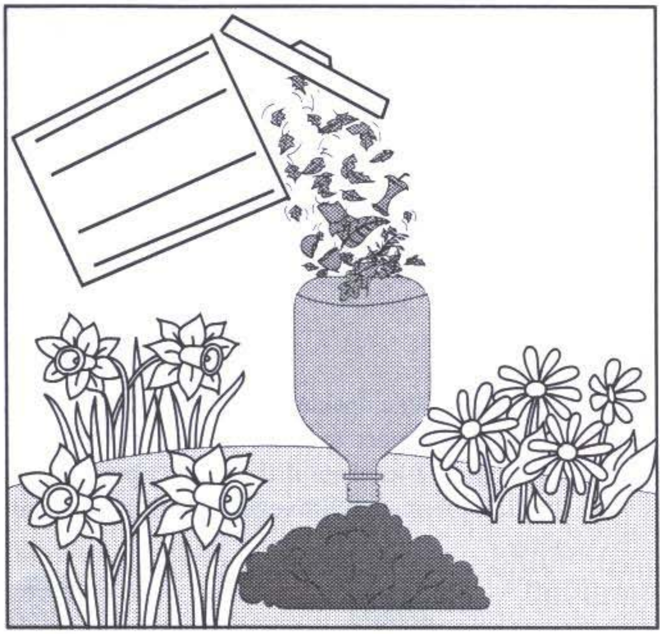
COMPARATIVE COMPOSTING



ISSUE: COMPOSTING

OBJECTIVES

Students will be able to: *construct a compost experiment; make observations* and *record data; make inferences* from the data collected.

DESCRIPTION

Composting chambers are constructed from 2-liter soft drink bottles. Students fill the chambers with various materials while carefully recording the mass and major chemical composition of each. Comparison tests are conducted by varying temperature, moisture, oxygen, and the size of the particles of compost material. Leachate is tested, and the presence of methane gas monitored.

SUBJECT
BIOLOGY, General Science

SUBJECT CONCEPTS
Decomposition, biodegradation

VOCABULARY
Aerobic, anaerobic, bacteria, biodegradable, biogas, compost, conservation, environmental degradation, ground water, landfill, law of conservation of matter, leachate, methane gas, pollution, recycling, resource recovery, sanitary landfill

GRADE: *7-12*

DURATION: *Five to 10 class periods*

SETTING: *Classroom, laboratory*

BACKGROUND

Over 50 percent of the materials in municipal solid waste (MSW) are biodegradable organic materials, including paper, yard waste, and food waste. Paper and paper products account for approximately 35 percent of MSW, yard waste approximately 20 percent, and food waste approximately 7 percent. Yard waste is the most commonly composted material, with approximately 12 percent composted. When conducted properly, composting can reduce the volume of waste materials by more than 50 percent. Composting is a complex technology requiring variations in materials, pH, air, and moisture to achieve the proper decomposition of organic waste material. Compost can then be processed for sale as a soil additive.

Refer to Section A, pp. A-17, A-35, A-37, and to the handout, ***Small Scale Composting***, in this activity, for an explanation of the composting process.

PREPARATION AND MATERIALS

Students should be introduced to the following: pH; basic chemical composition of organic materials; landfill practices and problems; types of compostable solid waste, the nitrogen, carbon, oxygen, and water cycles; and decomposition.

* Two 2-liter or 3-liter soda bottles for each chamber (two to five chambers per lab team if possible) and two or three additional bottles for methane collection chambers
* Cutting instruments (X-acto knives, scalpels, or linoleum knives work best)
* Nylon netting (old pantyhose or mesh produce bags)
* Duct tape (masking tape may be used for all but the methane collection chambers)
* Rubber bands
* An old food processor or chopping utensils (check garage sales, Goodwill, etc.)
* Balances (one per lab team is best)
* A pH-meter or sensitive wide range pH paper
* Thermometers
* Water test kits or materials for testing hardness, ammonia content, nitrogen content, dissolved oxygen, phosphate, chloride, hydrogen sulfide or other traits if desired
* Source of heat (incubator, sunny spot, greenhouse, etc.)
* Trays or pans.
* Organic garbage: grass, leaves, wood chips and shavings, table scraps (raw vegetables, cooked vegetables, fruit, baked goods, a little citrus rind), etc.

