied or evaporated. These should be constructed on fine-textured soils (such as silty clays, clay loams, or clay) or be sealed with liners or compacted bentonite. New lagoons must be designed to contain the runoff from a 25-year, 24-hour storm event and should be located above the 100-year floodplain.

Manure stockpiles should be located a safe distance away from any supply water and above the 100-year floodplain unless flood proofing measures are provided. Grass filter strips, filter fencing, or straw bales can be used effectively to filter solids and nutrients in runoff. For land with a slope of greater than 1%, plant a strip of a dense, sod-forming grass such as smooth brome (*Bromus inermis*) or orchardgrass (*Dactylis glomerata*) at least 20 feet wide around the downgradient side of any feedlot or manure stockpile to filter potential contaminants in runoff water.

Manure or wastewater applied to fields also represents a potential nonpoint source of water contamination if improperly managed. Nonpoint source contamination of surface water may occur if there is excessive runoff or erosion from sloping fields. Groundwater contamination occurs when nitrate from the manure leaches through the soil profile to the water table. To determine the pollution potential at your site, the following questions need to be considered:

1. Is the soil texture coarse (sandy with low amounts of clay) and the depth to groundwater less than 50 feet?
2. Does the field have greater than a 1% slope and little surface residue?
3. Is excess water from irrigation or precipitation available for runoff or leaching?
4. Is manure applied at rates greater than crop nutrient requirement?
5. Is there surface water or wells immediately downhill from the field?
6. Have recent well water analyses indicated that local groundwater has elevated NO_3-N levels (> 10 ppm)?
7. Does the field have a long history of manure application?

If the answer to any one of these questions is yes, manure application at your site may degrade water quality. Manure rates may need to be adjusted downward and all appropriate BMPs employed. Additionally, it may be helpful to periodically test wells near livestock operations and manured fields for NO_3 and bacterial contamination to determine if management practices are sufficiently protecting water quality.

Managing Land Application of Manure

Manure should be applied to land at rates that match annual expected crop nutrient uptake to ensure that excess loading does not lead to contamination. Manure applied in excess of crop needs will not increase crop yields, but will increase soil N and P to levels that can lead to nutrient leaching or runoff. Furthermore, excessive manure rates can lead to potentially high levels of plant damaging soluble salts. Manure application should be based upon actual nutrient content, soil fertility, crop, yield goal, field slope and drainage, irrigation method, and groundwater vulnerability. The application rate should be based upon a nutrient management plan which accounts for crop N needs and plant-available N in the manure. If commercial N fertilizer is used in addition to manure, the total available N should not exceed the N requirements of the crop.

The nutrient management approach is the most sound method for the beneficial use of manure. This approach requires farmers to account for all nutrient sources available from soil, water, fertilizer, and manure and balance them with the best estimate of crop needs. This method helps minimize residual nutrient leaching during the off-season and prevents excessive soil NO_3 buildup. Producers are encouraged to have manure, soil, and water tested annually, and to keep accurate records of application rates. (See Manure Management Record Sheet for suggested format.)

Soil and Manure Testing

Proper soil and manure testing are the foundation of a sound nutrient management program. A number of qualified labs in Colorado provide these services. Without a manure analysis, you may be buying unnecessary commercial fertilizer or applying too much manure to your fields. Neither practice is economically or environmentally sound. Manure can also be a source of salts and weed seeds, and these components should also be assessed prior to application.

Obtaining a representative sample is the key to good soil or manure analysis. Techniques for proper soil sampling are available from your local Cooperative Extension office. For proper manure sampling, you need a clean bucket and sample jar. If you are spreading manure daily, take many small samples over a representative period. For periodic spreading from a manure pack or pile, collect samples from a variety of locations in the pack or pile using a clean shovel or fork. Be sure that you collect both manure and bedding if they will be applied together. Agitate liquid manure handling systems before sampling and collect several separate samples. Combine the individual spot samples from a particular lot or lagoon in the bucket and mix thoroughly before filling the sample jar. Keep the sample refrigerated and deliver it to the laboratory within 24 hours. Collect the samples well in advance of your spreading date so that you will have time to obtain test results and calculate the correct application rate. An accurate manure test is an excellent investment of time and money, as it may help you realize significant savings on fertilizer bills while simultaneously avoiding water contamination problems.

