Soil Amendments: Manure and Organic Fertilizers

Segment 3: Compost and Biosolids

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What are Biosolids?

- Nutrient-rich organic materials resulting from the treatment of domestic sewage in a treatment facility.
- Class A biosolids contain no detectable levels of pathogens.
- Class B pathogens are treated but still contain detectable levels of pathogens.

Biosolids storage, handling, and application

- Class A biosolids:
  - Can be applied to fruits and vegetable crops when following PSR and EPA 40 CFR part 503.
  - Are not stored on a farm. Used on demand.
  - Are applied by custom applicators.
  - Are applied based on a nutrient management plan.

Biosolids are typically granular in nature.

Photo credit: GORDON KING/Yakima Herald-Republic

Definition of Compost

A group of organic residues or a mixture of organic residues and soil that have been piled, moistened, and allowed to undergo aerobic biological decomposition resulting in a dark or black carbon-rich relatively stable humus.

Photo credit: Charles Gould

Composted manure from an Ottawa County, MI dairy farm.

Source: Rynk, R., van de Kamp, M., Willson, G.B., Singley, M.E., Richard, T.L., Kolega, J.J., Gouin, F.R, Laliberty, Jr., L., Kay, D., Murphy, D.W., Hoitink, H., and Brinton, W.F. 1992. *On-Farm Composting Handbook*, Robert Rynk, editor. NRAES-54. Northeast Regional Agricultural Engineering Service, Cornell University, Ithaca, NY.

Definition of Composting

Composting is controlled decomposition, the natural breakdown process, of organic residues.

Rotating drum in-vessel composter

Tractor pulled compost turner

Photo credits: Charles Gould

Cooperband, Leslie. 2002. *The Art and Science of Composting.* Center for Integrated Agricultural Systems, University of Wisconsin-Madison, Madison, Wisc.

So Why Compost?

- Volume reduction
- Odor control
- Marketable product
- Pathogen, fly larva, and weed seed kill
- Personal value
- Part of a manure management plan
- Protect environment

Compost Conditions

- Carbon to nitrogen ratio – 20:1 to 40:1
- Moisture content – 40 to 65%
- Particle size – 1/8 to ½ inch
- pH – 5.5 to 9
- Temperature (deg. F) – 130 to 160

Renk et al. 1992

Constructing Your Compost Pile

1 part:2-3 parts

Green materials

- Grass clippings
- Coffee grounds
- Manure

Brown materials

- Dried leaves
- Chopped straw or hay
- Sawdust
- Wood shavings

Stage 1 of the Compost Process

- Approximately days 1-2.
- Mixed materials are the same temperature as the air temperature.
- **Psychrophilic bacteria** are active at this stage (0° - 55° F).
- Heat is produced when bacteria break down organic matter.

Stage 2 of the Compost Process

- Approximately days 1-2.
- Mixed materials are the same temperature as the air temperature.
- **Mesophilic bacteria**, active between 50° - 120° F, are the most abundant and do the most decomposition.
- Oxygen and moisture are critical at this stage.

Stage 2 of the Compost Process

- **Thermophilic bacteria** are active from 110° - 160° F.
- The fastest organic matter breakdown occurs during this stage because of the heat.
- C:N ratio decreases due to carbon loss.
- pH rises above neutral.