COMPARATIVE COMPOSTING

* Soil
* Red worms, other decomposers, and lime
* Four Erlenmeyer flasks, six two-holed rubber stoppers (two should fit the top of a 2-liter or 3-liter bottle), 12 pieces of glass tubing, eights pieces of rubber tubing, two pinch clamps, two glass droppers, and two well stretched balloons that have been inflated a couple of times. (These materials are for two methane gas collection chambers and are optional for this investigation.)
* Egg cartons, quick growing seeds, and soil (These are for an optional exercise using leachate and/or finished compost to grow seedlings and compare rates of growth while monitoring soil content using water test materials.)

NOTE: Be careful to state amounts when requesting that students bring in materials so you are not overwhelmed with more supplies than necessary.

HANDOUTS

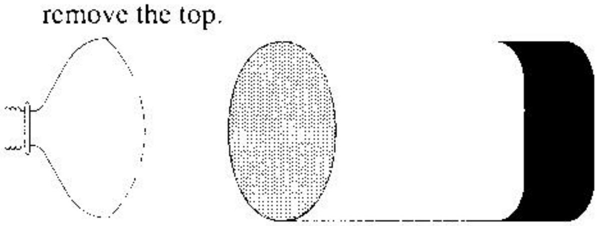
Data Table 1; Data Table 2; Data Table 3; Data Table 4; Comparative Composting Analysis; Small Scale Composting

PROCEDURES

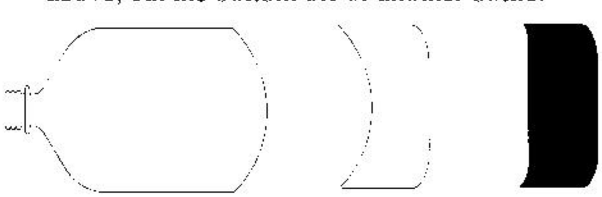
1. Prepare compost chambers.

   a. Place a 2-liter or a 3-liter bottle in warm water and remove all labels.

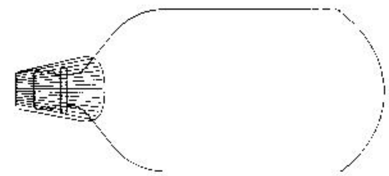
   b. Using an X-acto or linoleum knife, make a starting cut at the top of the bottle where the bottle becomes straight. Finish cutting with scissors to remove the top.



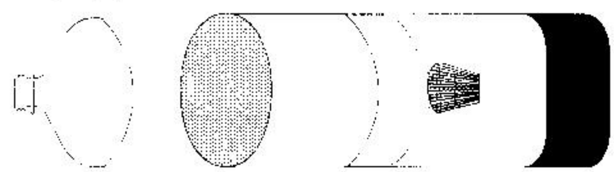
   c. Using the same procedure as steps "a" and "b" above, cut the bottom off of another bottle.



   d. Remove the cap from the bottle that has had its bottom removed. Use a rubber band to secure a piece of cheesecloth or netting over the opening of the bottle.



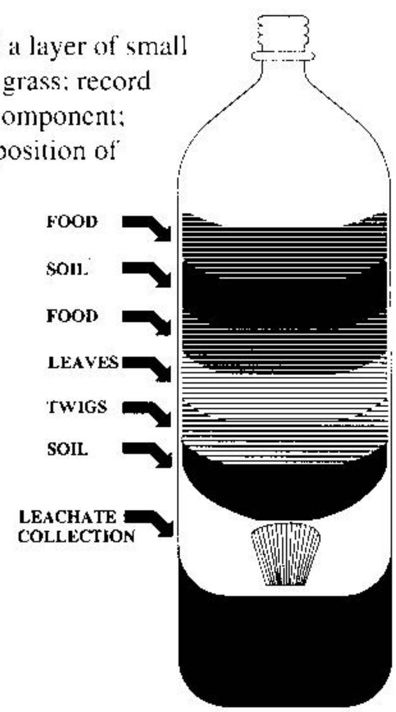
   e. Place this bottle upside down into the first bottle. (It may be easier to remove the top bottle for collection of leachate if the contact point of the bottle is lubricated with vegetable oil or petroleum jelly.)