Table 1. Approximate nutrient composition of various types of animal manure at time applied to the land

Type of manure		Dry matter	Total[a] N	NH_4	P_2O_5	K_2O
Solid handling systems		%	lb/ton			
Swine	Without bedding	18	10	6	9	8
	With bedding	18	8	5	7	7
Beef	Without bedding	52	21	7	14	23
	With bedding	50	21	8	18	26
Dairy cattle	Without bedding	18	9	4	4	10
	With bedding	21	9	5	4	10
Sheep	Without bedding	28	18	5	11	26
	With bedding	28	14	5	9	25
Poultry	Without litter	45	33	26	48	34
	With litter	75	56	36	45	34
	Deep pit (compost)	76	68	44	64	45
Turkeys	Without litter	22	27	17	20	17
	With litter	29	20	13	16	13
Horses	With bedding	46	14	4	4	14
Liquid handling systems[b]		lb/1,000 gal				
Swine	Liquid pit	4	36	26	27	22
	Lagoon[c]	1	4	3	2	7
Beef	Liquid pit	11	40	24	27	23
	Lagoon[c]	1	4	2	9	5
Dairy cattle	Liquid pit	8	24	12	18	29
	Lagoon[c]	1	4	2.5	4	10
Poultry	Liquid pit	13	80	64	36	96

[a] Ammonium N plus organic N, which is slow releasing.

[b] Application conversion factors: 1,000 gal = about 4 tons; 27,154 gal = 1 acre inch.

[c] Includes feedlot runoff water

Source: Colorado State University Cooperative Extension Bulletin 552A, Utilization of Animal Manure as Fertilizer, 1992.

Organic N Mineralization

The total amount of N in manure is not plant available in the first year after application due to the slow release of N tied up in organic forms. Organic N becomes available to plants when soil microorganisms decompose organic compounds such as proteins, and the N released is converted to NH_4. This process, known as mineralization, occurs over a period of several years after manure application. The amount mineralized in the first year depends upon manure source, soil temperature, moisture, and handling. In general, about 30% to 50% of the organic N becomes available in the first year (Table 2). Thereafter, the amount of N mineralized from the manure gradually decreases. In the absence of better estimates, producers should assume that 50% of the total N in applied manure is available the first year, 25% in the second year, and 12.5% in the third year. Producers should give three years of N credit from any application of manure.

All of the NO_3 and NH_4 contained in the manure is considered available to plants. However, some available N may be lost to volatilization, denitrification, leaching, or immobilization by soil microorganisms. Deep soil NO_3 testing should be used in subsequent years to keep application rates in line with crop needs. Fresh manure will usually mineralize at a faster rate than old or dry manure because it has not lost as much NH_3 to volatilization, and is therefore a better media for soil microbes.

Composting Manure

A growing number of producers have become interested in composting manure as a way to reduce volume and perhaps enhance the value and acceptance of manure as a source of plant nutrients. Composting is a biological process in which microorganisms convert organic materials, such as manure, into a soil-like material. It is the same process which causes decomposition of any organic material, only it is managed to control the balance of air and moisture, as well as the proportion of carbon to nitrogen so that materials decompose faster.

During composting, some N is lost from the manure as NH_3 is volatilized. Most of the remaining N is tied up within stable organic compounds which will become slowly available in the soil. Composted manure has less odor and is easier to haul and store than raw manure because the volume and weight can be reduced by 50% or more. The composting process produces heat, driving off excess moisture while killing pathogens and weed seeds. For maximum efficiency, pile temperature during composting should be maintained between 80°F and 130°F. Most seeds and disease causing organisms cannot survive 130°F for more than three days.

Table 2. Approximate fraction of organic N mineralized in the first year after application

Manure source	Fraction of organic N mineralized in first year
Beef and dairy cattle	
solid (without bedding)	.35
liquid (anaerobic)	.30
Swine	
solid	.50
liquid (anaerobic)	.35
Sheep	
solid	.25
Horse	
solid (with bedding)	.20
Poultry	
solid (without litter)	.35

Adapted from Nebraska Cooperative Extension Bulletin EC 89-117, Fertilizing Crops with Animal Manures, 1989.

