13 Nutrient Management Module No. 13

CCA
1.5 NM
CEU

Manure and Biosolids:
Regulation and Management

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Introduction

This module is the thirteenth in a series of Extension materials designed to provide Extension agents, Certified Crop Advisers (CCAs), consultants, and producers with pertinent information on nutrient management issues. To make the learning 'active,' and to provide credits to CCAs, a quiz accompanies this module. In addition, realizing that there are many other good information sources including previously developed Extension materials, books, web sites, and professionals in the field, we have provided a list of additional resources and contacts for those wanting more in-depth information. This module covers Rocky Mountain CCA Nutrient Management Competency Areas VI and VII: Nutrient Source and Applications, and Nutrient Management Planning, with the focus on manure and stabilized municipal wastewater sludge ('biosolids') management.

Objectives

1. Understand pros and cons of manure and biosolids application
2. Distinguish between animal feeding operations and *concentrated* animal feeding operations
3. Understand the regulations that affect a specific livestock operation
4. Be able to alter management practices to reduce water quality and regulatory impacts
5. Recognize the effects of manure and biosolids placement and timing
6. Be familiar with the composting process, including pros and cons of compost

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Background

Livestock manure includes liquid and solid forms of animal wastes, and can be either raw, or treated. Biosolids generally refers to stabilized municipal wastewater solids, but can refer to domestic septage (the solids at the bottom of a septic tank). Both manure and biosolids can be considered either waste products and/or beneficial resources, due to their high concentrations of nutrients and organic matter. Specifically, in concentrated animal feeding operations (CAFOs), and/or near cities, these materials may be considered wastes, yet in many farming operations, they may be beneficial resources. With increasing national focus on water quality, regulations are currently being adopted that stipulate how manure will be managed in CAFOs. Biosolids application to land is regulated by the Environmental Protection Agency (EPA) due to concerns with pathogens, heavy metals, and water quality. Stabilized municipal wastewater sludge has been termed 'biosolids' for at least a decade to differentiate it from industrial sludges or untreated/unstabilized wastewater solids.

Manure, compost, and biosolids are excellent sources of nutrients, as seen in Table 1. Additional manure characteristics can be found in NRCS's Agricultural Waste Management Field Handbook (http://www.info.usda.gov/CED/ftp/CED/neh651-ch4.pdf). Composition of manure is variable, and depends on feed, storage time, storage method, and climate. Depending on the type of manure, approximately 5-20 wet ton/ac would meet the nutrient needs of most Montana crops. In fact, Montana cattle and swine manure contain about as much N as commercial fertilizer applied to cropland each year (DEQ, 1996), although much of this manure is deposited on range and pasture land where it is not available to be applied to cropland. Advantages of using manure or biosolids to supplement or replace fertilizer include the slow-release of nutrients and an increase in soil organic matter. A potential disadvantage is that not all of these nutrients are immediately plant available, as many are tied up in organic forms that require microorganisms and time to release. Other disadvantages are high transport costs, odors, and high variability within, and between, different wastes. An additional disadvantage of manure is the presence of weed seeds. In general, the composition of composted manure and biosolids is less variable than uncomposted materials, and weed seeds and pathogens are lower in compost due to biological degradation and high temperatures.

Table 1. Manure, compost, and biosolids composition.

Estimated liquid pit manure characteristics				
Manure	**Concentration in lb/1,000 gallons of manure**			
	Total N	NH_4-N	P_2O_5	K_2O
Hog-Farrowing	15	8	12	11
Hog- Nursery	25	14	19	22
Hog-Grow-finish, (deep pit)	50	33	42	30
Dairy cow	31	6	15	19
Finishing cattle	29	8	18	26
Estimated solid manure, compost, or biosolids characteristics				
	Concentration in lb/wet ton			
Dairy cow	10	2	3	6
Beef cow	7	3	4	7
Feeder calves (500 lbs)	9	3	4	8
Finishing cattle	11	4	7	11
Layers	34	12	51	26
Cattle Compost	22	--	22	27
Swine Compost	19	--	59	34
Biosolids	64	15	82	7

Use only for planning purposes. These values should not be used in place of a regular manure analysis. Manure data from http://www.ipm.msu.edu/CAT01_field/FC10-05-01Manure.htm. Compost and biosolids data calculated from DEQ (1996) and Loehr et al. (1979), respectively.

Manure Regulations and Guidelines

Manure regulations and guidelines are described in much greater detail by the Montana and Wyoming Departments of Environmental Quality (DEQ) and Natural Resource Conservation Service (NRCS), respectively. The DEQ's regulations ('technical standards') are legally enforceable, whereas the NRCS guidelines are not. Websites to these organizations are listed in the Appendix; therefore, the below descriptions are designed to give the reader a general overview.

MPDES and NPDES Permits

The Clean Water Act directed the Environmental Protection Agency (EPA) to create a water discharge permitting system, called the National Pollutant Discharge Elimination System (NPDES). The EPA delegated administration of this program to Montana in 1974, and to Wyoming in 1975. The Montana and Wyoming DEQ oversee this program and issue permits to control point source discharges of pollution, including those from CAFOs. The Montana DEQ renamed this permitting program as the Montana Pollutant Discharge Elimination System (MPDES), whereas the Wyoming DEQ retained the name, NPDES. Both state-delegated programs detail the definitions of animal feeding operations (AFOs) and CAFOs. AFOs are considered to be nonpoint sources, whereas CAFOs are point sources and require a permit. Fortunately for livestock owners, not all animal operations are considered to be AFOs, and therefore cannot be CAFOs. For example, if livestock are not housed for more than 45 days during a one-year period, or if crops, pasture, or residue remain in the confined area, they are not considered to be AFOs. The 45 days do not need to be continuous, and incidental vegetation is not considered to be residue. In addition, if there is no potential to discharge pollutants to 'state waters', then CAFOs may submit a request that they do not need a permit; the DEQ must grant or deny this request within 90 days of submittal. If the request is granted, a public notice period is required. Definitions of 'state waters' differ slightly between Montana and Wyoming, but they are essentially defined as bodies of surface or ground water and include irrigation and drainage systems. The term excludes waste containment ponds, treatment ponds, irrigation, or land application systems with no discharge to state waters. There is potential to discharge pollutants from manure to state waters if there is a man-made ditch or pipe from the feeding area to surface water OR animals are in contact with surface water running through a confined area.

