

Bioreactor Water Heating

Lesson 2: Compost Bioreactor Design

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DESCRIPTION: Solar energy is available when the sun shines but energy can be supplemented at night by the release of energy during the composting of organic waste. In this activity we will experiment with the feasibility of harnessing thermal energy to heat water with a bioreactor. Students will experiment with using compost buckets as bioreactors, first experimenting to increase temperature yield of the compost and then using that generated thermal energy to heat water. This lesson is a prep lesson towards the ultimate goal of designing a system that uses compost and a heat exchanger to keep water from freezing over during the winter. To increase temperature yield, students will examine the effects of different types of “fuel,” or organic waste, for their bioreactor.

GRADE LEVEL(S): 7th-12th grades

SUBJECT AREA(S): Physical Science, Energy Fundamentals; Sustainable energy, Solar/Renewable energy,

ACTIVITY LENGTH: 2-3 class periods – over the course of 1 month

LEARNING GOAL(S):

1. Students will research the science of composting and proper maintenance methods to build their own bioreactor.
2. Students will research the proper composition of compost for maximum heat production.
3. Students will transfer the thermal energy in compost to a container of water heat water by placing a vessel in the middle of the active compost/bioreactor.

NEXT GENERATION SCIENCE STANDARDS:

MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Materials List

- Five- or ten-gallon containers—5-gallon Home Depot buckets work ok—large grease containers are the best (most restaurants who deep fry will save them for you for free)
- Probe thermometers: 1 per group
- Graph paper
- Beakers (250 mL – 1 L) or other small containers to hold water made of various materials (e.g. plastic, metal, glass) *Note: either select one type or let class decide*
- Outdoor space: protected so containers will not be disturbed
- Disposable gloves: medium/large size should be fine
- Composting materials:
 - Grass clippings
 - Horse/cow/sheep manure
 - Food leftovers collected from cafeteria
 - Chicken manure
 - Dry leaves/straw/shredded paper/sawdust
 - Put them in piles or garbage bags near a larger bioreactor so excess won't be wasted! Another great idea is to have a large garbage handy to use the excess to start a large bioreactor to produce heat and have students compare heat energy produced by different masses of bioreactors!
- Student lab notebooks for data collection and inquiry recording

Vocabulary

- | | |
|-----------------|--------------|
| • organic | • leachate |
| • decomposing | • humus |
| • aeration | • compost |
| • biodegradable | • bioreactor |
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Lesson Details

Planning and Prep

You will need a drill or nails and hammers to have the students prepare their composting containers/bioreactors before they are to be used. Aerating holes need to be drilled through the side approximately in the middle for the temperature probe/thermometer. Also 4-8 holes are needed to drain leachate from the bottom of the container—drill or poke the holes with a nail about an inch around the bottom of the container. Make sure where you place the containers outside that the leachate is allowed to drain properly. Warning—leachate will stain concrete! Composting requires aeration so do not cap or seal the top of the container and make sure the compost is moistened on a regular basis. Students can plan how and when and how much they moisten their bioreactor.

This is an excellent opportunity to teach lab notebooks and teach the importance of proper data collection. There is also the opportunity for inquiry learning by having the students determine what composting materials will be added, how much moisture will be added and how much aeration they will need, what type of water vessel will be placed in the compost and how much water they will add. However, make sure that they understand that for the scientific process, isolating variables is key! One way to leave some of these choices to the students is decide as a class on a set of variables to test and which group will test which variable. The teacher can outline any parameters and determine the minimum and maximum values the students use in terms of volume/mass of input materials for the compost. The class needs to agree (or be given) constraints, because of the complexity of variables that could be measured. Potential variables that students may want to change (or should decide to hold constant!) include:

- *Composition*
 - Ratios of different input materials
 - Number of inputs added
 - Methods for adding compost inputs (e.g. layers vs. mixed)
 - Total volume or mass of “starting compost” (Tip: This is a good one to hold relatively constant across groups—if their containers are all identical, they can simply fill them to the same line)
- *Maintenance*
 - Water
 - Amount of water to add to moisten soil (total or per compost-moistening)
 - Frequency of compost moistening
 - Aeration
 - Frequency of aeration
 - Method for aeration
 - Length of active aeration
- *Data gathering*
 - Time of day
 - Location within bioreactor measured

For the second part of this activity, students will attempt to heat water by placing a water vessel in the middle of their crafted bioreactors. For this second part, all variables should be the same, unless students/groups have identical compost set-ups. Variables that need to be addressed (e.g. decided upon/held constant) include:

- Type of water vessel to use (e.g. beaker)
- Amount of water to heat (this is an easy one to set as the teacher; 500 mL – 1 L is recommended)*
- Agitation (do you stir the water? How frequently? Leave it sitting still?)
- Time elapsed for water heating operation
- Frequency of temperature measurements

**Important Note: Trying to heat too much water will slow the decomposition process greatly as it moves more thermal energy away from the reaction site.*

These experiments have a *lot* of variables. Keeping accurate records should be a focus throughout this activity. It is not recommended to do this activity without students having experience with record collection in lab notebooks. The goal here is to determine optimum conditions to heat water to the maximum amount possible. Note the tradeoff implicit in the goal: a very small volume of water will heat the fastest and will reach the highest temperature which will be useful for determining effective variable manipulation during short class periods. However, it is important to remember that this activity is a preparatory activity to keep a large volume of water from freezing over in the winter and to bear in mind the effectiveness of such manipulations when scaled up.