Stage 2 of the Compost Process

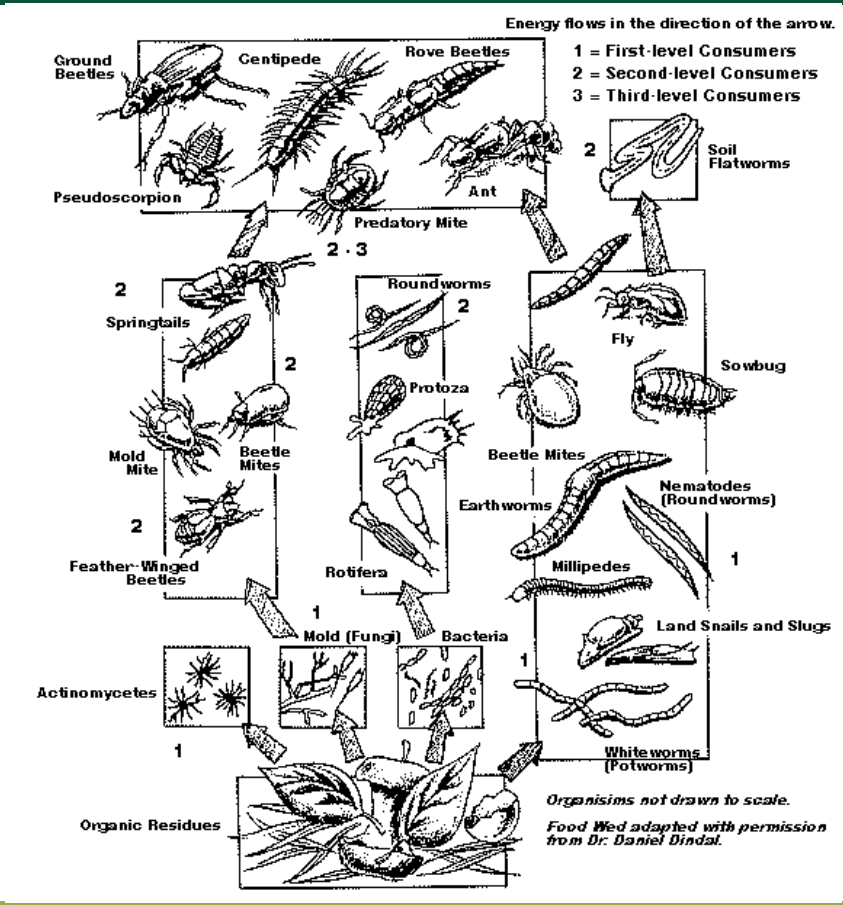
- Volume reduction of 50-60%.
- Weight reduction of 40-80%.
- At this stage, pathogens, weed seed, and fly larvae are destroyed.
- Temperatures above 160° F will cause microbial activity to cease.

Stage 3 of the Compost Process

- Approximately day 6 and beyond. This stage can last for several weeks or months, depending on how often the pile is turned.
- The pile begins to cool down.
- Turning the compost pile can jumpstart **Mesophilic bacteria**, reheating the pile.

Stage 4 of the Compost Process

- Compost temperature drops to ambient air temperature.
- “Curing” stage, where chemical reactions continue to occur that make nutrients in the compost stable and suitable for plant uses.
- This stage can last up to a year.
- Pile can be colonized with **actinomycetes, protozoa, rotifers, nematodes, fungi, and numerous species of invertebrates.**


Energy flows in the direction of the arrow.
1 = First-level Consumers
2 = Second-level Consumers
3 = Third-level Consumers
Ground Beetles
Centipede
Rove Beetles
Pseudoscorpion
Ant
Predatory Mite
2 · 3
2
Soil Flatworms
Springtails
Roundworms
2
Fly
Protoza
Sowbug
Mold Mite
Beetle Mites
Beetle Mites
Earthworms
Nematodes (Roundworms)
2
Feather-Winged Beetles
Rotifera
Millipedes
1
Mold (Fungi)
Bacteria
Land Snails and Slugs
Actinomycetes
Whiteworms (Potworms)
Organic Residues
Organisims not drawn to scale.
Food Wed adapted with permission from Dr. Daniel Dindal.

Compost Management

- Time
- Temperature
- Turning

Summary of Compost Process

- Microbial breakdown of organic matter.
- Reduction in particle size.
- C:N ratio decreases due to carbon loss.
- pH rises above neutral.
- Volume reduction of 50-60%.
- Weight reduction of 40-80%.

Management Factors that affect the Composting Process

- C:N Ratio
- Aeration
- pH
- Surface Area/Particle Size
- Moisture

Carbon to Nitrogen (C:N) Ratio

- Indicates (by weight or volume) the nutrient balance in a compost mix, which is the food source for the microorganisms.
- Optimal initial C:N ratio for effective composting is generally 30:1, roughly equivalent to 2 parts leaves to 1 part grass by volume.

