

SOILS AND FERTILIZERS
MODULE 12
CHARACTERISTICS AND USE OF NATURAL ORGANICS AS FERTILIZERS

1. Definitions

Animal Tankage - Rendered, dried, and ground byproducts of the slaughter of animals (largely meat and bone). Some is used as fertilizer but most is used in animal feeds.

Bone Meal - Organic source of calcium and phosphorus derived from dried and ground animal bones.

Biosolids (Sewage sludge) - Solids removed from sewage by screening, sedimentation, chemical precipitation, or bacterial digestion. Five types of sludge are produced: raw, digested, activated, digested activated, and chemically precipitated. *Activated sludge* is made from biosolids freed from grit and coarse solids, and aerated after being inoculated with microorganisms. The resulting flocculated organic matter is withdrawn from the tanks, coagulated, filtered, dried, ground, and screened.

Castor Pomace - The ground residue of castor beans, from which the oil has been extracted. Cannot be used for animal feed because its ricin content makes it poisonous.

Compost - Straw, peanut hulls, sawdust, leaves, and similar organic matter high in cellulose and pentosan, but low in nitrogen. Does not decompose readily. Addition of nitrogen fertilizer promotes rapid compost formation.

Fish scrap or Fish Tankage - Processed non-edible fish, spoiled edible fish, and entrails. Acid fish scrap has been treated with sulfuric acid. Mostly used for animal feed.

Garbage Tankage - Dried and ground product remaining from waste household food materials.

Guano - Partially decomposed excrements of birds, bats, seals, or other animals. (Was at one time a significant organic fertilizer source, but is no longer of major importance.)

Manure - Excreta of animals; dung and urine with the straw or other materials used as the absorbent. The plant nutrients in manures are almost entirely present in insoluble compounds that must be decomposed before they become available to plants.

Natural Organics - By-products from processing of animal or vegetable substances that contain sufficient plant nutrients to be of value as fertilizers.

Organic Fertilizer - A material containing carbon and one or more elements other than hydrogen and oxygen essential for plant growth. Originally the term was confined to

carbon compounds in organisms, but now includes carbon compounds of synthetic origin.

Process Tankage - A product made under steam pressure from crude, inert nitrogenous materials (leather scrap, feathers, hair, wool waste, rags, old fur garments, etc.) for the purpose of increasing the activity of N.

Seed meal - Ground-up seeds from which the fat has been extracted. Mostly used for animal feed.

2. Introduction

- a. The significant value of organic materials as fertilizers has long been realized. Economics is the main factor that has prevented their widespread use in modern commercial agriculture.
- b. In 1913, 42% of the N in mixed commercial fertilizers came from organic sources, whereas by 1926 the percentage had dropped to 22%, and in 1947 it was less than 15%. In 1978, largely because of the high cost per unit of N supplied, organic N carriers were estimated to supply less than 1% of the N added in commercial fertilizers.

3. Use of Organic Materials

- a. Florida farmers use approximately 7 times the number of pounds of nutrients per harvested acre as the average U.S. farmer. Reasons for this include:
 - i. sandy, low CEC soils
 - ii. high rainfall
 - iii. high cash value crops which require high levels of fertilization,
 - iv. a long growing season.
- b. Highly-soluble inorganic nitrogen fertilizers leach rapidly, whereas a natural organic nitrogen source that is not totally soluble would not be lost as rapidly through leaching. This is one of the reasons that natural organics may be more important in Florida agriculture than in some other locations.

4. Composition of Organic Materials

- a. As shown in Table 1, organic materials vary considerably in plant nutrient concentration.
- b. Most organics are usually purchased as a nitrogen source.
- c. Organic materials like animal manures, biosolids (sewage sludge), municipal solid waste compost, and yard trimmings compost usually average 1 to 3% N by weight, and are very "clean" with regard to heavy metal concentrations.
- d. Use of industrial waste could present the possibility of toxic heavy metal problems.