Possible Benefits and Disadvantages of On-Farm Composting

Benefits of Composting	Disadvantages of Composting
Dry end-product that is easily handled	Time, money, energy required
Excellent soil conditioner	Ammonia lost to volatilization
Reduced risk of pollution	Slow release of nutrients
Reduced pathogens and weed seeds	Land and machinery requirements
Reduced odor	Possible odor during composting
Marketable product	

Fresh manure is an excellent composting material but is generally too wet and N rich to be composted rapidly without adding a dry, high carbon (C) amendment. However, bedded pack manure is usually dry enough and has a good C:N ratio. Proper moisture content and C:N ratio are the most important aspects of composting. Microorganisms require C as a substrate for growth and N for protein synthesis. A C:N ratio of 30:1 is desirable, with an acceptable range of 26-35:1, depending on the material used. Moisture control is probably the most difficult aspect of large-scale composting in Colorado. If moisture falls below 40%, decomposition will be aerobic, but very slow. If moisture is above 60%, anaerobic decay occurs and foul odors can be a problem. At the proper moisture, the composting material should yield water when squeezed, but should not compact or feel soggy. Adding more high-carbon materials, shaping the windrow to either shed or absorb water, covering the pile, turning more or less frequently, and wetting the pile are all techniques that can be used to adjust moisture levels.

While composting allows the application of more manure on less land, producers should carefully analyze the returns to labor and capital that they will receive. If no suitable alternative exists for complying with environmental regulations, or if a significant market for compost is unsatisfied, then it may be an excellent way to use manure. Be sure to determine if any local zoning or environmental regulations are in effect prior to establishing a composting facility. The composting site should be engineered to avoid runoff or any of the environmental hazards associated with confined animal feeding. It is probably best to start composting on a small scale, using existing machinery such as a loader or manure spreader to windrow and turn the manure, before buying more specialized machinery.

Determining Manure Application Rates

Once you have an accurate analysis of soil fertility and manure nutrient content, you can determine application rates based upon crop needs (Table 3). Plant nutrient uptake depends upon crop, growing conditions, and actual yield. It can be estimated by multiplying average nutrient uptake of the plant by the expected yield. Yield estimations should be based upon actual field averages over a five-year period.

Table 3. Nitrogen removed in the harvested part of selected Colorado crops

Crop	Dry weight lb/bu	Typical yield/A	% N in dry harvested material
Grain crops			
Barley	48	80 bu	1.82
		2 tons straw	0.75
Corn	56	150 bu	1.61
		3.5 tons stover	1.11
Oats	32	60 bu	1.95
		1.5 tons straw	0.63
Rye	56	30 bu	2.08
		1.5 tons straw	0.50
Sorghum	56	60 bu	1.67
		3 tons stover	1.08
Wheat	60	40 bu	2.08
		1.5 tons straw	0.67
Oil crops			
Canola	50	35 bu	3.60
		3 tons straw	4.48
Soybeans	60	35 bu	6.25
		2 tons stover	2.25
Sunflower	25	1,100 lb	3.57
		2 tons stover	1.50
Forage crops			
Alfalfa		4 tons	2.25
Big bluestem		3 tons	0.99
Birdsfoot trefoil		3 tons	2.49
Bromegrass		3 tons	1.87
Alfalfa-grass		4 tons	1.52
Little bluestem		3 tons	1.10
Orchardgrass		4 tons	1.47
Red clover		3 tons	2.00
Reed canarygrass		4 tons	1.35
Ryegrass		4 tons	1.67
Switchgrass		3 tons	1.15
Tall fescue		4 tons	1.97
Timothy		3 tons	1.20
Wheatgrass		1 ton	1.42

Continued on next page

Table 3. Nitrogen removed in the harvested part of selected Colorado crops *(continued)*