Figure 1 (next page) defines the numbers of animals in small, medium, and large AFOs and illustrates how to determine if a MPDES permit is required for a specific operation. The criteria are the same for determining the need for a Wyoming NPDES permit except that the Wyoming DEQ does not differentiate between small and medium AFOs. For those facilities that do need a permit, wastewater storage facilities are needed to handle all manure and wastewater that would be generated in a 25-year, 24-hour storm, meaning a one-day storm that occurs, on average, only once in 25 years. For Montana and Wyoming valleys, a 25-year, 24-hour storm can range from approximately 1.6 to 3.2 inches (http://www.wrcc.dri.edu/pcpnfreq). For swine, poultry, or veal calf CAFOs that were designed and built after April 14, 2003, all wastewater, manure, litter, and runoff from a 100-year, 24-hour precipitation event (2.2 to 4.2 inches for Montana and Wyoming valleys) must be contained. In addition, permit holders need to meet all groundwater standards for the state, not exceed *average* annual crop nutrient requirements for applied manure, and prepare a Nutrient Management Plan (NMP) in accordance with technical standards adopted by the DEQ.

Due to the time and expense of the

Confinement-based systems

Confinement systems include open lots (typically little or no vegetation) and roofed animal housing or barns where animals are commonly housed or fed.

Pasture-based systems

Does livestock operation house or feed animals in a confined area for more than 45 days in any 12-month period?

YES → Does the animal confinement sustain any crops, pasture, or residue (incidental vegetation does not count) when animals are confined?

NO → **Not an AFO. No MPDES permit required**

(Crops, pasture, or residue sustained?) YES → **Not an AFO. No MPDES permit required**

(Crops, pasture, or residue sustained?) NO → Step 2

Step 2. Am I a CAFO (concentrated AFO) ? Check the number of animals in your AFO.

Species	Column A: Large	Column B: Medium	Column C: Small
Beef cattle or cow/calf pairs	____ 1,000 or more	____ 300 to 999	____ less than 300
Veal	____ 1,000 or more	____ 300 to 999	____ less than 300
Mature dairy cattle	____ 700 or more	____ 200 to 699	____ less than 200
Dairy heifers	____ 1,000 or more	____ 300 to 999	____ less than 300
Swine (55 lbs or more)	____ 2,500 or more	____ 750 to 2,499	____ less than 750
Swine (less than 55 lbs)	____ 10,000 or more	____ 3,000 to 9,999	____ less than 3,000
Turkeys	____ 55,000 or more	____ 16,500 to 54,999	____ less than 16,500
Laying hens or broilers [1]	____ 30,000 or more	____ 9,000 to 29,999	____ less than 9,000
Laying hens [2]	____ 82,000 or more	____ 25,000 to 81,999	____ less than 25,000
Chickens except laying hens	____ 125,000 or more	____ 37,500 to 124,999	____ less than 37,500
Ducks [1]	____ 5,000 or more	____ 1,500 to 4,999	____ less than 1,500
Ducks [2]	____ 30,000 or mo re	____ 10,000 to 29,999	____ less than 10,000
Sheep or lambs	____ 10,000 or more	____ 3,000 to 9,999	____ less than 3,000
Horses	____ 500 or more	____ 150 to 499	____ less than 150

Step 3. At least one check in Column A:

Animal operation is a **Large CAFO**. Large CAFOs have two options:

Demonstrate that CAFO has no potential to discharge. Must submit request to DEQ for approval or denial.

MPDES permit is required. Producer must submit application to MT DEQ.

Step 3. At least one check in Column B and no checks in Column A:

Animal operation is a **Medium AFO** and is defined as a CAFO if:

1) Animals are in contact with surface water running through the area where animals are confined.

OR

2) A man-made ditch or pipe carries manure or wastewater from animal housing or feeding area to surface water?

Step 3. At least one check in Column C and no checks in Columns A or B:

Animal operation is a **Small AFO** and may be designated a CAFO if:

1) Animals are in contact with surface water running through the area where animals are confined.

OR

2) A man-made ditch or pipe carries manure or wastewater from animal housing or feeding area to surface water?

(Column B: OR; Column C: AND) → 3) Regulatory Authority has determined that this operation is contributing significant pollutants to surface water?

YES → **MPDES permit is required.** Producer must submit application to MT DEQ.

NO → **No MPDES permit required**

1. Only applicable to poultry operations with liquid manure systems
2. Other than a liquid manure system

Figure 1. Flowchart to determine if a livestock operation requires a MPDES permit (Fisher and Surber, 2003). Note: Animals do not need to be confined for the entire day to count as one day.

permitting process, the best option for livestock owners may be to eliminate any potential for direct discharge to water. For those that cannot, financial assistance may be available (Q&A #1). Please see the Appendix for agency personnel who can help determine if you need a MPDES or NPDES permit, and can help you through the regulatory process.

