Global Decomposition Project

Background:
Soil decomposers, such as some bacteria and fungi, obtain energy needed for life from dead and decomposing plant and animal remains, known as *soil organic matter*. Soil organic matter is important to local ecosystems because it affects soil structure, regulates soil moisture and temperature, and provides energy and nutrients to soil organisms. It is also important globally, because it stores a large amount carbon, and when microbes "eat", or *decompose*, organic matter they release greenhouse gasses (primarily carbon dioxide (CO_2), but also methane (CH_4) when conditions are right) into the atmosphere, which affects the Earth's climate.

Aerobic decomposition (i.e., decomposition that requires oxygen) is the same chemical process as respiration, in which organisms, including humans, break down sugars to obtain energy:

$$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{energy}.$$

In addition to oxygen and sugar, aerobic decomposers require nutrients, water, and suitable temperatures. Other soil conditions, such as pH, as well as the chemical composition of organic matter also affect decomposition. It is important to understand the conditions that affect decomposition because of the role organic matter plays in local ecosystem processes as well as the role of decomposition in global climate.

Student Learning Objectives

1. Students will learn about decomposition and how it relates to respiration.
2. Students will learn about the role of decomposers in the formation of soil.
3. Students will look at conditions that control decomposition in the soil.
4. Students will make connections between greenhouse gasses from decomposition, such as carbon dioxide and methane, and how they affect the atmosphere and the earth's climate.
5. Students will collect meaningful data using lab equipment, such as electronic balances.

Project Objective:
The objective of the Global Decomposition Project (GDP) is to explore local and global patterns of soil organic matter decomposition, to educate students and the general public about soil organic matter and decomposition, and address these questions:

1. How do environmental conditions control decomposition of organic matter in soil?
2. Why do some areas accumulate organic matter and others do not?

We will answer these questions by comparing decomposition rates of a common substrate, cellulose paper, within and across ecosystems and biomes. The protocol below is a standard method for measuring decomposition using cellulose, which is a component of plant cell walls and common component of soil organic matter.

Next Generation Science Standards Learning Outcomes:

HS.Earth Systems

HS-ESS2-2 *Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.*

HS-ESS2-6 *Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.*

HS.Weather and Climate

HS-ESS2-4 *Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.*

HS-ESS3-5 *Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.*

HS.Human Sustainability

HS-ESS3-4 *Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*

HS-ESS3-6 *Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.*

HS.Engineering Design

HS-ETS1-1 *Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.*

HS-ETS1-2 *Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.*

HS-ETS1-3 *Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.*

HS-ETS1-4 *Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.*

Global Decomposition Project
Cellulose Decomposition Bag Protocol

Protocol overview: Cellulose decomposition bags are made of cellulose paper enclosed in a screen mesh. The bags are placed in the ground for a set period of time, then removed and weighed to determine mass loss. The screen allows decomposing organisms, such as bacteria and fungi, to access and decompose the cellulose.

We use cellulose because it is a main component of plants, which are the primary source of organic matter in soil. By using a common substrate, we can ask questions about how different environments affect decomposition. Another interesting question is how different substrates (e.g., leaves from different plant species) differ in their decomposition rates. While substrate differences are not addressed in this protocol, you can design an experiment to explore this question using substrates of local interest or importance.

You are encouraged to add experiments to the basic protocol to answer questions your students develop about decomposition in your area. To understand this process at larger scales (i.e., continent or globe), we would like to compare and share results with all participants, which will only be possible if data collection is standardized. One outcome of this project will be a global database and interactive map of decomposition rates. That database will be available to all GDP participants and to the broader public. **In order for this component of the project to succeed, it is important that you follow the methods outlined below and submit your final data back to the GDP.**

The protocol is broken down into four steps:

- **I. Field deployment**
- **II. Removing bags**
- **III. Processing the bags**
- **IV. Optional: Making more bags**

<u>**Supplies needed**</u>

Deployment

1. Serrated knife
2. Trowel or small flat shovel
3. Fishing line and flags, or another method of marking your bag locations
4. Decomposition bags

Processing

1. Drying oven or you can air dry
2. Paint brushes
3. Tweezers
4. Scale that weighs in increments of 0.001g (0.01 would also work).

The filters weigh ~ 0.45 g prior to deployment, so a 10% mass loss requires a scale that can detect ~ 0.04g. If you do not have access to a scale, mail your clean filters to the GDP address provided, or contact a scientist in your area. There are many reasonably priced 0.01 g increment scales available online. Please let me know if you find one you would recommend.