5. Release of Nitrogen from Organic Fertilizer

- a. Organic residues differ in N concentration, and during decomposition will have a varying effect on the amount of soil N that is made available to plants.

- b. Generally, available N in the soil will be temporarily depressed (**immobilized**) when residues contain less than 1.6% N or have a C:N ratio of greater than 30:1.
- c. Often, residues that are low in N, such as straw, are supplemented with inorganic N to avoid a temporary N-deficient period.
- d. The rate of N release is roughly related to the C:N ratio (see Table 2). However, some materials do not release their N at the same rate as others with similar C:N ratio. The release is more closely related to the type of cell wall constituents present. For example, a high lignin content (as in horse manure) tends to reduce the rate of decomposition.
- e. A theory for matching soil application rates to the crop requirement has been proposed based on the properties of the organic materials.
 - i. Organic N in animal and plant materials must be **mineralized** before it becomes available to the plant.
 - ii. The N concentration and mineralization rate determine the amount of material that must be applied to provide a given amount of N.
 - iii. Yearly mineralization rates are combined to form a "decay series" as shown in Table 3.
- f. Natural organic fertilizers commonly release their nitrogen at a slower rate during the cool season. The microbial activity decreases as the temperature decreases, slowing the rate of decomposition of the organic residue.

6. Advantages and disadvantages of organic and inorganic fertilizers.

Advantages	Disadvantages
Organic Fertilizer	
1. Slowly available.	1. Expensive.
2. Less burning potential.	2. Low nitrogen concentration.
3. Presence of micronutrients.	3. May not mineralize when needed most.
4. Good fertilizer conditioners.	
Inorganic Fertilizer	
1. Less expensive.	1. Danger of burning.
2. Very water soluble.	2. More likely to leach.
3. Readily available.	3. May be acid-forming.
4. Can be used in solution fertilizers.	4. Poor fertilizer conditioners.

One of the most significant advantages of inorganic N fertilizers is related to economics. The cost per pound of nutrient from inorganic sources is generally less than half that of organic sources. The soil conditioning properties of natural organics must be stressed in order to develop a market for them.

Table 1. Average composition of some natural organic materials.

SOURCE	N	P₂O₅	K₂O	Ca	Mg
Manures (dry wt. basis)	----- % -----				
Cow	2.8	1.5	2.5	1.5	0.6
Horse	1.8	0.9	1.8	0.9	0.4
Sheep	2.5	1.4	2.4	0.6	0.4
Poultry	2.5	1.4	2.4	1.1	0.4
Swine	2.8	2.0	1.8	0.8	0.1
Biosolids	3.0	2.2	0.5	2.5	1.5
Seed meals					
Cotton seed meal	6.0	2.5	2.8	0.5	1.5
Castor pomace	5.0	1.8	0.5	0.5	0.5
Cocoa meal	2.5	1.6	2.5	0.5	1.0
Peanut meal	7.2	1.5	1.2	0.5	0.5
Soybean meal	7.0	1.1	2.8	0.5	0.5
Plant materials					
Tobacco stems	1.5	0.5	5.0	5.0	0.5
Peanut hull meal	1.5	0.2	0.8	---	---
Animal products					
Animal tankage	9.0	5.3	1.6	15.5	0.5
Bone meal	4.0	22.0	0.0	31.5	1.0
Dried blood	13.0	1.6	0.8	0.5	---
Fish meal	10.0	5.9	0.0	8.5	0.5
Fish scrap	5.0	3.0	0.0	8.5	0.5
Miscellaneous					
Garbage tankage	2.5	1.6	2.8	4.5	0.5
Peat and muck	2.3	0.5	0.7	1.0	0.5
Process tankage	8.2	---	---	0.5	---

Table 2. Degradation rates for selected organic materials.