Land Application Guidelines

The NRCS Conservation Practices, 590 and 633, detail how, and how much, manure should be applied to fields. These guidelines consider not just manure, but also commercial fertilizers, legume crops, residues, and biosolids. NRCS Conservation Practice, Nutrient Management 590, describes steps and methods for preparing a comprehensive nutrient management plan (CNMP). Most CNMPs will cover all the requirements of a NMP (described in more detail in the next section). The NRCS Conservation Practice, Waste Utilization 633, describes how N or P uptake rates can be matched with applied nutrients. Specifically, the guidelines provide worksheets in either hardcopy form, or computer spreadsheet form (see Appendix for website), to determine application rates. These worksheets provide the fractions of N, P, and K that are assumed to be lost by various nutrient cycling mechanisms. For example, if the manure is broadcast and immediately incorporated, the Waste Utilization 633 guidelines assume that 30% of the initial N will volatilize in the first 12 hours and 50% will volatilize if incorporated after more than 4 days, whereas only 5% will volatilize if knife-injected. In addition, it is assumed that 20% of P will be unavailable for crop uptake (or movement). The worksheets, then, provide a method for calculating a nutrient mass balance for a specific field. Although the guidelines provide methods to estimate nutrient concentrations in manure, collecting and submitting manure samples for analysis is necessary for accurate characterization, and is required annually for CAFOs. Manure samples should be composited due to substantial variability within a manure pile. Furthermore, analyses should be done immediately prior to application because nutrient concentrations in manure can change with time.

A "P index" can be used to determine if manure application rates should be based on P, or on N. The P index considers: potential for runoff and erosion, the P soil test level, rates and methods of nutrient application (both commercial fertilizer and organic materials), and the distance to surface water (Table 2, next page). If the P index is 21 or less, then manure application rates can be based on N, meaning that crop N uptake should not exceed applied available N. Conversely, if the P index is 22 or greater, the NRCS recommends that manure application amounts be based on P. Application rates based on N will generally be at least 2 fold higher than if based on P. In addition, if application rates are based on P, supplemental N fertilizer may be needed to maximize crop yields in most cases. Therefore, it may be advantageous for livestock producers to keep the P index low.

Q&A #1

It looks like meeting CAFO regulations could cost a livestock owner a substantial amount of money. Is there any financial help out there?

Yes, the USDA-NRCS has money available to help with construction of dams, diversions, filter strips, fences, etc. to minimize or eliminate nutrient movement to waters. These grants generally have a cost-share component. Wyoming operations may also be eligible for financial assistance from the Agricultural Management Assistance (AMA) program. See the Appendix for the USDA and AMA websites or contact your local NRCS office for more information.

Nutrient Management Plans and Comprehensive Nutrient Management Plans

At the time of this writing (June 2004), neither Montana nor Wyoming had adopted standards for requirements of a NMP; however, state standards cannot be less restrictive than the federal EPA requirements. These requirements are included on the following website: http://www.epa.gov/npdes/pubs/cafo_prod_guide_ch5.pdf, and are similar to the CNMP contents outlined below with the following exceptions: The EPA NMP requires discussions of carcass disposal and chemical handling, whereas the NRCS CNMP does not. State requirements should be listed on each respective state DEQ's websites when they are finalized.

CNMPs are flexible plans that can be prepared with the assistance of the NRCS, or other certified CNMP planners, to help assure that the nutrient management objectives of the producer are being met for crop and forage production. The CNMP will also ensure that state and federal regulations for AFO/CAFO systems are being met, while optimizing nutrient reuse on a farm. CNMPs consider the following six aspects (NRCS, 2004): *Manure and Wastewater Handling and*

Table 2. Phosphorus Index Assessment (Fasching, 2001).

SITE CATEGORY	NONE (0) WEIGHTED	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	Risk Value (0,1,2,4,8)	Weight Factor	TOTAL
Soil Erosion	N/A	<5 tons/ac/yr	5-10 tons/ac/yr	10-15 tons/ac/yr	>15 tons/ac/yr		X 1.5	
Furrow Irrigation Erosion	N/A	Tailwater recovery, QS>6 very erodible soils, or QS>10 other soils	QS*>10 for erosion resistant soils	QS*>10 for erodible soils	QS*>6 for very erodible soils		X 1.5	
Sprinkler Irrigation Erosion	All sites 0-3% slope, all sandy sites, or site evaluation indicates little or no runoff, large spray on silts 3-8%	Medium spray on silty soils 3-15% slopes, large spray on silty soils 8-15% slope, low spray on silt soils 3-8%, large spray on clay soil 3-15% slope	Medium spray on clay soils 3-8% slopes, large spray on clay soils >15% slope, medium spray on silt soil >15% slope	Medium spray on clay soils >8% slope, low spray on clay soil 3-8% slope, low spray on silty soils >15% slope	Low spray on clay soils >8% slope		X 0.5	
Runoff Class	Negligible	Very low or low	Medium	High	Very High		X 0.5	
Bray P Soil Test **	-----	<30 ppm	30-60 ppm	60-120 ppm	>120 ppm		X 1.0	
Olsen P Soil Test**	-----	<20 ppm	20-40 ppm	40-80 ppm	>80 ppm		X 1.0	
Commercial P Fertilizer Application Method	None Applied	Placed with planter or injected deeper than 2 inches	Incorporated <3 months prior to planting or surface applied during the growing season	Incorporated >3 months before crop or surface applied <3 months before crop emerges	Surface applied >3 months before crop emerges		X 1.0	
Commercial P Fertilizer Application Rate	None Applied	<30 lb/ac P_2O_5	31-90 lb/ac P_2O_5	91-150 lb/ac P_2O_5	>150 lb/ac P_2O_5			
Organic P Source Application Method	None Applied	Injected deeper than 2 inches	Incorporated <3 months prior to planting or surface applied during the growing season	Incorporated >3 months before crop or surface applied <3 months before crop emerges	Surface applied to pasture or >3 months before crop emerges		X 1.0	
Organic P Application Rate	None Applied	<30 lb/ac P_2O_5	31-90 lb/ac P_2O_5	91-150 lb/ac P_2O_5	>150 lb/ac P_2O_5		X 1.0	
Distance to Concentrated Surface Water Flow	>1,000 feet	200-1,000 feet, or functioning grasses waterways in concentrated surface water	100-200 feet	<100 feet	0 feet or applications are directly into concentrated surface water flow areas		X 1.0	
					P INDEX VALUE (SUM OF TOTALS)			

*QS value = Furrow Flow Rate (gpm) X Furrow Slope (%).
**Only use one soil test (either Bray or Olsen).