Crop	% dry matter	Typical yield/A (tons)	% N in dry harvested material
Silage crops			
Alfalfa haylage	50	10 wet/5 dry	2.79
Corn silage	35	20 wet/7 dry	1.10
Forage sorghum	30	20 wet/6 dry	1.44
Oat haylage	40	10 wet/4 dry	1.60
Sorghum-sudan	50	10 wet/5 dry	1.36
Sugar crops			
Sugar beets		20	0.20
Turf grass			
Bluegrass		2	2.91
Bentgrass		2	3.10
Vegetable crops			
Bell peppers		9	0.40
Beans, dry		1	3.13
Cabbage		20	0.33
Carrots		13	0.19
Celery		27	0.17
Cucumbers		10	0.20
Lettuce (heads)		14	0.23
Onions		18	0.30
Peas		2	3.68
Potatoes		14	0.33
Snap beans		3	0.88
Sweet corn		6	0.89
Sweet potatoes		7	0.30

Adapted from USDA Agricultural Waste Management Field Handbook, 1992.

Calculation 1. Nitrogen uptake

Example: 150 bu/A corn x 56 lb/bu = 8,400 lb grain/A
8,400 lb/A x 1.61 % N = 135 lb N/A in grain (from Table 3)

Assuming fertilizer N is 66% efficient:
135 lb N x 100/66 = 205 lb N required/A

Be sure to subtract N available from soil, irrigation water, and organic matter before determining final N requirement.

If manure is applied at the maximum rate, additional fertilizer N should not be applied. Maximum rate is based upon a one-time application. If yearly application of manure is made, credit should be given to the N mineralized from manure applied during the two previous years.

Manures with high moisture and low N content require high tonnages to meet crop N requirements. This may result in application of excessive salts and P. Therefore, for land receiving frequent manure applications, it is recommended that approximately half of the crop N requirement should be met from manure and the other half from commercial N fertilizer. This will minimize the potential for salt problems or excessive P buildup.

Evaluating Sufficiency of Land Base for Application

Livestock producers should determine if they have adequate land for application of manure produced. If the land base is determined to be inadequate, arrangements must be made to apply manure to other crop lands. To calculate a conservative estimate of the minimum land base required, you need to know the total manure production of your facility and have a manure sample analyzed for N, P, and K (Table 4). Then determine the best estimate of annual crop nutrient removal and divide by total pounds of N per ton of manure. This will give you an estimate of the acceptable application rate in tons of manure per acre. Total manure production divided by acceptable tons per acre will give the minimum land base for annual manure application rates (Calculation 3).

Calculation 2. Maximum loading rates of manure

1. **Example manure analysis** (beef feedlot manure, wet weight basis; data from sample analysis)

Dry matter	20.0%
Total N	1.0%
NH_4-N	3,000.0 mg/kg
NO_3-N	10.0 mg/kg
P_2O_5	0.2%
K_2O	0.5%

2. **Available N in manure**

Total N = 1.0%

NO_3-N = 10 mg/kg/10,000 = .001% N
.001% N x 20 (lb/ton)/% = .02 lb NO_3-N/ton

NH_4-N = 3,000 mg/kg/10,000 = 0.3% N
0.3% N x 20 (lb/ton)/% = 6.0 lb N/ton manure

Organic N = Total N - (NO_3-N + NH_4-N)
= 1.0% - (.001% + .3%) = 0.70%
0.70% N x 20 (lb/ton)/%
= 14.0 lb Organic N/ton manure
14.0 lb N/ton x .35 N mineralized/yr (from Table 2)
= 4.9 lb Organic N/ton available in first year

Available N = 4.9 lb Organic N +
.02 lb NO_3-N + 6.0 lb NH_4-N
= 10.92 lb N/ton manure

3. **Available P in manure**

P_2O_5 = 0.2% x 20 (lb/ton)/%
= 4 lb P_2O_5/ton manure

4. **Crop N requirement -** Refer to Guide to Fertilizer Recommendations in Colorado (Bulletin XCM 37), or a current soil test report.

