New Age Materials…

Understanding Bio Sustainable Materials!!

Description

Sustainability is the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs (United Nations definition). It also refers to the capacity to improve the quality of human life while living within the carrying capacity of the Earth's supporting eco-systems.

Sustainable materials are materials used throughout our consumer and industrial economy that can be produced in required volumes without depleting non-renewable resources and without disrupting the established steady-state equilibrium of the environment and key natural resource systems.

Such materials vary enormously and may range from bio-based polymers derived from polysaccharides, or highly recyclable materials such as glass that can be reprocessed an indefinite number of times without requiring additional mineral resources.

The goal of this lesson is to understand the fundamental science behind new forms of sustainable bio-based materials and to look at promising opportunities to reduce adverse environmental and sociological effects of traditional petroleum intensive materials.

Objectives

Students will be able to:

- Distinguish between bio-based materials and synthetic materials,
- Understand the concept of sustainability as it applies to materials.
- Build composite materials with varying properties.
- Learn basic techniques of testing material performance
- Demonstrate the environmental application of biobased materials
- Demonstrate biodegradability of bio-based materials over synthetic materials.

North Dakota State Standards

9-10.2.6	Design and conduct a guided investigation
9-10.2.7	Maintain clear and accurate records of scientific investigations
9-10.2.8	Analyze data found in tables, charts, and graphs to formulate conclusions
9-10.6.3	Explain how emerging technologies may impact society and the environment
11-12.1.2	Identify structure, organization, and dynamics of components within a system
11-12.8.1	Identify the criteria that scientific explanations must meet to be considered valid

Next Generation Science Standards

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 or interactions within and between systems relevant to the problems
HS-LS2-7	Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
RST.11-12.7-	Integrate and evaluate multiple sources of information presented in diverse formats and media(e.g., quantitative data, video, multimedia inorder to address a question or solve a problem

Schedule

09:00-09:30	General Organization and Cultural Connection
09:30-10:00	PowerPoint Presentation
10:00-10:30	Activity 1 *Biobased or synthetic*
10:30-11:15	Activity 2 *Building composite materials of various types(build the day before)*
11:15-12:00	Activity 3 *Material performance testing*
12:00-12:45	Lunch
12:45-01:45	Activity 3 *Material performance testing*
01:45-02:30	Activity 4 *Environmental Application of Bio-based materials* Experiment A
02:30-02:50	Activity 4 *Environmental Application of Bio-based materials* Experiment B
02:50-03:00	Wrap-up activity and Reflection questions

Cultural Connection:

Terminology to Note:

Materials Sciences
Synthetic Materials
Bio-based Materials
Plant materials
Sustainability
Eco-friendly materials
Composites
Properties of materials
Biodegradable materials
Natural Resources
Renewable resources
Non-renewable resources
Resins
Polymers
Co-polymers
Waste stream
Veneers
Laminates
Adhesive

Why sustainable Materials?

The main driving force behind the development of sustainable materials is to achieve a significant reduction in the use of petroleum-based materials which have been proven to have considerable negative impacts throughout the product's life cycle. Other factors that have caused an increased interest in finding sustainable materials include:

- Increased cost of petroleum extraction and exploration given it is a non-renewable resource.
- Increased cost in the amount of energy needed to produce petroleum based products.
- The need to reduce the emission of green house gases coming mainly from petroleum product processing.
- Need to discover materials with better structural capacities for model applications.
- Social awareness and environmental consciousness of modern society

There are several types of sustainable materials. Most are bio-based from renewable sources, some are a combination of bio and petroleum –based mixtures, and some can be produced from petroleum itself. The intended purpose of the material typically determines its usefulness.