Source	C:N ratio	Relative mineralization rate
Corn stalks	40	Very slow
Compost	27	Slow
Bone meal	10	Slow to medium
Fish scrap	8	Slow
Cow manure	14	Medium
Horse manure	22	Medium
Poultry manure	9	Medium to rapid
Peruvian guano	4	Medium
Biosolids	7	Medium to rapid
Cotton seed meal	7	Slow to medium
Castor pomace	8	Slow
Processed tankage	5	Moderately rapid
Animal tankage	4	Medium
Garbage tankage	16	Very slow

Table 3. "Decay series" for selected organic materials.

Source	Decay series	Time (years)		
		1	2	3
Dry tons of material/year for 200 lbs N output				
Poultry manure (2.5% N)	0.50, 0.12, 0.05	8.0	6.1	5.7
Biosolids (3.0% N)	0.40, 0.10, 0.05	8.3	6.3	5.7
Cow manure (2.8% N)	0.20, 0.10, 0.05	17.8	8.9	8.9

7. Land application of biosolids
 - a. Definition
 - i. Solid or semi-solid residues of wastewater treatment.
 - ii. Domestic or industrial in origin.
 - iii. Also termed “Sewage Sludge” or “Wastewater Residuals.”
 - b. Why the increased interest in waste utilization?
 - i. We are more aware of the environmental damage of burning, burying or ocean-dumping wastes.
 - ii. However, environmentally-sound waste management is usually more expensive than the above disposal methods.
 - c. Where does land application of non-hazardous wastes fit in?
 - i. Land application is usually environmentally safer than other means of waste disposal.
 - ii. Spreading materials on land dilutes the waste and allows the environment to assimilate it.
 - iii. Nutrients and energy in the waste are food for living organisms.
 - d. Why would we want to apply wastes to land?
 - i. Soil can benefit chemically and physically.
 - ii. Returning waste to the land mimics natural recycling.
 - iii. Land disposal can be economical.
 - e. Don't wastes pollute soil and water?
 - i. Not if the materials are chosen carefully and applied properly.
 - ii. Animal manures have been used for centuries as fertilizer.
 - f. What about heavy metal contamination of biosolids?
 - i. Perception differs from reality.
 - ii. Industrial contamination has been greatly reduced.
 - iii. In 1992, about 70% of the nation's biosolids were cleaner than the standards for exceptionally high-quality sludges.
 - g. What are some precautions used when land-applying biosolids?
 - i. Materials are characterized as to potential hazard; only high-quality biosolids are used.
 - ii. Application rates are based on crop nutrient requirements and soil characteristics to avoid nutrient excesses.
 - iii. Application is not allowed too close to water.
 - h. Wastewater and sludge treatment
 - i. Raw sewage is screened and grit is removed (screenings and grit to landfill).
 - ii. Wastewater undergoes primary and secondary sedimentation to create “raw” sludge (effluent is discharged).
 - iii. Sludge is stabilized (disinfected).
 - iv. Sludge is land-applied.
 - i. Stabilization processes
 - i. Biosolids are stabilized to decrease pathogens and odor:
 - (1) Anaerobic digestion (15-60 days).
 - (2) Aerobic digestion (10-60 days).
 - (3) Lime addition (pH 12 for 2 hours).
 - (4) Composting.

- j. Water removal-Volume reduction
 - i. Thickening (separation of water and solids).
 - ii. Conditioning (addition of lime, FeCl₃, or organic polymers).
 - iii. Dewatering:
 - (1) Sludge “cake” 15-25% solids.
 - (2) Sludge “compost” 40-70% solids.
 - iv. Drying (air or heat) (>95% solids).

Table 4. Chemical properties of some local biosolids.

Material	N	P₂O₅	K₂O	Cd	Cu	Ni	Pb	Zn
	%	%	%	ppm	ppm	ppm	ppm	ppm
Dade county	5.0	3.6	0.1	20	520	75	170	1000
Largo	7.0	3.0	1.0	3	840	110	35	500
Cape Coral	2.3	1.7	0.05	1	46	4	7	115
EPA exceptional quality				39	1500	420	300	2800

- 8. EPA’s Sludge Rule - Does the sludge meet exceptional quality criteria?
 - a. If YES, then no restrictions on use, rate of application, or record-keeping.