Storage outlines physical structures used to store or transfer manure, including conservation measures such as lagoons or holding pits. *Feed Management* refers to steps taken to reduce the nutrient content of manure. This includes adding 'phytase' enzymes to the feed to increase P digestibility and minimize the amount of phosphorus excreted by animals. *Nutrient Management* describes the sources and amount, timing, and application methods of nutrients including manure to be applied to specific fields. This section will also document "planned crop rotations; realistic yield goals; current soil tests; manure and by-product nutrient concentration analysis; a description of application equipment; and the method used for calibration" (NRCS, 2004). *Land Treatment Practices* describes what methods are used to apply manure, as well as strategies to reduce offsite transport of nutrients, such as diversions, filter strips, residue management, contoured buffered strips, etc. This section should also describe when waste would not be applied, such as on saturated or frozen ground. *Record Keeping* is critical for livestock owners, or their consultants, in order to track a number of aspects of their livestock operation to document that they are meeting the Montana Water Quality Act or Wyoming Environmental Quality Act, and to possibly show that they do not meet the definition of a CAFO. This can be done by recording the number of each type of animal (from Figure 1) during each major season, and keeping track of manure application. Specifically, the amount of manure applied and to how much land needs to be documented (See Q&A #2). The record keeping portion of the CNMP will list the records that will be kept, and may include weather conditions 3 days prior to and 3 days after application events, crops planted, tillage methods, crop yield, and those items listed under Nutrient Management above. *Other Manure and Wastewater Utilization Options* simply lists if alternatives such as composting or biogas production (both described later) will be used. The NRCS has a copy of an example CNMP, entitled "Valley View Dairy Sample CNMP Plan," for those wanting more details on typical CNMP contents.

In order to develop CNMPs, the NRCS has developed a process for any consultant to become a certified Comprehensive Nutrient Management Planner (CCNMP). This process involves the following steps:

1. Complete NRCS's Introduction to Water Quality Modules (1-6)
2. Complete Nutrient and Pest Management Considerations in Conservation Planning
3. Take a Facilitated Course for Nutrient and Pest Management Considerations in Conservation Planning
4. Complete a CNMP plan, and have it reviewed and approved by the State Agronomist

The NRCS is currently considering ways to make CCAs eligible to become CCNMPs without completing all of the above requirements, although a CCA can become a CCNMP and receive Soil and Water Management CEUs for completing each step above. It should be noted that the NMP required by MPDES and NPDES permits does not need to be prepared by a CCNMP or CCA.

Q&A #2

How do I calculate the weight of manure if I don't have access to a truck scale?

Measure the average height, width, and length of a manure load in feet and multiply all 3 to obtain the manure volume in cubic feet. Then simply divide this number by 32 for wet manure or 36 for dry manure to obtain the wet tons per load.

Compost

A solid waste permit is required for all compost facilities built in Montana, whereas those built in Wyoming do not require a solid waste permit. For those considering bagging and marketing compost, compost will only need to be approved by the Department of

Agriculture in the state the product is sold *if* claims are made that the compost will produce a benefit, such as improving soil structure or increasing yields, or a fertilizer grade (N-P_2O_5-K_2O) is reported.

Biosolids Regulations

Biosolids management is regulated by the Environmental Protection Agency (EPA) in Title 40 of the Code of Federal Regulations (CFR) Part 503, which stipulates requirements for biosolids application to land. These requirements include 'pathogen reduction' (steps to decrease pathogens), methods to minimize human exposure to pathogens, metal loading and concentration standards, and nutrient guidelines. The Montana DEQ does not regulate the land application of biosolids, with the exception that wastes may not be placed where they may enter state waters. Instead, EPA Region 8 has issued a General Permit for the land application of biosolids, and coverage must be obtained under this permit prior to land applying biosolids. Additional regulations can be found on the EPA Region 8 website. The Wyoming DEQ issues permits for land application of biosolids for systems under 10,000 (EPA reviews these permits) and both the Montana and Wyoming DEQ regulate the management of domestic septage. The rules for land application of septage for both states, and for biosolids in Wyoming, are on websites listed in the Appendix.

Pathogens

Pathogens in biosolids and septage should be reduced prior to application to the land to minimize potential for disease. There are two classes of pathogen reduction: Class A and Class B. Class A pathogen reduction is necessary if biosolids or septage are to be applied to lawns or bagged for sale and requires that fecal coliform levels be reduced to less than 1000/g-biosolids. Public access is not restricted for wastes that meet Class A requirements. Class B pathogen reduction is necessary for any other application and requires that fecal coliform concentrations be decreased to less than 2 million/g. For Class B biosolids or septage, public access to land with a low threat of public exposure (likely most agriculture land) needs to be restricted for 30 days after biosolids application, and public access to land with a high potential for public exposure needs to be restricted for 1 year after application. In addition, food, feed, and fiber crops cannot be harvested for 30 days after biosolids are applied, and this required duration for harvested food crops increases (to up to 38 months) if the biosolids are not immediately incorporated into the soil. Finally, animals cannot be grazed within 30 days after application. The Appendix contains a website detailing additional pathogen requirements from 40 CFR 503.

Metals

Limits exist for maximum, or ceiling, metal concentrations and maximum cumulative metal loading rates (in lb/ac) of biosolids. Limits for the nine regulated potential pollutants are given in Table 3.

Table 3. Pollutant ceiling concentrations, typical MT concentrations, and cumulative loading amounts for biosolids (from 40 CFR 503.13).

Pollutant	Ceiling Concentration (ppm)	Selected* MT Biosolids Concentrations (ppm)	Cumulative Pollutant Limit Loading (lb/ac)
Arsenic	75	<0.4 – 7	37
Cadmium	85	<0.3 – 5.3	35
Copper	4300	18 - 700	1340
Lead	840	7.5 - 94	268
Mercury	57	<0.05 - 12	15
Molybdenum	75	<0.5 - 9	--
Nickel	420	4 - 13	375
Selenium	100	<0.3 - 6	89
Zinc	7500	23 - 1740	2500

* Ranges are from 2 treatment plants; one serves a city of 1,000, and includes 7 sub samples, and one serves a city of 30,000.