Optional: Making more bags

1. Cellulose filter paper (Fisher; Whatman P8; product # 09-802-1B), or lignin-free paper purchased from an office supply store
2. Fiberglass window screening (14 x 18 mesh), purchased at any hardware store
3. Aluminum tags (e.g., from Forestry Suppliers) for marking bags. You can also fold up a piece of aluminum foil to make a tag, or mark the bags in some other way that will stand up to several weeks or months of burial in the soil.
4. Heat sealer or an iron
5. Stapler
6. Scale that weighs in increments of 0.001g or 0.01g. See above for more information.
7. Optional for cutting: Foam mat, rotary cutter, ruler. Scissors and/or a paper cutter work.

I. Field deployment

You can place all of your bags in one location, or you can explore different ecosystems that may vary in soil nutrients, soil moisture, plant cover, or other factors. Place 3-5 replicate bags in each location with bags at least 1m apart.

1. Place decomposition bags in desired location. Insert bag by cutting 10 cm deep and 10 cm wide slit into the ground with a serrated knife (Fig. 1a). Open the slit in the ground with your hands or a trowel, and insert the bag (Fig. 1b). Insert bag vertically with the tag at the top, making sure that the bag does not fold when you insert (Fig. 1c). Close the opening in the soil with your hands. The bags should be placed so that the top of the screen is barely visible from the surface and the bottom of the bag is at 10 cm (Fig. 1d).

Figure 1. To install decomposition bags: A. Cut slit in ground; B. open slit with hands or trowel; C. insert bag vertically. D. Top of bag should just be visible.

2. **Important:** Mark bag locations so you can find the bags again! One option is to tie fishing line to the bags before deploying and attach the other end of the line to a flag. Record the flag location.

3. Record relevant information about your field site: location (city, state, country as well as latitude and longitude with a GPS if you have one), date bags deployed, description of site type (e.g., deciduous forest, lawn, wetland), air temperature on the day the bag was buried, other information that is relevant to describe your location. Collecting good field notes is a key skill for young scientists to develop, so this is an important exercise for student participation.

II. Removing the Bags

1. Determine the length of time you will leave your bags in the field. This will vary greatly by the temperature, precipitation, and nutrient status of your location. Below are some suggested deployment lengths. These are coarse estimates and will vary based on local site conditions. *Please help us to refine these times with information from your field site*!

Ecosystem Type	Mass loss/day	Suggested deployment Length*
Tropical rain forest	1-4% mass loss/day	2 weeks
Sub-tropical wetland	0.5-6% mass loss/day	2-3 weeks
Temperate forest	0.2-0.5% mass loss/day	2-3 months
Tropical, arid	0.5-2% mass loss/day	3-6 weeks
Arctic/subarctic	0.1% mass loss/day	3 months +

* Estimates are for spring/summer seasons

2. Remove the bags from the ground. Carefully remove soil from the outside of the bags, and place decomposition bags inside a sealed plastic bag. **If you cannot process bags immediately, place them in the freezer to stop/slow decomposition.** Record the date and weather conditions when the bags were removed from the ground.

3. *Optional:* When you remove the bags, collect ~ 50 g of soil (0-10 cm depth) near bag locations to determine soil moisture content.

Gravimetric water content = weight of water/weight of dry soil
=[(wet soil)-(dry soil)]/dry soil

4. *Optional:* Ship 5-10 g dry weight of each labeled soil sample to the WHRC (address at the end of this protocol) for carbon and nitrogen analysis.

III. Processing the Bags

1. Carefully wash the bags (the filter should still be encased in the screen mesh) in water to remove any soil attached to the outside surface of the screen. Either run water over the bags or wash them all in a bin of water. Wash the bags enough to clean them but not too much that the paper inside disintegrates.

2. Dry the bags (with filter paper still encased in the mesh) in a lab drying oven at 60° C for 48 hours, or at room temperature in a dry and sunny location until the bags are no longer losing water weight. If you have a balance, weigh the bags daily until the weight is constant. If you do not have a scale, then dry bags until filter papers are dry to the touch.

