Green Chemistry Module
Level: High School Regents

Bioplastics

Image: FreeDigitalPhotos.net

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Bioplastics

In this lab experiment, students will be making a bioplastic from corn starch, corn oil, and water. They will research bioplastics and formulate ideas about why and when bioplastics would be appropriate to use, and under what conditions they would not be recommended.

Two versions of the lab are provided. In both versions, students will prepare small samples of bioplastic material from cornstarch. In the basic level of instruction, students will follow a prescribed procedure to make an initial sample, and choose one variation for a second trial. In the advanced version, students will be given a list of materials and will design their own experimental procedures to determine the optimal combination of ingredients to prepare a useful bioplastic material.

Basic Level Instruction: This lab would be suitable for a Regents chemistry class. The procedure is relatively simple and can easily be accomplished in one class period. There is opportunity for extended studies to examine the biodegradable characteristics of the produced material.

Advanced Level Instruction: For an advanced class (AP or Honors), the lab would be useful for students to practice designing an experiment. The process for producing the bioplastic material is quite simple, allowing for multiple variations within a reasonable period of time. Follow up studies on biodegradability allow for more extended studies and creativity in experimental design. The laboratory write-up for the advanced level laboratory is a stand-alone report generated by the student.

Bioplastics: Teacher's Guide

Intended Audience: High School Regents Chemistry Students
This experiment is aimed at students in high school learning about chemical changes and reaction types. The experiment would also be suitable for an introductory college laboratory.

Recommended Student Background: *To be completed the day before the lab.* Students read the introduction and complete the pre-lab questions.

Activity Timeline: ***All times are estimates***

Make Mixture	Mixing	Microwave	Observations	Questions	TOTAL TIME
10 min	5 min	10 min	5 min	15 min	45 min

Safety Issues: Wear approved safety goggles and suitable clothing when working with or near all chemicals in this experiment. As they leave the laboratory, students should wash hands well.

Keys to Success: Use a microwave to heat the bioplastic solution. It's possible to use a hot plate and aluminum foil mold if a microwave is not available, but better results are obtained with a microwave.

Advanced Preparation:
The instructor should run trials in advance to determine reasonable microwaving times for the particular microwave being used, and provide students with a range of reasonable times. The instructor may wish to schedule the pre-lab a week or so ahead of the laboratory activity in order to allow students time to bring in samples of biodegradable materials from home.

Materials Check List: (per lab group)

9.5 g	Corn starch (1 Tablespoon; 1/3 oz)
15 mL	Water (1 Tablespoon)
2 drops	Corn oil
1	Ziploc Bag
1 drop	Food Coloring (optional)
Dropper	
Balance	
Microwave	

Measurements:

Appearance before heating
Appearance immediately after heating
Physical characteristics immediately after heating
Appearance at next class period
Physical characteristics at next class period

Recycling and disposal: The samples produced in this experiment are non-toxic and biodegradable, so they can be disposed of as regular waste, or composted.

Green Chemistry: Making materials sustainably

Chemical manufacturing is as old as civilization and the discoveries of bronze and iron came to define the eras that ensued. In modern times, we take for granted a plentiful supply of metals, plastics, dyestuffs and medicines. We have come to depend on the chemical industry to provide us with all the materials we need for our "materialist" society.

But the supply of these materials is not infinite. As the human population grows, and demands an ever higher standard of living, the consumption of the Earth's materials is in danger of getting out of control. It is therefore essential that chemists become responsible stewards of the raw materials that remain. We need to develop methods for chemical processing that are both chemically and environmentally efficient, and which move us towards a sustainable society. We need new materials that can provide what we need without destroying the Earth.

Green chemistry is designed to help us meet these needs. It aims not just to treat waste, but to avoid producing waste in the first place. Products and processes should be "benign by design," but they must also be practicable.

In this lab manual, we will explore how we can this can be achieved in practice – how we can use chemistry to help solve our environmental problems. We will never be able to build a sustainable society if we don't understand the basic science of where our materials come from, and how they are produced. The goal of this manual is to provide that science, presented within the context of green chemistry.