Due to limited industry in Montana and Wyoming, the ceiling pollutant concentrations are likely not exceeded in either of these two states. In addition, cumulative loading limits would likely not be reached for many centuries of application (see Calculation Box #1). Therefore, nutrients, rather than metals, will most likely limit biosolids application rates in Montana and Wyoming.

Nutrients

Unlike manure regulations, maximum nutrient application rates in federal biosolids regulations are not well defined. Instead, the EPA 503 regulations simply stipulate that agronomic rates cannot be exceeded. Therefore, a similar nutrient budget would need to be conducted for biosolids application using book values or NRCS values for N mineralization, volatilization, and denitrification. For example, typical values for N mineralization in the first year of biosolids application range from 20% to 45% for anaerobically digested biosolids and activated, unstabilized biosolids, respectively (Brady and Weil, 2002). The NRCS recommends using a mineralization rate of 35% for digested biosolids in the first year after application. Similar to manure application guidelines, biosolids application amounts should be based on N application rates if the P index is low or medium, but should be based on matching P uptake if the P index is high. Maximum septage application rates are generally limited by N application rates and are given by the following in both Montana and Wyoming regulations:

AAR = N/0.0026

where AAR = annual domestic septage application rate in gallons/ac-year and N = nitrogen needed by the crop in lb/ac-year.

Calculation Box #1

How many years can biosolids with 530 ppm copper (530×10^{-6} lb Cu/lb-dry biosolids) be applied if the biosolids application rate is 6,000 dry lb/ac-year? (This Cu concentration and application rate were obtained from a municipal wastewater treatment plant in Montana).

$$\text{Calculation: Time} = \frac{\text{Cumulative Loading Rate}}{\text{Cu applied per year}}$$

$$\text{Time} = \frac{1340 \text{ lb Cu/ac (from Table 3)}}{(530 \times 10^{-6} \text{ lb Cu/lb-dry biosolids})(6{,}000 \text{ lb/ac-year})}$$

= 421 years

This calculation would need to be repeated for each of the potential pollutants with cumulative pollutant loading limits shown in Table 3, and the minimum years used as a site life.

Manure Management and Water Quality

This section does not pertain to manure management in rangeland or pasture, where little, if any manure management is necessary. It instead focuses on manure management in confined locations, where the manure will need to be managed to protect water quality and will likely be used as a nutrient source.

Runon-Runoff Control

Whether the manure is scraped, hauled, and stored, or left in place, there will always be time periods when some

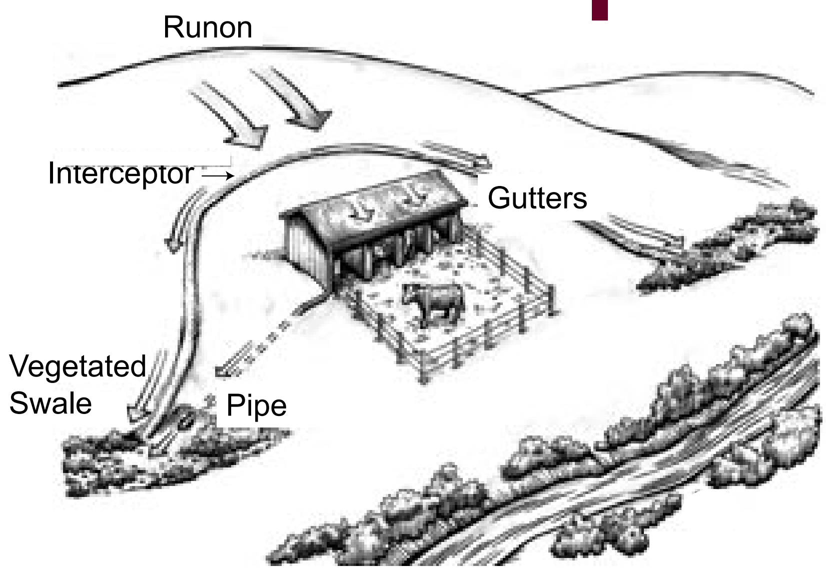

Figure 2. Runon control for an animal feeding operation. Modified from DEQ (1996).

Figure 3. Filter strip for a horse corral.

manure is on the soil surface. Proper runon-runoff control can be very effective at preventing this manure, or nutrients in this manure, from leaving the property and possibly entering waterways.

Runon

By reducing or eliminating 'runon' (water that enters the waste management area), there is less water to runoff, and also less water to store or treat (Figure 2, previous page). Runon control can be accomplished on the uphill side of waste management areas by constructing *clean water 'interceptors'* such as ditches, swales, berms (earthen, straw, or sandbag), curbs (wood, concrete, or rubber), or an interceptor trench (DEQ, 1996). An interceptor trench is dug perpendicular to the water flow direction and filled with rocks. *Roof runon controls* can also be used to keep roof runoff from entering waste management areas. These controls include gutters connected to drainage systems to move water away, and keep it away, from waste management areas. Finally, *temporary covers* can be used for manure that is not contained in a building. This, of course, is primarily practical for smaller waste piles.