Activity 1: *Sustainable or synthetic?*

Introduction

In this activity we will do an internet search to identify and list the various types of materials that are considered bio-based and those that are considered synthetic (from hydrocarbons). We will use the 5 criteria typically mentioned to determine whether a product is a sustainable material

1. Made from renewable resources
2. Recyclable
3. Biodegradable (end-of-life)
4. Environmentally acceptable
5. Economically viable

You will use these five criteria to determine whether the following materials are bio-based (sustainable) or are synthetic (petroleum based) fill in the table provided below:

Materials: (Each student)

Computer and internet
Printed recording sheet and pencil

Material	Made from renewable resource	Economically viable	Recyclable	Biodegradable (end-of-life)	Environmentally acceptable	Where do we use them
Glass						
Nylon						
Granite						
PVC						
Wood						
Epoxy						
Teflon						
Silk						
Marble						
Polystyrene						
Wool						
Fiberglass						
Polyester						
Rubber						

Questions

1. How many materials were synthetic (petroleum based)?

2. How many materials were sustainable materials?

3. Is there an alternative to these materials not considered sustainable?

4. What is the biggest challenge with using sustainable materials?

5. Can you suggest a way to overcome this challenge?

Activity 2: *Building composite materials of various types*

Introduction:

The biggest challenge facing the use of sustainable materials is trying to make them perform as best as or even better than synthetic materials. Several techniques and methods exist to achieve equal or superior performance of materials. For structural materials, combining 2- biobased materials, or reinforcing a bio-based material with some synthetic material to improve performance can be achieved.

When 2 or more materials are combined and bonded together to improve their respective usable properties or performance, they are referred to as composites. A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components.

Students will work in groups for this activity. They will be provided with a variety of materials and necessary bonding resin for them to build composites of specified dimensions and combinations. This activity needs the composites to cure over night for about 20 to 24 hours.

Materials

- Biobased materials cut to specification
  - Hemp mat
  - Flax mat
  - Kenaf mat
  - Corn mat
  - Balsa wood
  - Cork
- Other materials to be bought at local hardware stores
  - Paper
  - Glass
  - Thin metal sheet (copper or zinc)
  - Foam
  - Plastic tile
  - Synthetic wood tile
- Epoxy based resin and other types of bonding agents and spreader
- Safety apparel (gloves aprons, masks, and eye protection)
- Safe location for curing over night
- Water for wet bonding

Procedure:

- Students will work in groups to build composites of various materials bonded by a resin (resins such as epoxy and glue are also considered to be materials)
- Safety first (gloves, apron, eye wear, and masks)
- The composite needs to cure for at least 20 hours, it is suggested to make them the day before. Otherwise you will have to build them and test them the following day 9Activity 3).
- At most 3 pieces of the material can be used (sides and a core) and each material should be 4 by 4 by 1 at least.(bio materials will be pre-cut)
- The instructor will prep the epoxy and hardener resin while the students will select which materials to combine to form their composite.

- Select materials for constructing a composite tile.
- Record the sequence in which the laminates will be laid.
- Weigh the exact amount of the glue to be applied and apply a thin coat making sure you take off any excess.
- Spread the glue on one side of tile sheet.
- Compress the laminate and sheets using a standard weight.
- Make another composite with the elongated materials provided following the same guidelines.
- Cure the composites for 20 – 24 hours.
- Store in safe well aerated location to cure and testing the next day.

Composite	**Material 1**	**Material 2**	**Material 3**
1			
2			
3			
4			
Elongated composite			

Questions

1. Provide a reason for selecting the materials found in:

- Composite 1:

- Composite 2:

- Composite 3:

- Composite 4:

2. Overall, list 4 properties of your materials you considered for inclusion in all your composite materials?

Activity 3: *Material performance testing*

Introduction

Material testing is a fundamental part of any engineering process that involve the creation of materials to be used in structures. The aim of testing is to ascertain the material's performance suitability for a given purpose. For sustainable materials with the potential to replace existing petroleum based materials, this is an important step. These "new age" materials have to perform at similar level, or significantly better levels for the intended purpose than the current material in use. Testing is a time consuming, and very tedious and efficient process. Composite materials currently approved for commercial use have gone through a series of rigorous testing before they can be approved for use.