2. Repeat Steps "a" through "e" above for the number of chambers each lab team is to assemble. Label each chamber with a number.

3. Have students place a layer of soil (about 2 inches) in the top bottle of each chamber. Be sure to mass the solid for each so that their contents are equal and enter the data on ***Data Table 1.***

4. Have students add a layer of small twigs, leaves, and grass; record the mass of each component; and keep the composition of each chamber the same. Chop the material added to one of the chambers into smaller pieces or grind it up in a food processor (see Step 7 for possible variation in composition of chamber materials).



5. Using the same procedure as Step 4, continue the process of layering by using the organic garbage that has been collected and an occasional layer of soil.

   BE SURE TO KEEP ONE UNTREATED CHAMBER AS A CONTROL SAMPLE.

6. Wet the compost in the chambers and keep data on the amount of water added to each chamber.

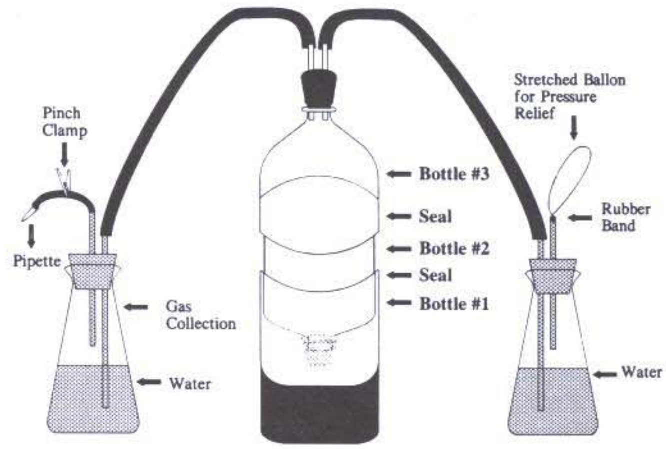
7. A variety of chambers should be used in this experiment. The following are suggestions for variations in the compost chambers.

   a. Vary the amounts of moisture in the chambers from little or nothing to a saturation point.
   b. Keep one chamber warmed to 40°C and one cooled to 10°C.
   c. Put ventilation holes in a chamber. Seal another off after using a vacuum pump to remove the oxygen from the chamber (duct tape may be used to seal seams and keep out air).
   d. Add lime to the layers of a chamber to alter the acidity of the compost.
   e. Add citrus rind to a chamber.
   f. Use various types of animal manure in different chambers (cow, horse, sheep, rabbit).
   g. Vary the amount of protein in a chamber (nitrogen source).
   h. Add black walnut leaves to a chamber.
   i. Recycle the leachate through a chamber.
   j. Add red worms or other decomposers to a chamber (be sure to aerate this chamber well).
   k. Stir a chamber on a regular basis.

8. Assemble a digestion chamber as shown below to demonstrate methane production. Materials required include a third bottle with the bottom cut off, glass tubing, rubber hoses, rubber stoppers, flasks, balloon, pinch clamp, dropper, and rubber bands. Chambers with various contents may be made to compare methane production.

   CAUTION:

   a. All connections must be tight.
   b. Lubricate connections of tubes and hoses.
   c. Balloon should be well stretched and blown up previously.
   d. The two tubes from the digestion chamber should be kept well under water in the flasks but should not be touching the bottom of the flask.



9. Use a thermometer to monitor the temperature of the center of the compost in each chamber daily and record the results on ***Data Table 2*** along with other indicated observations.

10. Withdraw samples of leachate on days designated by the instructor and record pH, hardness, and chemical content (ammonia, nitrogen, dissolved oxygen, phosphate, chloride, hydrogen sulfide) on ***Data Table 3***.

11. Plant seeds in egg cartons. Water some with water, and others with leachate from various chambers. Record the growth of the seedlings on ***Data Table 4***.