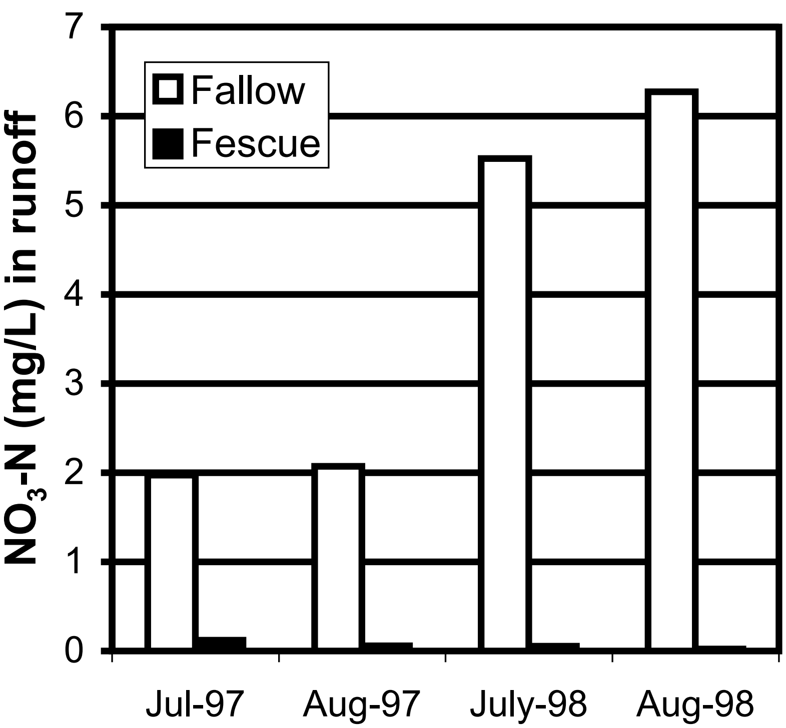

Figure 4. Effects of fallow and vegetated filter strips (100 ft. long) on nitrate concentrations in runoff from manure piles (Fajardo et al., 2001). Each concentration is averaged from four samples collected at 0, 20, 40, and 60 minutes after the beginning of a 0.8 inch simulated rain event.

Runoff

While the best way to reduce runoff is by controlling runon, there may still be runoff from outdoor animal facilities, even if runon is completely controlled. To prevent runoff, it may be necessary to install ponds or tanks to store manure until it can be transported. These storage facilities need to be able to contain runoff generated in a 25 year-24 hour storm, as stated earlier. Storage systems primarily consist of storage lagoons or evaporation ponds. Some runoff can be diverted to vegetated filter strips (VFS), which are areas of vegetation that promote infiltration, sediment retention, and nutrient removal (Figure 3), as long as this runoff does not reach surface water and does not contaminate groundwater. Small AFOs are more suited for VFS than large operations. Vegetation would need to be harvested occasionally from these strips to prevent excessive nutrient accumulation. A two-year VFS study in Montana found that 100-foot long filter strips of tall fescue decreased nitrate concentrations from manure runoff by approximately 98% compared to fallow strips (Figure 4).

Direct Animal-Water Contact

There are a number of available methods to prevent direct contact of animals, and hence manure, with surface waters. These include permanent and temporary fences, and off-stream water development such as troughs that have been filled from either an upstream diversion or from groundwater pumping (DEQ, 1996).

Land Application

Manure and biosolids are excellent soil amendments and fertilizers, and can match or exceed yields attained with commercial fertilizer, especially when applied for multiple years. Specifically, manure and biosolids applied at 6 dry t/ac produced slightly higher grass yields than urea applied at 240 lb N/ac in the second year of a study conducted in Washington State. In the third year, no manure and biosolids were applied, yet yields were still higher in the manure and biosolids plots than when 160 lb N/ac of urea was applied (Figure 5). The 6 dry t/ac rate was designed to apply 120 lb available N/ac based on N mineralization rates of 35% and 20% for manure and biosolids, respectively. The comparable yields between commercial fertilizers and the organic fertilizers strongly suggest that more N can become plant-available than had been assumed. Just like with commercial fertilizers, placement methods and rates can have large effects on yield, protein, weeds, and water quality, as covered in detail in Nutrient Management Module 11 (*NM 11*), with specifics on organic waste placement methods and rates introduced below.

Placement Methods

Various methods exist for applying organic wastes (Table 4). The advantages and disadvantages of each may vary with the operation's goals. For example, for a facility that produces a large amount of manure and has minimal nearby land, the goal may be to apply as much as legally possible. If land application rates are based on N for this facility, maximizing ammonia volatilization is advantageous because it will allow a larger amount of manure to be applied (although downwind odors may need to be considered). This can be accomplished by storing the waste material for longer periods and

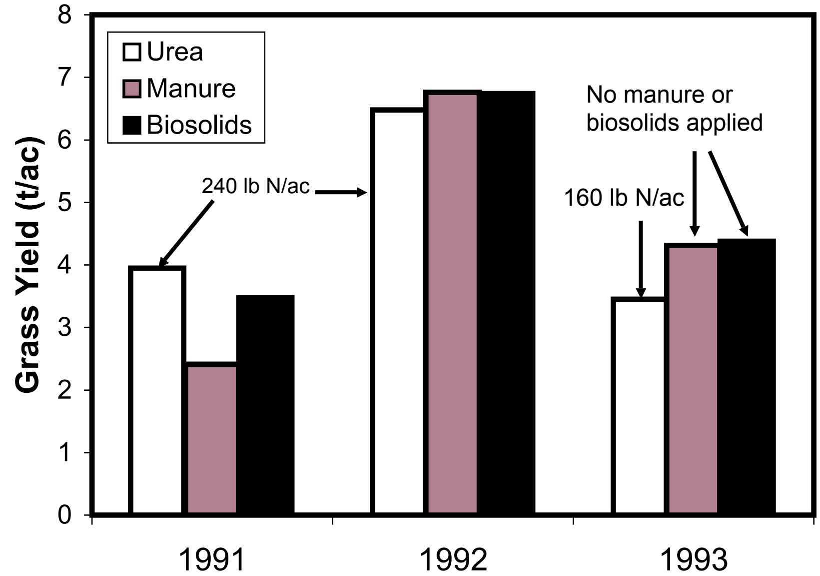

Figure 5. Effect of manure and biosolids application on grass yield compared to urea application (Sullivan et al., 1997).