The Twelve Principles of Green Chemistry

The basic principles of green chemistry were first laid out by two US chemists, Paul Anastas and John Warner, in their 1998 book, "Green Chemistry: Theory and Practice:"

1. **Prevent waste:** Design chemical syntheses to prevent waste, leaving no waste to treat or clean up.
2. **Design safer chemicals and products:** Design chemical products to be fully effective, yet have little or no toxicity.
3. **Design less hazardous chemical syntheses:** Design syntheses to use and generate substances with little or no toxicity to humans and the environment.
4. **Use renewable feedstocks:** Use raw materials and feedstocks that are renewable rather than depleting. Renewable feedstocks are often made from agricultural products or are the wastes of other processes; depleting feedstocks are made from fossil fuels (petroleum, natural gas, or coal) or are mined.
5. **Use catalysts, not stoichiometric reagents:** Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once.
6. **Avoid chemical derivatives:** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.
7. **Maximize atom economy:** Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms.
8. **Use safer solvents and reaction conditions:** Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals.
9. **Increase energy efficiency:** Run chemical reactions at ambient temperature and pressure whenever possible.
10. **Design chemicals and products to degrade after use:** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.
11. **Analyze in real time to prevent pollution:** Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.
12. **Minimize the potential for accidents:** Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

It must be recognized that these represent a target, and we will not be able to satisfy every principle immediately with every process and product. Nevertheless, if we design our chemistry with these principles in mind, we will make great strides towards achieving sustainability.

Why should you teach about bioplastics?

Bioplastics are becoming an increasingly important commercial product as consumers and the government become more demanding of environmentally responsible products. Many products do not need to have a long useful lifetime, and can be produced from renewable biomass resources to reduce reliance on fossil fuels, and eliminate solid waste. Environmental chemistry is a growing career field with many opportunities for specialization. Exposure to this type of chemistry process may spark interest in a wide open career field. The opportunity for true inquiry and experimentation in this lab will appeal to most students, as will the environmental aspect of the learning.

Correlation of the experiment with Green Chemistry

Green Chemistry Principles: 2. Design safer chemicals and products.
4. Use renewable feedstocks.
10. Design chemicals and products to degrade after use.

Curriculum alignment

Alignment to the NYS Regents Chemistry Curriculum:

VII.1 Organic compounds contain carbon atoms which bond to one another in chains, rings, and networks to form a variety of structures. Organic compounds can be named using the IUPAC system. (3.1ff)

V.22 The structure and arrangement of particles and their interactions determine the physical state of a substance at a given temperature and pressure. (3.1jj)

This experiment correlates directly with the following section of the New York State Core Curriculum:

Standard 4: The Physical Setting.

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

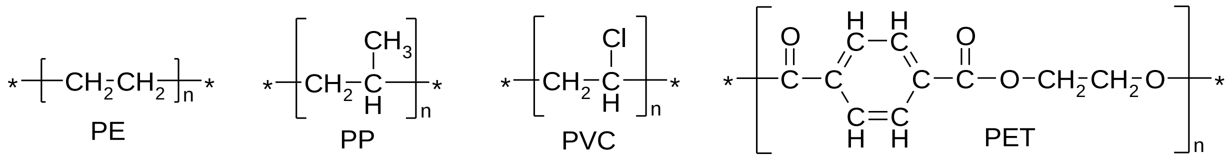
Performance Indicator 3.1 Explain the properties of materials in terms of the arrangement and properties of the atoms that compose them.

Major Understandings 3.1jj The structure and arrangement of particles and their interactions determine the physical state of a substance at a given temperature and pressure.

Background and Fundamentals for Basic Level Instruction:

Plastics are everywhere! They are some of the most common and important materials we use every day. Being moldable and easy to work with, they can be made into almost any shape. They are used to make most containers, and in consumer products such as toys and electronics. Modern plastics are strong yet lightweight, which means they reduce transportation costs and they do not use a lot of material for a given purpose.[1] For example, a plastic grocery bag weighs only 6 g, compared to 56 g for a (albeit slightly larger) paper grocery bag.[2] Plastics are long-lasting, and do not corrode, and it is hard to imagine modern life without them. However, these versatile materials have contributed to our "disposable culture," and plastics now make up around 12% of municipal solid waste in the US.[3] Most plastics are based on non-renewable resources such as petroleum. In addition, there have been safety concerns about residual amounts of bisphenol A (BPA) and phthalate plasticizers, though the former is still widely used in plastics in the US and the EU.

Some common plastics include polyethylene (PE), polypropylene (PP), polystyrene, poly(vinyl chloride) (PVC), nylon and poly(ethylene terephthalate) (PET). These are all polymers, which are huge molecules built from many repeating units. As you can see, some such as PE (used for grocery bags and common consumables) have very simple structures, whereas some such as PET (used in clothing and for drinks bottles) are more complex.