Student Background

Students participating in this lesson should be familiar with the following:

- Composting basics
- Bioreactor vocabulary
- Energy Transfer - chemical decomposition to heat energy
- Composting Basics
- Properties of Water video- YouTube: 2 Minute Classroom:
<https://youtu.be/VzJliO8URVM?si=S0Wg71CLTLL9F94k>
- Composting Components Explained-Wisconsin Public TV Video
<https://video.pbswisconsin.org/video/the-wisconsin-gardener-composting-basics/>
- Previous Unit would be helpful to complete: Bioreactor Water Heating: Lesson 1

Educator Background

Educators leading this lesson should be familiar with the following:

- Basic Composting
- Ecological footprints
- Use of compost and humus
- Review background information and planning suggestions.
 - Preview videos in the student background, in preparation for showing videos to students

Other Helpful Websites:

- High School Composting Curriculum:
 - <https://cwmi.css.cornell.edu/compostingintheclassroom.pdf>
- Basic Principles of Composting-Oregon State University:
 - <https://seafood.oregonstate.edu/sites/agscid7/files/snic/basic-principles-of-composting-lsu.pdf>
- Life Lab - K-12 Composting Curricula and Resources:
 - <https://www.lifelab.org/school-garden-resources-all/2014/02/composting-curriculum?rq=%E2%80%A2%20High%20School%20Composting%20Curriculum%3A%20>

Lesson/Procedure:

After watching the Unique Properties of Water and the Composting Components Explained videos (links in student background section), students should choose their container and layer their bioreactor with the components they feel will create maximum decomposition.

All students should view the videos on the unique properties of water and on composting materials. It will give them a broad spectrum of ideas for their bioreactor. Decomposition takes time but certain components and additives will speed up the process and produce more thermal energy. Students will be able to modify their components as they monitor the decomposition as it takes place.

Note: These variables may be either limited by the teacher or constrained by the classroom. If students explore too many variables, they need to understand that complex systems require more complex modeling, and a simple cause and effect investigation will not be possible.

Students should begin gathering temperature data of their bioreactor daily, preferably at the same time of day and at the same location in their container. Mark the container hole where they will be inserting the thermometer or temperature probe. Students can set up their graph with temperature as the y-axis and days (or hours, if measurements are taken more than once a day) on the x-axis and begin graphing their temperature to time chart.

After approximately two weeks of data collection and sharing of class data, where all students will predict which compost will heat water the most, students should choose a water container (Such as a beaker, a plastic cup, or a tin can) and measure the amount of water suggested by the instructor. Note: this is another variable that classrooms could decide to test, but only if there are at least two practically identical bioreactors. (Teachers should practice ahead of time to see the correct amount of water to be added; too much water might cause the bioreactor to cool too much to create decomposing heat. No more than 1 liter should be added to prevent the bioreactor reactions from slowing down too much).

Extensions:

- Students can set up inquiries to address more of the variables outlined in the lesson prep.
- Students could also place heated water (greater than measured compost temperature) into the water vessel to see if that speeds up the bioreactor as an extension to the lesson. Teachers or students would need to develop an appropriate metric for determining what evidence will indicate that the reactions within the compost have “sped up.”

Assessment/Rubric

The rubric below is a great resource for laboratory science classroom assessment.

Student Qualities Assessment Rubric				
	Honors-ready Learner	Independent Scientist	Dependent Learner	Disengaged Student
Investigation (Engage)	- I independently explore questions beyond the scope of the class on my own time for my own fulfillment. - I use materials to solve open-ended questions. - I can write about what it is in my head in detail. - I am curious about the world.	- I raise questions and don't only give answers. - I can use materials to solve open-ended questions. - I can state what's in my head. - I am curious about the world.	- I am curious about the world, BUT I want the teacher to just tell me the answer. - I cannot use materials to solve open-ended questions. - I can talk about what is in my head.	- I am curious about the world but I choose not to talk about what is in my head. - I am curious about the world but I choose not to try to use materials to solve open-ended questions. - I am unsafe and am not allowed to participate.
Experimentation (Explore)	- I can do the procedure myself and may even think of better ways to do a procedure. - All data is measured precisely (estimated one digit beyond the smallest scaling) and is recorded in correct data tables. - My written observations or drawings are detailed and labeled. - I compare my ideas with others and am willing to confront my own wrong ideas.	- I can do the procedure by myself. - I record data into correct data tables. - I write or draw observations. - I compare my ideas with others.	- I can use materials but can't collect my data. - I depend on the teacher for help with procedures. - I copy other students' data instead of measuring for myself. - If I don't solve the problem the 1st time, I give up. - My data tables lack correct titles, labels or units.	- I choose not to participate. - I am unsafe and am not allowed to participate.
Conclusion (Explain)	- I evaluate my own explanations for incorrect examples. - I use percentages and other calculations to fully explain my numeric data in my paragraphs. - I reflect on my notes and use advanced strategies like illustration, highlighting and synthesis to fully own material. - I use science words powerfully.	- I can explain ideas and concepts in my own words. - I use paragraphs to answer questions fully. - I use reading and note-taking strategies to construct my own understanding from texts. - I use science words correctly.	- I can explain ideas and concepts but only if the teacher tells me first. - I try to use complete sentences and paragraphs but leave out part of the answer. - I use reading and note-taking strategies with some help from the teacher. - I use some science words incorrectly.	I choose not to participate.
Application (Extend)	- I connect what I just learned to my previous learning and can compare and contrast ideas. - I write short, clear paragraphs to answer questions. - I use science words correctly and carefully. - I learn and reflect. I actively search out my own misunderstandings. I am excited to replace limited ideas with clearer understandings. I continually work to come up with a clearer understanding.	- I can correctly use what I just learned on a new question or challenge. - I use paragraphs to make conclusions. - I use scientific words correctly. - I learn. When needed, I can confront my own misunderstandings. I replace weaker ideas with stronger ideas based on evidence.	- I cannot yet use what I just learned on a new question. - My conclusions are not based on observations or data. - I do not use science words correctly.	I choose not to participate.