Table 4. Land application methods. (Adapted from DEQ, 1996)

Application Method	Major Advantages	Major Disadvantages
Big gun irrigation	Fast, flexibility with application time	Odors, pumping costs, ammonia volatilization
Incorporation	Minimizes ammonia volatilization and odor	Reduces residue cover, may need specialized equipment
Lump spreading	Inexpensive/low maintenance	Uneven distribution
Manure Spreader	Relatively inexpensive	Difficult to apply uniformly
Tank wagon	Uniform application	Slow, soil compaction, ammonia volatilization

surface applying the material without incorporation. For smaller operations that wish to maximize the nutrient resource in the manure, or when manure application rates are based on P, not N, minimizing N losses is the likely goal. In these situations, it will be advantageous to incorporate the manure as soon as possible after application.

Based on research conducted on commercial fertilizers, it is likely advantageous to apply organic wastes near the area of maximum root growth (*NM 10*). Specifically, both barley and oat vegetation indices (measure of growth) were found to be significantly greater when liquid manure was injected rather than surface-applied (Rasmussen, 2002). This study also found that weed biomass was reduced 52% by injecting manure, likely due to more vigorous crop growth outcompeting the weeds. In addition, dissolved P concentrations in runoff have been found to be 2- to 5-fold less when manure is incorporated rather than broadcast (Tabarra, 2003).

Application rates

Manure application rates should be based on matching either N or P uptake rates of the crop. The NRCS, many County Extension Agents, and Extension Specialists can help determine whether rates should be based on N or P, as determined by the P index. If rates are based on P (meaning the P index is high), application rates will be calculated by assuming that 80% of the P in manure is plant available. The amount of plant available P is then matched with P uptake amounts that are given in Table 21 of EB 161, *Fertilizer Guidelines for Montana Crops* (see Calculation Box #2). If rates are based on N, calculations become more complicated. Specifically, an N mass balance needs to consider manure mineralization from the current and two previous years, credits from previous legume crops, volatilization losses, and denitrification losses, as detailed in NRCS Code 633. As mentioned previously, software is available to help with these calculations.

Calculation Box #2

Question: My client is growing grass and expects a yield of 3 t/acre. How much manure that contains 20 lb P_2O_5/wet ton can be applied if the goal is to match manure application rates with P uptake rates? (The P index is apparently high; otherwise, the goal would be to match application rates with N uptake rates)

Calculation: Manure application rate = P removed by crop/ (P concentration in manure x 0.8)

From EB 161, Table 21, it is found that grass removes 10 lb P_2O_5/t

Manure application rate = (3 t grass) x (10 lb P_2O_5/t grass)/((20 lb P_2O_5/wet ton manure) x 0.8)
Manure application rate = 1.9 wet ton/ac

Follow-up question: How much total N would this supply if the manure contained 8 lb N/wet ton, and it is assumed that volatilization and denitrification losses are minimal.

Calculation: N applied = manure application rate x N concentration

N applied in manure = (1.9 wet ton/ac) x (8 lb N/wet ton) = **15 lb N/ac**

Composting and Biogas

Composting

Composting refers to the biological aerobic decomposition of an organic material, such as manure or biosolids, to produce a more stable soil amendment, with higher economic value than the uncomposted material. Other advantages of compost compared to raw manure or biosolids include decreased volume of material, slow-release of nutrients, and reduction in weed seeds and pathogens. Compost can be used on farmland but is more often used for restoration, revegetation, landscaping, or gardening, due to expense. Producing compost to sell may be a viable alternative for livestock producers with limited land to apply their manure to, especially if there's a demand for compost in the vicinity.

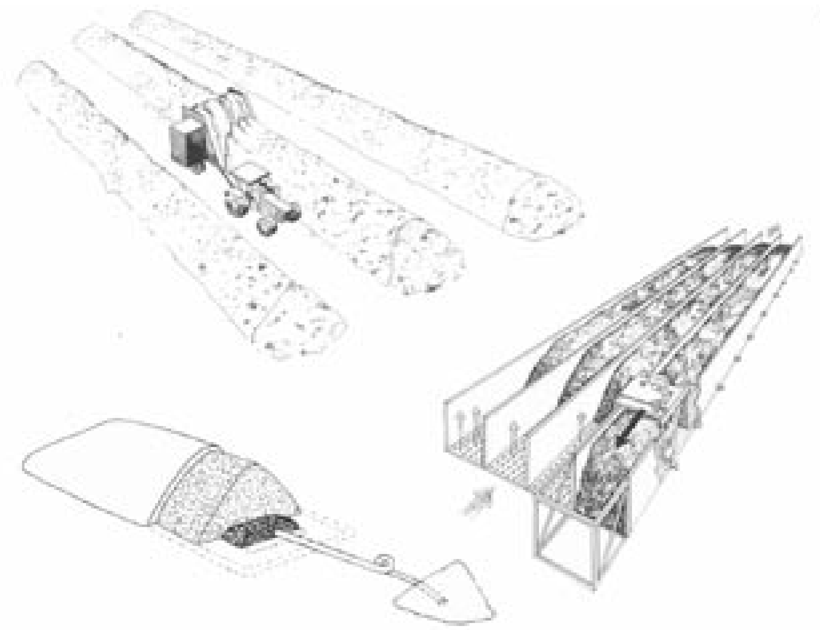

Figure 6. Windrow (upper), static pile (left), and in-vessel composting (lower right). From NRAES (1992).

Bulking agents

Manure and biosolids will slowly decompose if left untreated, but this often results in anaerobic and odorous conditions, due to a low C:N ratio and high moisture content. Therefore, a 'bulking agent', such as straw, sawdust, or chipped yard waste, is often added to help with the composting process. All of these bulking agents have high C:N ratios which help offset the relatively low C:N ratio of manure and biosolids (approximately 7-20:1), and can soak up excess water. To determine how much bulking agent to add, you would first need to know the approximate C:N ratio in the organic waste, and then target a final C:N ratio of 25-30:1, and a moisture content of 50-60%. If the C:N ratio is too high, the composting will come to a halt (generally judged by compost temperatures below 100° F), and if too low, the compost pile will become odorous.