The square brackets indicate the basic unit of the polymer; this unit is repeated typically thousands of times over (indicated by the *n*).

Flatware made from a biodegradable starch-polyester material. (Photo by USDA.)

Clearly there is a need to develop plastics from renewable resources; these are frequently referred to as bioplastics. Such materials should not only be strong and lightweight, but also biodegradable

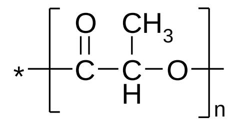
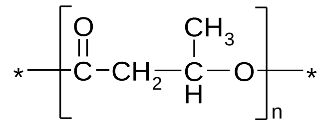
[1] For more information, see the website Plastics Division of the American Chemistry Council at http://www.americanchemistry.com/plastics/

[2] Both bags from Big-M market in Potsdam, NY, tested January 20, 2010. For comparison, a gallon of gasoline weighs 2760 g.

[3] US EPA, "Plastics", accessed January 20, 2010. http://www.epa.gov/osw/conserve/materials/plastics.htm

(though not while in use!). Some are manufactured from virgin renewable materials, while others are designed to use biodegradable waste products such as starch or lignin.

Some common bioplastics:

Name	Acronym	Made from	Structure
Poly(lactic acid)	PLA	Sugar	
Poly(hydroxybutyric acid)	PHB	fermentation of starch	
Starch-based materials		Starch	Carbohydrate-based polymer

PLA is currently being manufactured by BASF and sold as Ecovio®,[4] while PHB is produced by Metabolix as Biopol.

In this experiment, students will prepare a starch based plastic from corn starch, using corn oil as a filler. The plastic produced will be quite brittle, but for industrial manufacturing, the conditions could be adjusted to produce a stronger material.

Guidance Notes: Students should be given as much latitude as possible to choose their modifications in the second trial. You may get some very creative changes, and it will be interesting as a class to compare the various trials and see which modifications made the best final product.

Cleanup and disposal: The samples produced in this experiment are non-toxic and biodegradable, so they can be disposed of as regular waste, or composted.

[4] " Ecovio® – First BASF plastic derived from renewable raw materials", BASF Plastics Portal, accessed January 20, 2010. http://www.plasticsportal.net/wa/plasticsEU/portal/show/content/products/biodegradable_plastics/ecovio

Answers

Pre-lab:

1. Use the internet to find examples of products being made from bioplastics at the present time. List five examples. Bring in one item from home that you think may be made from bioplastics.

   flatware, iphone cases, booster seats, plastic bags, etc. (found at bgreentoday.com and bioplasticproducts.info/index.htm)

   Students will bring in a variety of products which may or may not actually be made from bioplastics. Have students observe and discuss each of the products they brought in, and have them form hypotheses about which would degrade. These products could become the basis of a long-term experiment.

2. Why is it useful to develop plastics that are biodegradable (i.e., they can be decomposed in the environment)?

   Once not in use the products biodegrade so they reduce the amount of trash that we add to landfills and dumps. Also, the products are safer for us! They are made from natural, non toxic ingredients!

Conclusion:

1. Did you successfully make a plastic? How can you tell? (You may refer back to the introduction to refresh your memory of what a "plastic" is.)

   Yes. The material made is a single homogenous piece that is strong but pliable as well as lightweight.

2. What characteristics of your sample could be improved, to make it into a useful plastic?

   The product would be more useful if it was denser in order to make is stronger and less susceptible to tears and breaks. Needs to be harder.

3. What suggestions do you have for how those improvements might be achieved?

   Adjust the ingredient proportions, i.e. more cornstarch and less water. We already realized that more cornstarch with the same volume of water produced a stronger material, so further proportion adjustments would continue to strengthen the material.

Discussion points:

1. What are some applications for bioplastics where their biodegradable properties would be advantageous? What are some areas that plastics are used where you would not want them to be biodegradable? Do you think we could meet the demand for plastic materials using bioplastics alone? Present evidence to support your argument.

   I don't think we could meet the demands of plastics using bioplastics alone. We could not use the bioplastics for long term use products like piping of outdoor structures, which are currently made of plastic, but bioplastics could be useful in these areas: disposable dinner ware (plates, cups, silverware), single use water bottles, etc.