Example: N required for 150 bu corn crop = 205 lb N/A (from Calculation 1) Subtract N credits from other sources such as soil NO_3, legume crop, irrigation water NO_3.
If 205 lb additional N required for expected yield,
Maximum manure loading rate = (205 lb N/A)/ (10.9 lb available N/ton manure) = 18.8 tons manure/A

5. **Phosphorous supplied by manure**

18.8 tons manure/A x 4 lb P_2O_5/ton manure = 75 lb P_2O_5/A

Conversion factors:

ppm = mg/kg	P x 2.3 = P_2O_5
ppm ÷ 10,000 = %	K x 1.2 = K_2O
% nutrient x 20 = lb nutrient/ton	

Total N can be used to calculate a conservative estimate of safe continuous manure application, as all N will eventually become available. However, the most precise method of calculating long-term application rates requires a calculation of decay rate over a period of three to four years. Computer software is available to help make this calculation. Phosphorus loading should also be considered in determining an acceptable long-term loading rate. In general, P loading is not a primary concern in Colorado because of the large capacity for P fixation of most Colorado soils. It is recommended that manure be applied on a rotational basis to fields going into a high N use crop such as irrigated corn or forage. In situations where a field is loaded with very high amounts of residual NO_3, alfalfa is a good scavenger crop to remove deep NO_3.

Manure Application

Surface applied manure should be incorporated as soon as possible to reduce odor and nutrient loss by volatilization or runoff. The risk of surface loss is reduced by injection application under the soil surface, but still may cause problems on sloping or erosive fields. In general, manure application should be avoided on frozen or saturated fields, unless very level (less than 1% slope), to avoid surface runoff. Delayed incorporation may be acceptable on level fields if sunlight decomposition of pathogens or NH_3 volatilization is desired. If fresh manure is not incorporated within 72 hours after application, more than 30% of the NH_4-N may be lost to volatilization. The rate of volatilization increases in warm, dry, windy conditions.

Calculation 3. Land base for long-term manure disposal

Example: Beef feedlot with 150 steers at 1,000 lb each

Total manure produced	=	11.5 tons/yr/1,000 lb animal (from Table 4)
11.5 ton x 150 animals	=	1,725 tons/yr
150 bu corn/A crop x 1.35 lb N/bu	=	200 lb N/A
Total N in manure	=	10 lb/ton
$\frac{200 \text{ lb N/A}}{10 \text{ lb N/ton}}$	=	20 tons manure/A
$\frac{1{,}725 \text{ tons/yr}}{20 \text{ tons/A}}$	=	86 A minimum land base

Table 4. Typical manure and nutrient production by livestock calculated on an "as excreted" basis per 1,000 pounds of animal

Animal	Raw manure/1,000 lb animal (lb/day)	(tons/yr)	(gal/yr)	N	P_2O_5	K_2O
				----------------	(lb/day/1,000 lb animal)	----------------
Beef cow	60	11.5	2,880	0.34	0.27	0.31
Dairy cow	82	15.0	3,610	0.36	0.10	0.27
Broilers	80	14.5	3,500	1.10	0.78	0.55
Horse	50	9.0	2,160	0.28	0.12	0.23
Lamb	40	7.0	1,680	0.45	0.16	0.36
Swine (grower)	63	11.5	2,800	0.42	0.37	0.26
Turkey	43	8.0	1,880	0.74	0.64	0.64

Source: USDA, Agricultural Waste Management Field Handbook, 1992. Actual amount and content may vary significantly with age, feed ration, breed, and handling.

Manure is most valuable as a nutrient source for crops if it is applied as close to planting as possible. However, manure with a high salt content may affect germination and seedling growth of sensitive crops such as beans. If fall application is necessary in order to clean out manure storage areas, try to wait until after soil temperature is less than 50°F to reduce organic and NH_4 conversion to NO_3. If irrigation equipment is available to apply liquid manure, the best practice is to apply manure in frequent, light applications to match crop uptake patterns and nutrient needs.

Spreader Calibration

The value of carefully calculating manure application rates is seriously diminished if manure spreaders are poorly calibrated. Proper calibration is essential in order to apply manure correctly. Manure spreaders discharge at widely varying rates, depending on travel speed, PTO speed, gear box settings, discharge openings, and manure moisture and consistency.