12. Plant seeds in the completed compost from various chambers and monitor their growth.

EVALUATION

Have students complete the handout, ***Comparative Composting Analysis.***

EXTENSION

Conduct small scale outdoor composting. Refer to the handout, ***Small Scale Composting.***

DATA TABLE 1

BOTTLE #			BOTTLE #			BOTTLE #		
Material	Mass (g)	Approximate Size of Pieces	Material	Mass (g)	Approximate Size of Pieces	Material	Mass (g)	Approximate Size of Pieces

DATA TABLE 2

Date	Bottle #			Bottle #			Bottle #		
	Temp °C	Observations	Treatment	Temp °C	Observations	Treatment	Temp °C	Observations	Treatment

DATA TABLE 3

	DATE	BOTTLE #	BOTTLE #	BOTTLE #
pH				
HARDNESS				
AMMONIA (NH_3)				
NITROGEN				
DISSOLVED O_2				
PHOSPHATES				
CHLORIDE				
HYDROGEN SULFIDE				
ODOR				
COLOR				

DATA TABLE 4

Chamber Number	Date	Seedling Size	Observations (Color, etc.)	Chamber Number	Date	Seedling Size	Observations (Color, etc.)

COMPARATIVE COMPOSTING ANALYSIS

NAME ____ DATE____________________

1. List four advantages of composting organic materials.

   a. ____

   b. ____

   c. ____

   d. ____

2. List two disadvantages of composting.

   a. ____

   b. ____

3. What factors accelerated decomposition?

4. What factors decreased the rate of decomposition?

5. Explain why the lowest pH was reached earlier in some chambers than in others.

6. List three reasons why composting should be used as an alternative to disposal (landfilling and incineration) of organic materials.

   a. ____

   b. ____

   c. ____

7. Write a *letter to the Editor* explaining why we should compost more of our organic solid waste.

SMALL SCALE COMPOSTING*

The Requirements of Composting

Composting is the work of decomposers (bacteria and fungi), often aided by tiny scavengers such as insects, mites, and especially earthworms. To explain how composting works is really to explain how decomposer plants and animals meet their needs and multiply depending upon different environmental conditions. The needs of aerobic bacteria, fungi, and small organisms at work in a compost pile are as follows:

OXYGEN - needed by most plants and animals to live. Oxygen is increased in compost by turning the pile occasionally or by aerating it.

MOISTURE - needed by bacteria to carry on metabolism or the breaking down of matter. Compost piles should be watered so they are like a wrung-out sponge.

ENERGY SOURCE - needed by all living organisms to survive and carry on life processes. In compost, energy is provided in the form of garbage which contains carbon compounds such as simple sugars, cellulose, and lignin.

NUTRIENTS - represented by a variety of minerals and vitamins needed in varying amounts by different organisms. Vitamins can be found in most plant and animal tissue while manure or fertilizers are rich in nitrogen and other elements needed by plants.

When these needs are supplied by their environment, bacteria begin to multiply, giving off heat as a product of bacteria metabolism.

Heat then becomes an important variable for the existence of different types of bacteria. When a compost pile is first formed, it starts out cool which enhances the reproduction of bacteria known as psychrophiles. They multiply in temperatures from 30° to 50°F. As the temperature increases to 70° and up to 100°F, another type of bacteria start to multiply, the mesophiles. As the temperature reaches anywhere from 100° to 160°F, bacteria called thermophiles begin to reproduce. Thermophilic bacteria, at a temperature of about 140°F, begin to kill disease-causing microbes (pathogens) by producing organic compounds known as antibiotics. The temperature of a compost pile will generally stabilize at about 158° for three to five days and then drop down to a range where mesophiles take over again.

Bacteria are not the only organisms at work in a compost pile. Fungi clean up after bacteria, consuming what they leave behind, including tougher matter such as the remaining cellulose, starches, and lignin. It is fungi that usually break down paper, a human-made product more durable than most food garbage. Another decomposer often found in compost is the actinomycete, a type of bacterium resembling grey cobwebs, which gives the compost an earthy smell.

Making Compost

To ensure a variety of nutrients and a good consistency, a general rule is to add as many different organic items to your compost pile as possible. A few precautions should be taken, as some items can create undesirable conditions. These variables and others are discussed below.