C:N Ratio

Giving your compost a “balanced diet”

Approximate Concentration Of Nitrogen And Carbon To Nitrogen (C/N) Ratios of Various Materials Used in Municipal and Backyard Composts

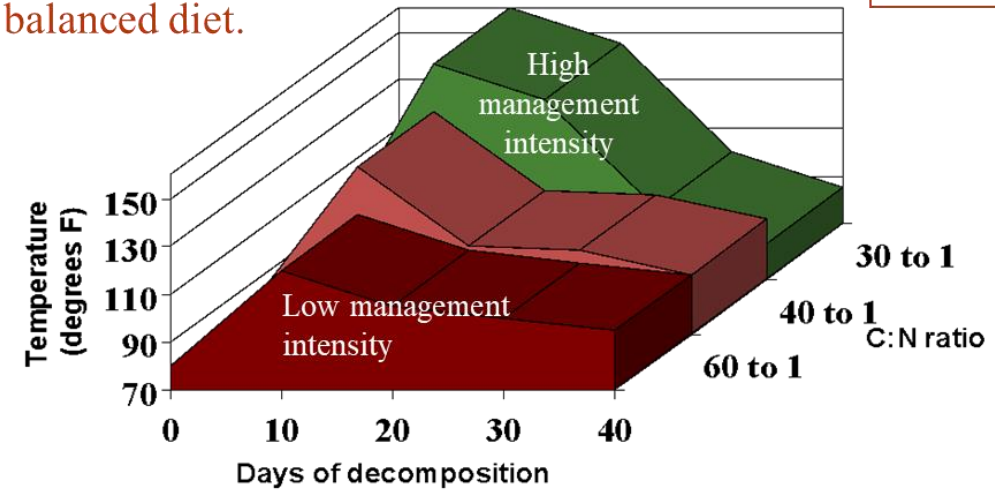
Material	Nitrogen (% Dry Weight)	C/N Ratio (Dry Weight)
Grass Clippings	3-6	20
Leaves	0.5 - 1.0	40-80
Sawdust	0.11	511
Wood	0.07	400-800
Fruit Wastes	1.52	35
Paper	0.25	170
Livestock Manure	1-4	10-12

Source: AG-FO-3296, 1990 U. Minnesota

Effects of C:N Ratio on Compost Temperature

Microorganisms function most efficiently with a balanced diet.

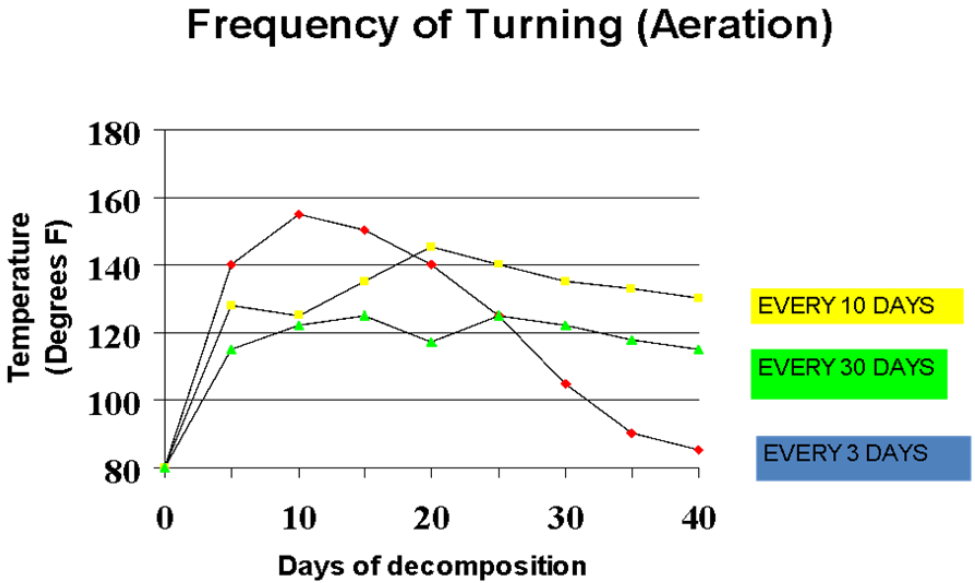
Higher likelihood of odors from ammonia release