Table 5. Exceptional quality criteria for ten heavy metals.

Pollutant	Conc. (mg/kg)	Pollutant	Conc. (mg/kg)
Arsenic	41	Mercury	17
Cadmium	39	Molybdenum	18
Chromium	1200	Nickel	420
Copper	1500	Selenium	36
Lead	300	Zinc	2800

- b. If NO, then does the biosolid meet the criteria for land application, i.e. no element exceeds the ceiling concentrations:

Table 6. Ceiling concentrations for ten heavy metals.

Pollutant	Conc. (mg/kg)	Pollutant	Conc. (mg/kg)
Arsenic	75	Mercury	57
Cadmium	85	Molybdenum	75
Chromium	3000	Nickel	420
Copper	4300	Selenium	100
Lead	840	Zinc	7500

- c. If YES, sludge may be applied provided no element exceeds:

Table 7. Field loading rate limits.

Pollutant	Annual loading rate	Cumulative loading rate	Pollutant	Annual loading rate	Cumulative loading rate
	lbs/acre/yr	lbs/acre		lbs/acre/yr	lbs/acre
Arsenic	1.8	37	Mercury	0.8	15
Cadmium	1.7	35	Molybdenum	0.8	16
Chromium	134	2680	Nickel	19	375
Copper	67	1340	Selenium	4.5	90
Lead	13	270	Zinc	125	2500

Table 8. Estimated nitrogen mineralization from biosolids.

Biosolids type	Years after application				
	1	2	3	4	5
	% of original biosolids N mineralized per year				
Raw or lime stabilized	40	20	10	5	3
Aerobic digestion	30	15	8	4	3
Anaerobic digestion	20	10	5	3	3
Composted	10	5	3	3	3

9. Beneficial effects of biosolids
 - a. Soil acidity and aluminum detoxification.
 - b. Increased cation exchange capacity.
 - c. Improved soil physical properties.
 - d. Increased soil microbial activity.
 - e. Slow-release N, P, and micronutrient source (especially Fe).

Table 9. Nutrients in 1 ton of Dade county biosolids (wet ton = 22% solids by weight)

Nutrient	lbs per wet ton	lbs per dry ton
N	19	88
P ₂ O ₅	22	102
K ₂ O	0.5	2
Ca	28	128
Mg	3	13
Fe	5	21
Zn	0.4	2
Cu	0.2	1
Mn	0.02	0.1
B	0.02	0.07
Mo	0.01	0.04

10. Poultry manure as a fertilizer
 - a. Animal manures have been used effectively as fertilizers for centuries. Poultry manure has long been recognized as perhaps the most desirable of these natural fertilizers because of its high nitrogen content. In addition, manures supply other essential nutrients and serve as a soil amendment by adding organic matter. Organic matter persistence will vary with temperature, drainage, rainfall, and other environmental factors. Organic matter in soil improves water and nutrient retention. The use of manure is an integral part of sustainable agriculture.
 - b. Poultry manure is often produced in areas where it is needed for crop, hay, and pasture fertilization. The increased size and frequent clean-out of many poultry operations make poultry manure available in sufficient quantities and on a timely basis to supply fertilization needs.
 - c. The most common procedure for determining the amount of manure to add per acre is to consider the manure's nitrogen concentration and the nitrogen needs of the crop. In areas where phosphorus movement off-site can lead to eutrophication of surface waters, phosphorus rather than nitrogen may be the factor determining the application rate of manure.
 - d. Why apply poultry manure to agricultural land?
 - i. It is a source of plant nutrients.