Compost is most often prepared outdoors in a pile and often some type of support structure for the pile is used, but extra support is not necessary. Composting can also be done in garbage cans kept in a garage or basement, or in a large tub or

* The information in this handout has been extrapolated from Stu Cambell, *Let It Rot!* (Powman, Vermont: Garden Way Publishing, 1975.) Printed by permission of the publisher.

aquarium kept in the classroom for observation. Regardless of where or how you construct your compost pile, the general rule of thumb for building the compost heap is as follows:

1. Mix the variety of vegetable matter you have collected as thoroughly as possible, chopping it into little pieces.

2. Obtain manure (or fertilizer) and animal remains if you have them. Chop animal remains into little pieces. (Avoid using animal fat or grease.)

3. At the bottom of your compost heap create a structure to allow water to drain and to allow a bit of air in. If building outdoors, this could be accomplished with a layer of gravel and/or brush that has not been chopped up. If using a garbage can, drill holes in the bottom, layer the bottom with coarse material and set the can on blocks with drain pans beneath. If using an aquarium, place a layer of finely crushed limestone (which neutralizes acid) with coarse material in the bottom.

4. Begin with a layer of vegetable matter, followed by a second layer of different vegetable matter if you wish. Then add a layer of animal matter (livestock manure or fertilizer). Then cover with a thin layer of soil. You may want to put on a sprinkling of lime or put limestone on the soil to neutralize acids which may develop.

5. Dampen these layers with water and repeat the process of layering as designated in Step 4 above. You can build as many of these layered sections as you wish. (If building outside, a good rule is to keep any one layer of material to 6 inches or less; if building indoors in small containers, layers of 1 inch or 2 inches will suffice.)

6. If building outdoors, make the pile somewhere between 4-6 feet in height. If composting in a garbage can or aquarium, fill to the top.

7. If making a pile outdoors, cover the entire pile with a layer of soil, straw, or sod to keep the flies out.

8. Make sure to ventilate the pile. If compost is outdoors or in a garbage can, a section of perforated pipe could be inserted into the center. If using an aquarium, put a small piece of wood or cloth under the cover at the corners to lift the top up. If you have a wooden top of plywood you could drill holes in it. You could also poke holes into the pile and stick straw or a cornstalk into the holes. After initially sitting for a week or so, start turning the pile about every week to aerate it.

When is Compost Ready?

There are several indicators to tell if compost is ready and if it is of good quality. Generally, the process takes about four to six months; if temperatures are higher, as in summer, it may take less time. In winter months outdoors, it could take longer. The observations and measurements used to check on finished compost are listed below:

CONSISTENCY:	should be crumbly and fluffy, not sticky or stringy
COLOR:	dark in color, but not black which could indicate too much moisture and acid in the compost
SMELL:	sweet and earthy, not moldy or rotten
TEMPERATURE:	should be that of surrounding temperature having come down from higher levels of about 150° or so

It is always better to use compost which is not quite finished rather than using over-done compost which is dried out.

Apply compost at anytime and in any amount. Just spread it on top of the soil or work into the soil. Generally, compost is added to soil in the fall or in the spring one month before planting. Also, it is an excellent soil additive for indoor house plants.

Remember, compost does not contain everything a plant needs. It could be lacking in some essential nutrients such as phosphorous, so you may want to add a commercial fertilizer to the soil along with your compost.

Variables and Experimenting

The basic variables when composting are moisture, air and heat. Another important variable is the type of organic material put in the compost. Additional variables include acidity level and the carbon/nitrogen balance. Each of these factors is considered below.

MOISTURE allows organic matter to be broken down more easily by bacteria. Water the pile and/or add green matter if the pile is too dry. Too much moisture, however, can lead to a restriction of air and cause anaerobic bacteria to multiply. Moisture content of the material in the pile should be about 40-60 percent (like a wrung-out sponge). Use rain water because it picks up a lot of oxygen, minerals, and microorganisms, or tap water which has been set out for several days so that chemicals harmful to bacteria can evaporate.