Students will work in groups to test certain properties of their built composite materials. The students will record their test results and these will be compared among all the groups. Comparative analysis will be run on the data to identify performance suitability of each composite created.

Some properties to be tested include:

- How heavy is the composite (mass)
- Buoyancy (its ability to float in water)
- Resistance to impact (does it break or deform under impact)
- Thermal insulation transfer properties (does it transmit heat and how fast does this occur)
- Flexibility (does it bend under a constant load force or does it maintain its shape) – Use the elongated composite for this test.
- Moisture absorption (does it expand when submerge in water or contract)
- Resistance to high temperatures (is its shape and structure deformed if exposed to high temperatures)

Materials and Preparation:

- Rectangular plastic container to hold water
- Hot plate
- Calipers
- 6ft long PVC pipe and metal ball
- Scale
- Thermometer
- Anchor posts
- Stop watch
- Graphing paper

Procedure:

1. **Mass of composite:**
   - Weigh each manufactured composite on the scale provided and record its mass.

2. **Thermal transfer**:
   - Is your composite a good insulator? Does it transmit heat and how fast does this occur?
   - Place one side of the material on a hot plate set at 200^{o} C.
   - With a digital thermometer placed on the top side, measure with a stop watch how long it takes for the thermometer to record a temperature of 200^{o} C.
   - Record your observations

3. **Resistance to impact:**
   - Assess the impact of a metal ball dropped through a 6ft PVC pipe on your composite material.
   - Record whether the material stays intact or is cracked or shattered.

4. **Flexibility**:
   - Use the elongated composite for this test.
   - Using two anchor posts (2 chairs or 2 stacks of books) place the composite length-wise to form a bridge across the anchors
   - Place a set amount of weights (books, or materials of known mass) at the center of the composite
   - Observe whether it bends or breaks, or does it hold its shape.
   - How much weight can it carry?
   - Record your observations

5. **Buoyancy**:
   - Fill the plastic container with enough water to enable the material to float.
   - Place its composite on water and determine how long it takes for it to float or sink.
   - Record your results.

6. **Moisture absorption**
   - Using calipers (does it expand when submerge in water or contract)
   - Weigh the sample in grams (W1).
   - Measure and dimensions in millimeter (length L1, width, W1 and thickness. T1)
   - Calculate the volume of the sample (V1). (LxWxH)
   - Completely soak the samples in water for 30 minutes.
   - After 30 minutes take the samples out and quickly dry with paper towel.
   - Again take the weight of sample (W2) and measure the dimensions, L2, W2, T2.
   - Calculate the volume after the soak (V2).
   - Calculate % water absorption (WA).

$$\%\ Water\ Absorption = \frac{(\mathbf{W2 - W1})}{\mathbf{W1}} * 100$$

   - Record your results

Test	Composite 1	Composite 2	Composite 3	Composite 4	Elongated
Mass of Composite					
Thermal Transfer (Minutes)					
Impact resistance shatter=1, cracks=2, intact= 3					
Flexibility (Mass supported)					
Buoyancy (Minutes)					
Moisture absorption (%)					

Questions

1. Graph the results of each row to show comparison between these properties tested.
2. Which composite material performed best based on the results of your tests?
3. Which composite material performed least based on the results of your tests?
4. Which of your composites will you recommend as bathroom structural material? Why?

Activity 4: *Environmental Application of Bio-based materials*

Introduction

Applications for bio-based sustainable materials are diverse and vast. Most bio-based composed have been successfully used a structural replacements for petroleum based materials. Other materials have been inserted into non-sustainable materials to make them some desired properties of sustainability. Still, scientist have been able to convert materials that were generally unsustainable to forms that are partially or completely sustainable.

In this activity we are going to demonstrate the environmental application and performance of some materials considered bio based compared to synthetic materials. Two experiments will be conducted and these will record results over at least 3 days.