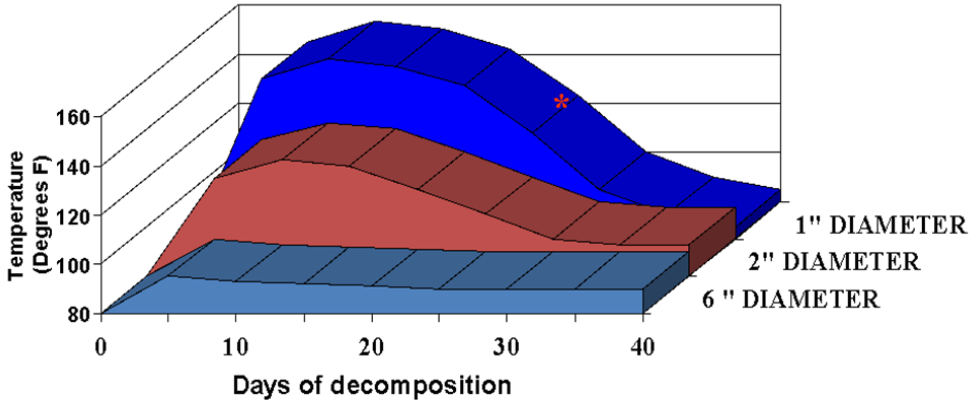
Role of Aeration in Composting

- Delivers Oxygen
  - Aerobic conditions results in biochemical reactions which generate more heat than anaerobic conditions (>5% optimal).
  - Avoids odors which result from anaerobic activity (methane gas, hydrogen sulfide, etc.)
- Removes heat (can help control composting in the early stages), moisture, and CO_2.

Effect of Aeration on Compost Temperature



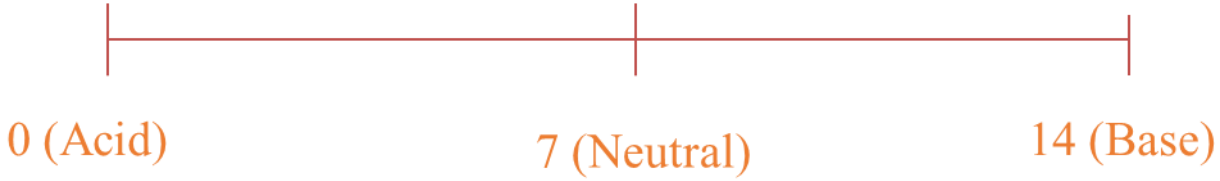
Effect of Particle Size on Compost Temperature



* Small particle size >less air flow >less O_2 > odors?

pH

- Scale used to express acidity and basicity in compost.



Moisture Content

- Microorganisms need water!
- Optimum: 40-60%
- Finished: 25-27%
- Shape of the pile will influence moisture holding ability

Composting Methods

- Static Pile
- Aerated Pile
  - Active
  - Passive
- Vermicomposting
- In-vessel
- Windrows
  - Covered
  - Uncovered
- Transfer Bays
  - Covered
  - Uncovered

Static Pile

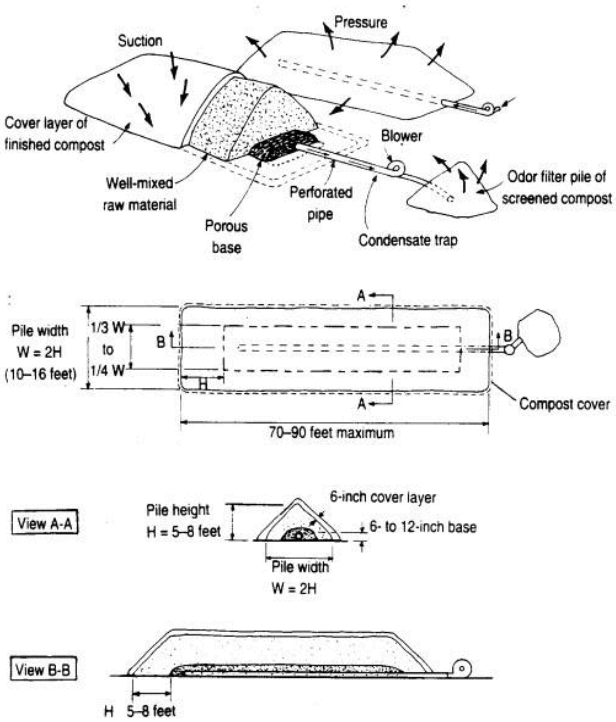
- Leaving raw manure in a pile for a long period of time does not yield compost
- Static piles generally have odors and flies
- More likely to have complaints

Aerated Pile – Active or Passive

- Can be a pile or windrow
- Active Aeration
  - Use blower to force air through pile
- Passive Aeration
  - Natural airflow through vented pipe keeps pile aerobic

Aerated Pile – Active or Passive

- Covered piles are easier to control
  - Can use a tarp – should be held above pile
  - Can also use peat moss (6” thick) over pile
  - Commercial compost covers also available
    - These allow the pile to breathe but help to control moisture