OXYGEN allows aerobic bacteria to survive; too much air may cool the pile down, but not enough oxygen inhibits decay. Turning the pile will generally allow it to heat up, because oxygen allows bacteria to work and they in turn generate heat. To keep the pile at a maximum heat capacity, turn it whenever the temperature gets below 104°F. If bluish-grey mold appears (indicating anaerobic conditions) turn the pile right away.

HEAT is important because it destroys pathogenic organisms, weed seeds, and insect larvae. For at least a short period of time, the temperature of the pile should be around 150°. This may be difficult to achieve if the pile is not at least a cubic yard in size so it will self-insulate.

THE FORM OF ORGANIC MATTER often causes different things to happen in your pile. Make sure to chop and grind waste matter to make it decay faster, especially in the case of items such as broccoli stems, corn stalks, wet leaves, and sticks. Chopping helps break down cell walls made of cellulose, which are difficult for bacteria to work on. Be careful not to make a fine mixture or you may create a paste-like barrier against water and air. If you blend kitchen garbage into a slurry, spread it out over the pile evenly. One rule of thumb regarding materials is to include two parts vegetable matter to one part animal. AVOID grease, oil, and animal fat. These are hard to break down and will attract flies and vermin. A few suggestions of the many different items you could use are as follows:

Animal matter - dead fish or fish cleanings, dead birds, manure, bones, scraps, feathers, leather dust, wool rags. (These items add nitrogen and/or phosphorous to your compost.) Livestock manure can be used instead of any other animal matter to supply nitrogen.

Vegetable matter - beet tops, broccoli and cabbage stalks, potato skins, citrus rinds, coffee grounds, egg shells, tea leaves, corn cobs and stalks, grass and hedge clippings, leaves, pine needles, saw dust, tomato plants and stems, peanut hulls, weathered hay or straw (if not weathered, straw will require a lot of nitrogen to decay). Partially rotted leaves (leaf mold) are closest thing to pure humus, but mix and chop leaves if they are not weathered.

Mineral matter - rocks (granite and marble dust), ground limestone, and shells (crushed oyster, clam, and lobster shells).

Matter changed chemically - wood ashes (source of potash and calcium). Ashes from burning banana skins, lemon skins and cucumbers are high in phosphorus and potassium.

DO NOT ADD root crops suffering from dry rot, onions with onion mildew, or other questionable vegetable or animal matter. Often the "thermal kill" of the composting process will not kill all pathogenic organisms and disease could be spread to plants when the compost is put on soil. Coal ashes have excessive amounts of sulfur and iron, which are toxic to plants. Charcoal takes a long time to decay.

NUTRIENTS are needed by plants. Some of these are as follows:

Major Nutrients - phosphorous, nitrogen, and potassium or potash (nitrogen is perhaps the most important)
Minor Nutrients - calcium, magnesium, iron
Trace Elements - zinc and copper

ACIDITY (pH level): Plants will be poisoned if the pH level of the compost is too high or too low. There are various tests to show pH levels. A test which shows degrees of acidity based on colors is a popular one in school labs. If the pH is too acidic (too low), wood ashes, bone meal, lime or crushed limestone will neutralize acid. If the pH is too alkaline (too high) manure will generally lower the pH. Oak leaves, pine needles, and pine sawdust are highly acidic and could be added to lower pH or not added at all to avoid a low pH. In the early stages the compost pile tends to be more acidic than it should be later.

CARBON/NITROGEN BALANCE: Humus is usually 10 parts carbon and 1 part nitrogen. Compost should be around 25 to 1. Too much carbon (from items such as straw, corncobs, sawdust and pine needles) causes the pile to decay very slowly. This can be corrected by adding nitrogen in the form of manure. You can also get too much nitrogen, which gives off ammonia causing anaerobic bacteria to appear. If your pile smells of ammonia, let more air into the pile.

There are tests to show the carbon/nitrogen balance in your pile and to show the nutrient content. These can be expensive and difficult to use but may be worth trying if you have the time and money.

THE VALUE OF COMPOST

Composting recycles nutrients. However, the value of compost extends beyond its contribution of nutrients to the soil. Unlike chemical fertilizers, it contributes to good soil structure. Good structure allows soil to retain nutrients, moisture and oxygen over a long period of time. Therefore, compost extends the life of soil which is one of our most valuable resources.