Calibration requires measurement of manure applied on a given area. The simplest technique for solid manure is to lay out a 10-x-10-foot plastic sheet or tarp in the field and drive over it at the speed and settings you assume are correct for the chosen application rate. Transfer the manure on the tarp to a bucket or washtub and weigh it. Subtract the weight of the bucket, and multiply manure weight (in pounds) by 0.22 to determine tons applied per acre. Best results are obtained by repeating the procedure three times and using the average value. Adjust the spreader or ground speed as necessary to achieve the desired rate. Remember to recheck the calibration whenever a different manure source with a new moisture content or density is applied. Using good equipment and the proper overlap distance will ensure better nutrient distribution and help avoid "hot spots" or areas with nutrient deficiency.

Calculation 4. Manure spreader calibration

Example: Manure collected 3 times on a 10 x 10 ft plastic sheet

(40 lb + 45 lb + 35 lb)/3 = 40 lb manure average

40 lb x 0.22 = 8.8 tons manure applied per acre

Recordkeeping

Accurate recordkeeping is a critical component of any manure management program. Keeping accurate records allows managers to make good decisions regarding manure and nutrient applications. Additionally, these records provide documentation that you are complying with state and local regulations to protect Colorado's water resources. All operators should maintain records of manure applications, laboratory analyses, and crop yields for at least three years. (See Manure Management Record Sheet for suggested format.)

The Bottom Line

New regulations and public concern about our water resources have changed the way that we view animal manure management in Colorado. This so-called "waste" is actually a useful by-product and should be recycled for beneficial purposes. Proper use of manure can be economically advantageous for farmers, saving fertilizer costs and improving soil properties. Voluntary adoption of BMPs for manure utilization can benefit producers and our environment.

Best Management Practices For Manure Utilization

Guidance Principle: Collect, store, and apply animal manures to land at agronomic rates to ensure maximum crop growth and economic return while protecting water quality.

To select manure BMPs that achieve water quality goals and the greatest net returns for your operation, consider:

- most suitable practice to your site and management constraints
- potential leaching hazard of the application site.

General BMPs

3.1 Analyze manure for nutrient content prior to determining application rate.

3.2 Credit nitrate (NO_3) in soil and manure to crop N fertilizer requirement. Account for all available N from crop residues, irrigation, subsoil, and carry-over from previous manure application in establishing any additional fertilizer requirement. Apply commercial fertilizer to manured fields only when soil available N and P, plus nutrients from manure application, do not satisfy crop demands.

3.3 Use a land area of sufficient size to safely accommodate the amount of manure generated by the animal feeding operation (Calculation 3).

3.4 Calculate long-term manure loading rates by using data on organic N mineralization (Table 2) or other appropriate sources. Use soil test data and manure decay constants to determine available nutrients after repeated manure application.

3.5 Maintain records of manure and soil analyses used for determining acceptable land application rates for three years. Also, keep records of all manure applications, fertilizer applied, and crop yields.

Manure Application BMPs

3.6 Base manure application rates upon a site-specific nutrient management plan.

a. Credit of all plant available nutrients from manure, irrigation water, crop residues, residual soil nutrients, and soil organic matter should be based upon laboratory analysis of soil, water, and manure. (See Manure Management Record Sheet for suggested format.)

b. Use calculated plant available nutrients and the crop yield goal to calculate appropriate manure loading rates. Base the yield goal upon an established five-year field average plus a modest increase (5% suggested; see N fertilizer BMPs).

c. Use management factors such as handling, application method, tillage, irrigation regime, cropping pattern, and grazing pattern, and site factors such as soil texture, slope, and aspect in the site-specific nutrient management plan to modify the prescribed manure application rates.

3.7 Incorporate manure as soon as possible after application to prevent surface runoff. Avoid application of manure to lands subject to excessive water erosion.

3.8 Determine soil type and aquifer contamination potential of the application site. If manure is applied on coarse-textured soils, apply near planting time to minimize NO_3 leaching. Multiple light applications are better than a single heavy application.

3.9 Apply manure uniformly with properly calibrated equipment.

3.10 Delay fall application until soil temperatures are below 50 degrees symbol F. Application of manure to frozen or saturated ground should be limited to lands not subject to excessive surface runoff.

3.11 Create an adequate buffer area around surface water and wells where no manure is applied to prevent the possibility of water contamination.

3.12 Plant grass strips around the perimeter of surface water and erosive fields to catch and filter nutrients and sediments in surface runoff.