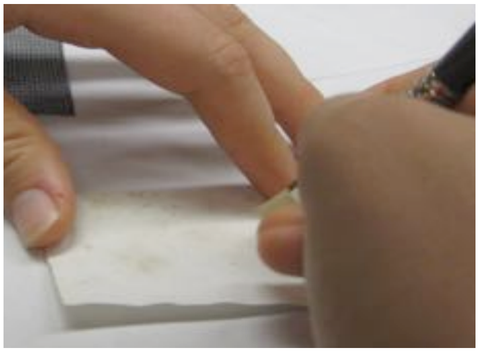

Figure 2: Clean off soil/debris using a dry and clean paintbrush.

3. Clean the cellulose paper: Once the filters are dry, open each bag (the edges of the sealed screen will easily pull apart), remove the filter, and use a paintbrush to clean soil from the filters before weighing them (Figure 2). You may also need to use tweezers to remove debris that is stuck onto the paper (Figure 3). If your paper is in many pieces, be careful not to lose any of the pieces during this step.

Figure 3. Some debris may be easier to remove with tweezers.

4. Weigh the cellulose paper: After the decomposition paper has been cleaned (Figure 4), weigh the paper (Figure 5). If you plan to clean all the decomposition papers first before weighing them (which may be necessary if you don't have a scale), then place each cleaned decomposition paper in a separate envelope/bag labeled with the decomposition bag number.

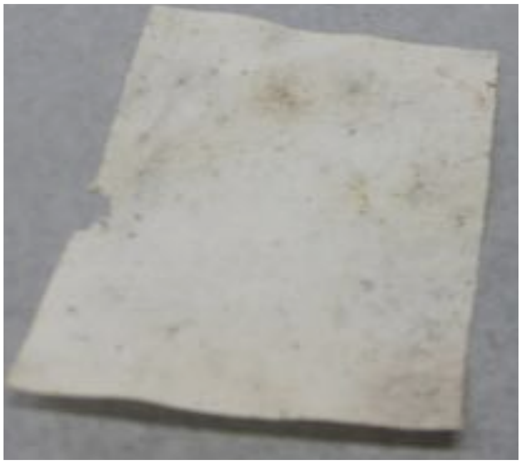

Figure 4. This paper has been cleaned. Although it still looks a little dirty, some stains on the paper won't come off.

Figure 5. Weigh cleaned filter paper, making sure to record sample number.

5. Enter your data into an excel file (See template) and calculate percent mass loss over time:

% mass loss = [(initial paper weight – final paper weight)/initial paper weight] * 100

% mass loss/day = % mass loss/# days bags were in the ground

6. Create a notes tab on your excel file that includes your "Metadata"-- relevant field and lab notes, and information about your site and samples (See template).

7. Send data to snatali@whrc.org. I will archive data, and once we obtain a critical mass, will post the data online as a database and an interactive map. Until that point, all data will be available to GDP participants or anyone who requests the data.

You can mail cleaned filter papers and soil samples (only U.S. samples) to:

Global Decomposition Project
c/o Sue Natali
Woods Hole Research Center
149 Woods Hole Road
Falmouth, MA 02540

Questions can be addressed to Dr. Sue Natali: snatali@whrc.org

Protocol updated on 11 February 2015 by S. Natali

Extending the Cellulose Decomposition Bag Protocol

You may want to extend this project by making more cellulose bags or using a different substrate. Here are some ideas for extending this project:

1. How does screen size affect decomposition?
2. How do different materials vary in their decomposition rates?
3. How does experimental soil warming (e.g., by placing black plastic over soil to warm it), drying, wetting, fertilization affect decomposition?
4. How does mass loss change over time? Does mass loss/unit day depend on the number of days the bags were placed in the ground?

We would love to hear additional ideas and projects that you and your students develop!

IV. Making More Bags

1. Cut the mesh screen into 10.5 cm x 10.5 cm**.** Screen can be reused after you take bags out of the field. Wash them in tap water, then reuse.

2. Cut the filter paper into 7.5 cm x 7.5 cm squares.

3. Use a heat sealer or an iron to seal the edges of two mesh pieces together on three sides.

4. Cut the aluminum tags, engrave them with the Bag ID's (a ballpoint pen works well for this), and staple them to the upper left corner of the mesh bag.

5. Weigh each filter paper, record weight, and place in the mesh bag.

6. Finish sealing the mesh bags by sealing the remaining edge.

7. Attach bags to ~ 1m of fishing line for field deployment.