2. Review the Washington Post article[5] at the end of this packet and discuss the evidence that BPA is safe or unsafe to use. Would your family be willing to spend an extra $10 per month to buy things free from BPA?[6] If you have access to the internet, research what alternatives may (or may not) be available.

   This is an opinion question…

Questions

1. If you wanted to use this type of material and process make plastic flatware, as shown in the above picture, how could you do that?

   Mix and heat the ingredients in molds of the silverware

2. Look at the chemical structures of PET and PVC (page 1 of this handout). What functional group(s) is/are present?

   PVC: Halides

   PET: ester, alkene, aromatic ring

Extension Activities:

1. Design a testing procedure for a long-term study of how well your bioplastic degrades. Include at least two different testing environments. Be sure to include specific characteristics to observe or measure to evaluate the biodegradability of the product.
2. Conduct a biodegradability study on materials that were brought in by the class. Determine whether you feel each of these products is biodegradable or not based on your test results.

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[5] Layton, Lindsey (September 16, 2008). "Study Links Chemical BPA to Health Problems". Washington Post. pp. A03. retrieved January 22, 2010.

[6] This is an arbitrary figure for discussion only; the added cost will vary greatly from family to family.

Background and Fundamentals for Advanced Level Instruction:

The background and fundamentals of the lab are the same as in the basic level instruction. Advanced level students will design and conduct their own series of experiments in two parts. In the first part, students will design experiments to determine the optimal conditions for production of a usable bioplastic material. In Part 2, students will design and conduct studies to determine how well their produced material biodegrades, and compare it to commercial samples of bioplastics.

Prelab

1. Use the Internet to research bioplastics. What makes a substance a *bio*plastic, as opposed to a regular plastic? What are the environmental advantages of bioplastics? What are the limitations?

   Bioplastics are produced from renewable biomass sources, rather than from fossil fuels (petroleum products). Some, but not all, bioplastics are designed to be biodegradable. Environmental advantages include using less space for disposal of waste, as the product will degrade rather than remaining stable in a landfill for decades. When bioplastics are produced from recycled materials, they help to keep other waste products from being landfilled. The raw materials are easily regenerated rather than being used up as fossil fuels are.

   Some limitations are dependent on the use of the final product. Products that are used for only a short period of time are likely candidates for bioplastics. Products that must remain useful for long periods of time, such as plastic piping, computer housings, etc would not be likely uses, as the bioplastics may begin to degrade before the end of the intended lifetime of the product.

2. Find at least 3 samples of materials you believe are bioplastics at home, in school, or from a local business. Bring these materials in to school. You will use them in your experiments.

   Students will bring in a variety of materials. Testing in Part 2 will help to determine whether these products are easily biodegradable.

Discussion Questions:

1. Review the Washington Post article[7] at the end of this packet and discuss the evidence that BPA is safe or unsafe to use. Would your family be willing to spend an extra $10 per month to buy products free from BPA?[8] Use the internet to research what alternatives may (or may not) be available.

   This is an opinion question. Answers will vary but should be well thought out and presented.

Questions:

1. Describe the polymerization process used to make plastics. How is the bioplastic you produced different than traditional plastics such as polyethylene?

[7] Layton, Lindsey (September 16, 2008). "Study Links Chemical BPA to Health Problems". Washington Post. pp. A03. retrieved January 22, 2010.

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Polymerization is a process of reacting monomer molecules together in a chemical reaction to form three-dimensional networks or polymer chains. The bioplastic produced simply uses a different, plant-based molecule as the monomer that is chained together instead of the petroleum based monomer (ethylene in polyethylene).

2. Compare the composition of your bioplastic material before and after cooking. What changes took place during the cooking process? How do these changes explain the final properties of the bioplastic material?

   Before cooking, the bioplastic was a liquidy sludge, but after cooking, it was a plastic-like solid. The cooking process allowed bonds to form between the cornstarch molecules, joining them into a linked chain. The structure of the resulting product is more tightly packed, resulting in a more solid structure than the original material.

3. What characteristics of your material should be improved in order to make it a useful commercial product? What process improvements do you think would accomplish these improvements?

   Answers will vary depending on the product produced, but may include some of the following:
   The product would be more useful if it was denser in order to make is stronger and less susceptible to tears and breaks. The product needs to be harder. The product needs to be more flexible to take the required shapes.