3.13 Apply manure on a rotational basis to fields that will be planted with high N use crops such as corn or forage. Annual applications to the same field are not recommended, except at low rates.

Storage BMPs

3.14 Locate manure stockpiles a safe distance from all water supply wells. Manure stockpiles should be located on areas not subject to leaching and above the 100-year flood plain, unless adequate flood proofing structures are provided.

3.15 Divert runoff from manure storage sites away from surface waters by construction of ditches or terraces.

3.16 Avoid mechanical disturbance of the manure-soil seal when cleaning feedlots.

3.17 Scrape feedlots or manure storage areas down to bare earth and revegetate after they are permanently abandoned.

For more information about manure management or specific inquiries about BMPs, contact Colorado State University Cooperative Extension. They have publications, programs, and specialists available to help you answer questions about water quality.

Related source material from Colorado State University Cooperative Extension:

SIA	**.549**	**Use of manure in crop production**
	.550	**Nitrogen sources and transformations**
	3.762	**Economics of composting feedlot manure**
Bulletin 552A		**Utilization of Animal Manure as Fertilizer**
XCM-37		**Guide to Fertilizer Recommendations in Colorado**

Additional resources:
USDA Agricultural Waste Management Field Handbook, 1992.

MANURE MANAGEMENT RECORD SHEET

Field description: ______________________________

Previous crop: ______________________________ Yield: ______________

Manure tested by: ____________________ Soil tested by: ____________________

Water tested by: ______________________________

Crop season: ____________________ Crop and variety: ____________________

N Requirement

1. Expected yield: ______________________________ bu/A
   (Past 5-year average + 5%)
2. Total N needed to achieve expected yield: ______________________________ lb/A
   (expected yield x crop factor/efficiency factor)

N Credits

3. Residual soil NO_3 credit: ______________________________ lb N/A
4. Irrigation water NO_3 credit: ______________________________ lb N/A
   (ppm NO_3-N x 2.7 = lb/AF water)
5. Soil organic matter credit: ______________________________ lb N/A
   (credit 30 lb N per % OM)
6. Nitrogen available from previous legume crop: ______________________________ lb N/A
7. N available to crops: ______________________________ lb N/A
   (sum of lines 3, 4, 5, and 6)
8. Plant available N/ton manure: ______________________________ lb/ton
9. Maximum manure application rate: ______________________________ tons/A

Total manure applied: ______________ tons/A Actual yield: ______________ bu/A

N fertilizer applied: ______________ lb/A Total irrigation water applied: ______________ AF

Notes:

Approximate nutrient credits[1] from various manure sources (calculated on a wet weight basis)

Manure	% Moisture	------------Available nutrients in lb/ton ------------			
		First year		Second year	Third year
		N	P_2O_5	N	N
Beef					
feedlot	48	10	8	3	2
with bedding	50	10	10	3	2
lagoon sludge (lb/1,000 gal)	89	36	15	10	5
Dairy					
without bedding	82	6	2	1	1
with bedding	79	6	2	1	1
lagoon sludge (lb/1,000 gal)	92	16	10	3	2
Swine					
without bedding	82	8	5	1	1
with bedding	82	6	4	1	1
lagoon sludge (lb/1,000 gal)	96	38	15	9	4
Sheep					
without bedding	72	8	6	3	2
with bedding	72	7	5	2	2
Horses					
with bedding	54	6	2	2	1
Poultry					
without litter	55	28	26	2	1
with litter	25	43	25	5	2
deep pit (compost)	24	52	35	6	3
Turkeys					
without litter	78	20	11	2	1
with litter	71	15	9	2	1

[1] Values given are approximations only. Analysis of manure and soil is the only accurate way to determine nutrient loading rates due to the wide range of variability in nutrient content caused by source, moisture, age, and handling.

[2] N credit assumes all NH_4-N and NO_3-N is available during the first crop season. Organic N becomes available slowly over a longer period of time. First year N credit assumes manure is incorporated and little volitization occurs. P credit assumes 60% of the P is available in the first year. P credit thereafter should be determined by soil testing.

Values derived from Colorado State University Cooperative Extension Bulletin 552A, Utilization of Animal Manure as Fertilizer, 1992.