Composting Method – Aerated Pile Windrow

Vermicomposting

- Use red worms to “work” manure into compost
  - Requires 1 pound of worms per square foot of windrow surface area
- Yields very high quality compost
- Worms can be sold also
- Must maintain a temperature of 50° F

Composting Methods

Turned Windrow

- Can turn by hand – small amounts
- Front loader best option for small farms
- Large turners available
- Covered windrows yield the best compost

Transfer Bays

- Manure or other material is added to 1 bay then moved (turned) to other bays
- 4-6 bays are needed
- When manure reaches last bay it should be finished compost

Compost Do's and Don'ts

- DO provide provisions for adding supplemental water
- DO make sure the area is well drained
- DO monitor temperature every few days
- DO keep all garbage, plastics, etc. out of compost
- DO keep area well maintained

Compost Do's and Don'ts

- DO use finished product on your own landscapes, pasture, and garden
- DO have lab analysis of compost annually
- DON'T add soil from lots or pastures to the compost
- DON'T start a new pile in the winter
- DON'T continue to compost with damaged equipment
- DON'T limit your composting methods

When is Compost Ready to Use?

- Compost is ready for use when:
  - It smells earthy – not sour, putrid or ammonia-like
  - It no longer heats up after being turned or watered
  - It looks like dark soil
  - It's crumbly, and doesn't have identifiable items, i.e. manure, wood shavings, leaves, etc.
  - The pH is usually around 7.5, and it will have a C:N ratio ranging from 10:1 to 20:1.
  - It has a moisture content like a damp sponge.

Benefits of Composting

- Converts nutrients to a more stable form
- Adds humic acid to the soil
- Compost buffers the soil, neutralized both acid and alkaline soils
- Increases beneficial soil organisms
- Increases water retention
  - Only a 5% increase in organic material quadruples the soil's water holding capacity
- Improves soil tilth and aeration
- Reduces amount of manure runoff

Benefits of Composting

- Substantially reduces dangerous fecal coliform bacteria
- Reduces nutrient over-loading of soil
- Reduces volume and moisture content of raw manure
- Can be used as a mulch or peat substitute
- Reduces raw manure odors

Benefits of Composting

- Kills weed seeds and many pathogens
  - Chick weed, curly dock, foxtail, lambs quarter, quack grass, and tall buttercup
- Reduces reliance on synthetic fertilizers
- May improve crop quality and yield
- Potentially marketable end product

All Soils Benefit from Compost!

- All soils benefit from compost.
- “Sick” soils lack microorganisms and organic matter.
- Compost promotes a balanced ecosystem.
- Compost improves soil health by…

Source: www.mastercomposter.com

Compost Improves Soil Health By…

- Encouraging the formation of appropriately-sized aggregates which protect soil from erosion and compaction.
- Eliminating (some say compost reduces) the need for chemicals which may pollute groundwater.
- Conserving water as penetration and retention are improved, erosion, and run-off are reduced.

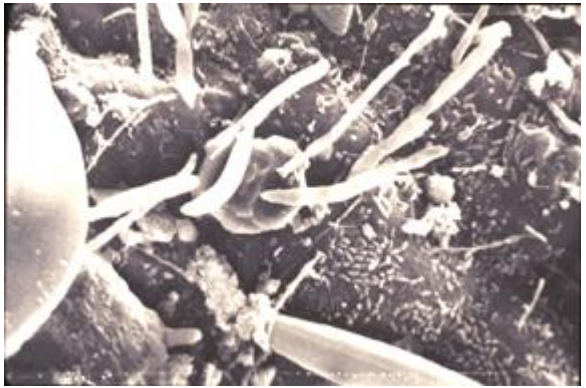
Source: www.mastercomposter.com

Compost Improves Soil Health By…

- Stabilizing and regulating pH a optimum level for nutrient stability.
- Allowing better root penetration in clay soils.
- Improving moisture retention in sandy soils so water loss and leaching are reduced or eliminated.
- Improving drainage in clay soils.
- Promoting fertility through higher quantities of macro- and micro- nutrition, as well as improving the availability of nutrients.

Compost Improves Soil Health By…

- Stimulating plant root development; overall root development is improved due to better soil structure, porosity and density.
- Controlling or suppressing soil-borne pathogens.