   Process improvements might include things like precise temperature control, pressure control, accurate dosing of ingredients, perhaps some stabilizers or additives to enhance the desired properties (plasticizers, stabilizers, colorants). Student research may uncover other appropriate process controls.

Bioplastics **Laboratory Experiment # ______**

Name ____________________________________ Date ________________________________

Partner ___________________________________

Introduction

Plastics are any of a wide range of synthetic or semi-synthetic organic solids that are moldable. Plastics are everywhere! They are some of the most common and important materials we use every day. Being moldable and easy to work with, they can be made into almost any shape. They are used to make most containers, and in consumer products such as toys and electronics. Modern plastics are strong yet lightweight, which means they reduce transportation costs and they do not use a lot of material for a given purpose.[9] For example, a plastic grocery bag weighs only 6 g, compared to 56 g for a (albeit slightly larger) paper grocery bag.[10] Plastics are long-lasting, and do not corrode, and it is hard to imagine modern life without them. However, these versatile materials have contributed to our "disposable culture," and plastics now make up around 12% of municipal solid waste in the US.[11] Most plastics are based on non-renewable resources such as petroleum. In addition, there have been safety concerns about residual amounts of bisphenol A (BPA) and phthalate plasticizers, though the former is still widely used in plastics in the US and the EU.[12]

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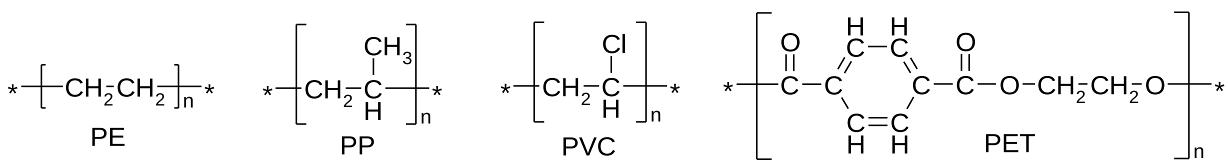

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Flatware made from a biodegradable starch-polyester material. (Photo courtesy of USDA.)

Clearly there is a need to develop plastics from renewable resources; these are frequently referred to as bioplastics. Such materials should not only be strong and lightweight, but also biodegradable (though not while in use!). Some are manufactured from virgin renewable materials, while others are designed to use biodegradable waste products such as starch or lignin.

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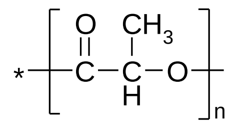
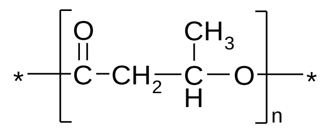
Poly(lactic acid)	PLA	Sugar	
Poly(hydroxybutyric acid)	PHB	fermentation of starch	
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<u>What is Green Chemistry?</u>

The goal of green chemistry is to design chemicals and processes that reduce or eliminate negative environmental impacts. This includes products and processes that use or generate less hazardous substances, reduced waste products, less or non-toxic components, and using substances more efficiently. Green chemistry is a highly effective approach to pollution prevention because it applies innovative scientific solutions to real-world environmental situations.

Green chemistry provides a number of benefits, including:

- reduced waste, eliminating costly end-of-the-pipe treatments
- safer products
- reduced use of energy and resources

[13] "Ecovio® – First BASF plastic derived from renewable raw materials", BASF Plastics Portal, accessed January 20, 2010. http://www.plasticsportal.net/wa/plasticsEU/portal/show/content/products/biodegradable_plastics/ecovio

- improved competitiveness of chemical manufacturers and their customers.

There are twelve principles that green chemistry relies on that were first laid out by two US chemists, Paul Anastas and John Warner, in their 1998 book, "Green Chemistry: Theory and Practice":

1. **Prevent waste:** Design chemical syntheses to prevent waste, leaving no waste to treat or clean up.
2. **Design safer chemicals and products:** Design chemical products to be fully effective, yet have little or no toxicity.
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11. **Analyze in real time to prevent pollution:** Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.
12. **Minimize the potential for accidents:** Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

<u>Why is this experiment green?</u>
This experiment is green as it illustrates the use of a natural substance as the feedstock for a final product, as well as producing a product that degrades into non-hazardous substances after use. The product produced is also safe and non-toxic. The process illustrated in this lab is actually used in industry, and will become more important in the future as our society works to design more environmentally-friendly products.