- (1) Poultry manure contains the major plant nutrients nitrogen (N), phosphorus (P), and potassium (K). The amounts of these nutrients can vary depending on factors like the age and diet of the flock, as well as the moisture content and age of the manure.
- (2) Poultry manure also contains the secondary plant nutrients calcium, sulfur, and magnesium, and the micronutrients zinc, copper, boron, iron, and manganese.
- ii. It is a source of lime. Poultry manure containing large quantities of calcium carbonate can improve acidic soils for crop production.
- iii. It is a source of organic matter. Poultry manure applications increase soil organic matter and thus improve Florida's sandy soil for crop production. This occurs in three ways:
 - (1) If applied at a high enough rate, poultry manure can increase the water-holding capacity of the soil and improve lateral water movement, thus improving irrigation efficiency and decreasing the general droughtiness of sandy soils.
 - (2) Poultry manure applications improve soil retention and uptake of plant nutrients, a particular problem in sandy soils.
 - (3) Poultry manure applications increase the number and diversity of soil microorganisms, particularly in sandy conditions. This effect enhances crop health by increasing water and nutrient availability, as well as suppressing harmful plant parasitic nematodes, fungi, and bacteria.
- iv. It is a recommended Best Management Practice. Using poultry manure as a high-quality fertilizer is a recommended best management practice for sustainable agriculture when applied to meet plant nutrient needs of the intended crop in conjunction with soil tests.

11. Calculating poultry manure application rates

- a. To calculate the amount of poultry waste to apply to a crop, you need to know:
 - i. Total nitrogen
 - ii. Organic nitrogen
 - iii. ammonium nitrogen
- b. Example: Total N = 2.0%, Ammonium N = 0.6%, Organic N = 1.4%
 - i. Step 1: Determine the amount of N available from poultry waste the first year of application
 - (1) Multiply % Ammonium-N by lbs/ton
 - (2) Calculate amount of ammonium volatilization
 - (a) 0.75 Broadcast with no incorporation
 - (b) 0.80 Incorporated within 7 days
 - (c) 0.90 Incorporated within 4 days
 - (d) 0.95 Incorporated within 2 days
 - (3) Calculate the amount of organic N available the first year. Assume 50% mineralization.
 - (4) Add the factored amount of ammonium N available to the amount of organic N available the first year. This gives the total amount available for the first year.

- (5) Determine how much poultry manure to apply based on the crop N requirement.
- ii. Step 2: Determine the amount of N available from the previous years of application.
 - (1) Multiply the percentage organic N in your waste sample by lbs/ton
 - (2) Multiply the tons per acre of poultry waste applied during the previous year by the pounds per acre of organic N by 12% to find out how much residual N is available to the crop during the second year after application.
 - (3) Multiply the tons per acre of poultry waste applied 2 years ago by the pounds per acre of organic N by 5% to find out how much residual N is available to the crop during the third year after application.
 - (4) Subtract the total pounds of residual N per acre from the total pounds of N per acre recommended for this year's crop. This will give the number of pounds N per acre you will need to add.
- iii. Step 3: Calculate the number of tons of poultry waste to add to provide N needed this year.
- iv. Step 4: Calculate amounts of P_2O_5 and K_2O supplied by poultry waste.

Table 10. Average nutrient composition of poultry manures.

Manure type	Total N	Ammonium N (NH₄)	Phosphorus as P₂O₅	Potassium as K₂O
<u>Broiler</u>				
			lbs/ton	
Fresh (no litter)	26	10	17	11
Broiler house litter ¹	72	11	78	46
Breeder house litter ¹	31	7	54	31
Stockpiled litter ¹	36	8	80	34
<u>Layer</u>				
Fresh (no litter)	26	6	22	11
Undercage scraped ²	28	14	31	20
Highrise stored ³	38	18	56	30
			lbs/1000 gallons	
Liquid slurry ⁴	62	42	59	37
Anaerobic lagoon sludge	26	8	92	13
			lbs/acre-inch	
Anaerobic lagoon liquid	180	155	45	265

¹Annual manure and litter accumulation; typical litter base is sawdust, wood shavings, or peanut hulls.

²Manure collected within 2 days.

³Annual manure accumulation on unpaved surfaces.

⁴6 to 12 months' accumulation of manure, excess water usage, and storage-surface rainfall surplus; does not include fresh water for flushing.