Compost Benefits

- Compost helps bind clusters of soil particles (aggregates) which provide good soil structure.
  - Compost helps sandy soils retain water.
  - Compost loosens tightly bound particles in clay or silt soils to improve root growth, water drainage, and air penetration.
  - Compost alters soil structure resulting in reduced erosion and soil splattering on plants.
  - Compost hold nutrients tightly enough to prevent washout yet loosely enough for plant uptake.
  - Compose makes any soil easier to work (soil tilth).

Compost Benefits

- Compost brings and feeds diverse life in the soil.
- Bacteria, fungi, insects, worms, and more support healthy plant growth.
  - Compost bacteria break down organics into plant-available nutrients. Some bacteria convert nitrogen from the air into PAN.
  - Compost enriched soil have lots of beneficial insects, worms, and other organisms that burrow through the soil, keeping it well aerated.
  - Compost may suppress diseases and harmful pests.

Compost Benefits

- Compost increases soil's ability to retain water and decreases runoff.
  - Compost encourages healthy root systems, which decreases runoff.
  - Compost can reduce or eliminate the use of synthetic fertilizers.
  - Compost can reduce chemical pesticides since it contains beneficial microorganisms that may protect plants from diseases and pests.
  - Only a 5% increase in organic material quadruples the soil's water holding capacity.

Soil Amendment - Compost

- Composting livestock manure reduces many of the drawbacks associated with raw manure use.
- The quality of compost depends on the feedstocks used to make it.
- The value of compost lies in its biology.
- Composting will not eliminate heavy metals.

Compost Handling and Application

- Application rates are determined based on crop yields, compost analysis, and soil test results.
- Calibrate spreader before applying compost.

Photo credit: Charles Gould

Spreaders with vertical discharge beaters easily apply heavy and dense amendments like compost.

Compost Handling and Application

- Minimize the potential of re-contaminating the compost through barriers, containment, or coverage.

Photo credit: Charles Gould

Composting site under roof at the Michigan State University Swine Teaching and Research Center.

Food Safety Considerations

- There is no time interval recommended between compost application and crop harvest due to the reduction in pathogens by the high temperature phase of composting.
- If there are any doubts about the compost, treat it like raw manure.

Food Safety Considerations cont.

- Compost must maintain a temperature of between 131 and 171°F for:
  - 3 days (enclosed system) or;
  - 15 days (windrow system),
  - During which period the composting materials must be turned a minimum of five times.
- The compost pile should then be cured for 45 days.
- Finished and curing compost piles should be covered in order to prevent recontamination.

Photo credits: Charles Gould

In-vessel composter on a pullet farm (enclosed system)

Turning a windrow of dairy manure compost (windrow system)

Pathogen Kill During the Composting Process

- Pathogen kill is a function of temperature and time.
- Common pathogens killed in this phase are *Escherichia coli, Staphylococcus aureus, Bacillus subtillus,* and *Clostridium botulinum.*

Compost thermometer reading 144 degrees Fahrenheit.

Photo credit: Charles Gould

Food Safety Considerations cont.

- Tools and equipment should be cleaned and sanitized if going between composting and produce use.
  - Develop SOPs
- Direct foot and animal traffic around storage area.

Recordkeeping

- Recordkeeping is an important component of a food safety program. Document the following:
  - Type of soil amendment being applied
  - Composting method and microbial testing (if applicable)
  - Fields receiving application
  - Date of application
  - Rate (quantity applied per acre)
  - Method of application
  - What crops will be planted

Compost made from crabs from the Chesapeake Bay.

Photo credit: Charles Gould

Recordkeeping for Food Safety

- Time, temperature, turnings, and any other processing step(s)
- Third party documentation that composting was completed in a scientifically valid process.

Buyer Demand

- Biosolids
  - Rarely applied to fruit and vegetable crops
- Compost
  - True value = beneficial microorganisms
  - Market price
    - Yard waste compost ≈ $10/cy
    - Manure-based compost ≈ $60-200/cy
- Great demand for compost (15.3 million cy!)

Poultry manure-based compost.

Photo credit: Charles Gould

Key Points

- Biosolids and compost increase soil organic matter and are sources of plant nutrients.
- Class A & B biosolids can be used on frits and vegetables according to EPA and State laws.
- Compost must be managed to kill pathogens.
- Time intervals do not apply to compost that meets temperature and time standards. If there are doubts, treat it like raw manure.
- There is demand for compost in Michigan!

Contact Information

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