Experiment 1: Weed control using Biobased material versus synthetic mulch material
Experiment 2: Fermentation (biodegradation) of bio based and synthetic materials using Yeast culture.

Materials

Various mats of materials developed from flax, hemp, kanaff and synthetic materials
Exposed and clear cut piece of soil
Yeast
Canning jar
Mulch pegs

Experiment 1: Weed control using Biobased material versus synthetic mulch material

In this experiment we will be comparing the performance of a bio based material and the standard synthetic product being currently marketed. The objective is to show that the bio based material can control the growth of weeds as effectively as the synthetic material. This process, known as mulching will be experimented over a 3 day period.

Students will work in groups to complete this experiment.

Procedure:

1. This is an outdoor experiment which can be conducted in a garden or a potted soil kept in an environment ideal for plant growth.
2. 3 small plots measuring 50x50 cm each should be clear cut and weeded to expose the bare soil.
3. The plots should be in conducive environments for plant growth and germination.
4. Each group will be provided: a synthetic plastic mulch, and bio-based mat mulch
5. The mulches will be used to cover 2 plots, while the third plot will serve as control
6. Peg the mulches into the plot. Leave the control plot bare.

7. Students will be expected to measure and observe the percentage cover or new growth in the plots over a 3 day period.
8. Cover is measured twice a day: morning, and evening before leaving for the day.
9. Estimate foliar or canopy cover of plants in the plot.
    a. Record estimate by cover class using the following table:

Cover Class	Range of Coverage	Midpoint of Range
1	0-5%	2.5%
2	5-25%	15.5%
3	25-50%	37.5%
4	50-75%	62.5%
5	75-95%	85.0%
6	95-100%	97.5%

b. These cover classes were designed to make if faster to estimate cover (don't need to decide if it is a few percentages more or less just need to put coverage into classes).

10. Record your observations in the table below

Day	**Plot 1 (Bio mulch)**		**Plot 2 (plastic mulch)**		**Plot 3 (control)**	
	AM	**PM**	**AM**	**PM**	**AM**	**PM**
Day 1						
Day 2						
Day 3						

11. Cover calculation:

*% cover of plot # = (# of plots cover class 1 * 2.5%*
*+ # of plots cover class 2 * 15.5%*
*+ # of plots cover class 3 * 37.5%*
+ # of plots cover class 4 * 62.5%
+ # of plots cover class 5 * 85.0%
+ # of plots cover class 6 * 97.5%) ÷ total number of plots

Questions

1. Which plot had the least plant cover?.

2. Which material performed best based on the results of your experiment?

Experiment 2: Fermentation (biodegradation) of bio based and synthetic materials using Yeast culture.

In this experiment we will be comparing the performance of a bio based material and the standard synthetic product being currently marketed. The objective is to show that the bio based material can be effectively biodegraded compared to the synthetic material. This process, known as microbial biodegradation will be experimented over a 3 day period.

Students will work in groups to complete this experiment.

Procedure:

1. This experiment will be conducted in a canning jar with regular yeast bought from a grocery store. Label three canning jars as "BIO", "SYNTH", and "CONTROL" respectively.
2. Fill up halfway the three regular canning jars with warm water.
3. Add a teaspoon of yeast into the jars labeled BIO and SYNTH. No yeast should be added to the jar labeled CONTROL.
4. Each group will be provided: a synthetic plastic mat (mulch), and bio-based mat (mulch)
5. Add the bio based material to the jar labeled BIO, add the synthetic material to the jar labeled SYNTH, and add another bio-based material to the jar labeled CONTROL.
6. Seal the cap on these jars and set aside overnight.
7. Students will be expected to observe biodegradation occurring in these jars over a one day period.
8. Observed the material texture, material color, and smell emanating from the jar once opened.
9. Answer the following questions based off your observations.

Questions

1. Which jar shows the greatest amount of change?

2. Which material performed best based on the expectations of your experiment?

3. How can you make a material more biodegradable?