Methods

Composting of the manure or biosolids/bulking agent mixture can be done in static piles that have perforated pipes running through the pile for aeration, long piled 'windrows' that need to be turned frequently, or in enclosed vessels, called in-vessel composting (Figure 6). The 'active' composting portion can take 4-12 months, followed by a curing period of at least 2 months. 'Vermicomposting' uses earthworms to break down organic matter, and can turn manure into a composted product in a much shorter time period than traditional composting. The finished product, sometimes simply called "worm castings," draws a higher price than traditional compost, but is much more time intensive to produce. Composting is most effective if performed in a covered area to prevent rain or snowfall from increasing moisture and decreasing temperatures in the pile. In addition, covering compost should protect water quality.

Nutrient Availability

Finished compost will have less immediately available nutrients than the raw uncomposted material because these nutrients are tied up in microorganisms. For example, compost fertilizer grades may be as low as 1-0.1-0.1, indicating that not much of the nutrients in the compost are immediately available. However, total nutrients are often higher in compost than manure (Table 1) and will release these nutrients more gradually over several growing seasons.

Biogas Production

Microorganisms can break down manure into methane, or natural gas, which could then be sold or utilized onsite. This process requires sophisticated equipment and high initial and maintenance costs. Although the by-products could be used as fertilizer, much of the C and N in the original waste will be lost, decreasing the worth of the by-product. Therefore, the fertilizer value of the original waste may be higher than the value of the energy produced. There are a large numbers of resources on biogas production, including methods and economic analyses, available on the Internet, and selected websites are contained in the Appendix. There are no known biogas generators in Montana or Wyoming, although one will be built soon at a dairy farm in Gallatin County, Montana.

Summary

Manure and biosolids can be excellent sources of organic matter and nutrients, yet need to be managed carefully to meet federal and state regulations that were designed to protect water quality and human health. Proper runon and runoff control at animal feeding operations avoid directly discharging manure and nutrients to water.

Both manure and biosolids can be applied to the land. Yields, grain protein, weeds, and runoff water quality can all be affected by application rates, placement, and timing. Developing a comprehensive nutrient management plan with help from state and federal agencies, combined with record keeping, will prove useful for those using manure or biosolids as fertilizers or soil amendments. Composting of organic materials can be economically advantageous in regions with high landscaping or reclamation compost needs and those that are close to their final market. Finally, producing biogas from manure or sludge may help offset energy costs, yet more experimental biogas generators in this region will be necessary to know their worth.

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APPENDIX

Books

Field Guide to On-Farm Composting, 1999. NRAES-114. This publication is a handy reference guide that helps on-farm composters find practical information about composting quickly and easily. 128 pages. ISBN: 0935817395. Order from: http://www.mwpshq.org/. $14.

Composting for Manure Management and **The Composters' Answers** Book. Volume I. Order either of these two or other composting books from: http://www.jgpress.com/BioCycle/Books.html. Both are $39.

Extension Materials

Fertilizer Guidelines for Montana Crops. EB 161. Free.

Nutrient Management Modules 1-15
Available and can be obtained online or at the address below (add $1 for shipping).

Extension Service Materials can be obtained from:

MSU Extension Publications
P.O. Box 172040
Bozeman, MT 59717-2040

See **Web Resources** below for online ordering information.

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Web Resources

http://www.deq.state.mt.us/wqinfo/MPDES/CAFO.asp
MT DEQ website with information on the MPDES, including an application for a CAFO discharge permit.

http://cfpub.epa.gov/npdes/afo/compliance.cfm#copy
EPA Producer's Guide answering questions such as "Do these regulations apply to me?" (Chap. 3) and information on Nutrient Management Plans (Chap. 5).

http://deq.state.wy.us/wqd/pointsources.asp
Wyoming DEQ site with information on the NDPES, including an application for a CAFO discharge permit and contact information for permitting personnel.

http://www.esri.sc.edu/Projects/usda/application_development/afopro.asp
Software for calculating manure application rates. NRCS-USDA sponsored site.

http://www.epa.gov/region08/water/wastewater/biohome/biosolidsdown/handbook/handbook.html
Biosolids Management Handbook from the EPA, Region 8 website.

http://www.mt.nrcs.usda.gov
Montana's NRCS homepage.

http://www.wy.nrcs.usda.gov
Wyoming's NRCS homepage.

http://www.nrcs.usda.gov/programs/afo/CAFO_RuleFacts.pdf
NRCS webpage with information on financial and technical assistance available for CAFOs.

http://www.nrcs.usda.gov/programs/eqip/
Information on USDA EQIP program.

http://www.deq.state.mt.us/dir/legal/Chapters/CH50-08.pdf
Septage rules in Montana.

http://soswy.state.wy.us/rules/2805.pdf
Biosolids and septage rules in Wyoming.

http://www.tmecc.org/links.html
The Composting Council Research and Education Foundation (CCREF) page with links to composting websites and EPA 503 Regulations.

http://www.agr.gov.sk.ca/docs/crops/integrated_pest_management/Soil_fertility_fertilizers/CompostManure02.asp
An overview of composting operations, including details such as carbon to nitrogen ratios, and ideal temperature and moisture.

http://www.epa.gov/region08/water/wastewater/biohome/biohome.html
EPA Region 8 sewage biosolids regulations and general permit for disposal.

http://www.ext.colostate.edu/pubs/farmmgt/05002.html
An overview of biogas production, including the digester process, gas production, and basic components needed for a biogas generator.

http://redhot.ncat.org/mirrors/attra.internal.ncat.org/attra-pub/anaerobic.html
Website with an introduction to anaerobic digestion and biogas production. Includes information on biogas uses, design factors, system costs, and additional resources.

http://www.montana.edu/publications
Montana State University Publications ordering information for Extension Service Publications.

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