Safety Issues: Wear approved safety goggles and suitable clothing when working with or near all chemicals in this experiment. As they leave the laboratory, students should wash their hands well.

Materials and Equipment

9.5 g	Corn starch (1 Tablespoon; 1/3 oz)
15 mL	Water (1 Tablespoon)
2 drops	Corn oil
1	Ziploc Bag
1 drop	Food Coloring (optional)
Dropper	
Balance	

Pre-lab:

1. Use the internet to find examples of products being made from bioplastics at the present time. List five examples. Bring in one item from home that you think may be made from bioplastics.

2. Why is it useful to develop plastics that are biodegradable (i.e., they can be decomposed in the environment)?

<u>Procedure:</u>

1. Place 9.45 g of corn starch into a plastic Ziploc bag.
2. Add two drops of corn oil to the corn starch in the bag.
3. Add 15 mL of water (with added coloring if you wish) to the cornstarch.
4. Using your fingers through the bag, mix the solution well. It is important that the mixture is homogenous – failure to do so will cause uneven cooking and give starchy patches throughout.
5. Once the solution is mixed, place the bag in a microwave oven and heat on high power for about 20-25 seconds. †**DO NOT** microwave the bag while it is completely sealed. Leave a small opening for steam to escape.
6. After the sample has cooled, check its physical characteristics such as texture and flexibility (carefully – it will be quite delicate).
7. Leave the sample until the next class, then once again check its properties.

† The ideal time depends on the particular oven; the exact time will be given to you by the instructor.

Recycling and disposal:
The samples produced in this experiment are non-toxic and biodegradable, so they can be disposed of as regular waste, or composted.

Options: Depending on the time available, select one or more of the following options (or your own alternate idea) to repeat the experiment for trial 2.

A. Repeat the experiment with different colorings
B. Repeat the experiment using 12 g corn starch. How is the product different?
C. Repeat the experiment using 5 seconds less heating time. How is the product different?

Observations:
Trial 1:

Appearance before heating	
Appearance immediately after heating	
Physical characteristics immediately after heating	
Appearance at next class period	
Physical characteristics at next class period	

Trial 2 (describe the modification made):

Appearance before heating	
Appearance immediately after heating	
Physical characteristics immediately after heating	
Appearance at next class period	
Physical characteristics at next class period	

Conclusion:

1. Did you successfully make a plastic? How can you tell? (You may refer back to the introduction to refresh your memory of what a "plastic" is.)

2. What characteristics of your sample could be improved, to make it into a useful plastic?

3. What suggestions do you have for how those improvements might be achieved?

Discussion points:

1. What are some applications for bioplastics where their biodegradable properties would be advantageous? What are some areas that plastics are used where you would not want them to be biodegradable? Do you think we could meet the demand for plastic materials using bioplastics alone? Present evidence to support your argument.

2. Review the Washington Post article[14] at the end of this packet and discuss the evidence that BPA is safe or unsafe to use. Would your family be willing to spend an extra $10 per month to buy things free from BPA?[15] If you have access to the internet, research what alternatives may (or may not) be available.

Questions

1. If you wanted to use this type of material and process make plastic flatware, as shown in the above picture, how could you do that?

2. Look at the chemical structures of PET and PVC (page 1 of this handout). What functional group(s) is/are present?

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Extension Activities:

1. Design a testing procedure for a long-term study of how well your bioplastic degrades. Include at least two different testing environments. Be sure to include specific characteristics to observe or measure to evaluate the biodegradability of the product.

2. Conduct a biodegradability study on materials that were brought in by the class. Determine whether you feel each of these products is biodegradable or not based on your test results.

Study Links Chemical BPA to Health Problems

Findings Reignite Debate Over Safety; Scientists Say More Research Is Needed

By Lyndsey Layton
Washington Post Staff Writer
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http://www.washingtonpost.com/wp-dyn/content/story/2008/09/16/ST2008091601215.html?sid=ST2008091601215&s_pos=list

The first large study in humans of a chemical widely used in everyday plastics has found that people with higher levels of bisphenol A had higher rates of heart disease, diabetes and liver abnormalities, a finding that immediately became the focus of the increasingly heated debate over the safety of the chemical.

The research, published yesterday in the Journal of the American Medical Association by a team of British and American scientists, compared the health status of 1,455 men and women with the levels of the chemical, known as BPA, in their urine.

The researchers divided the subjects into four statistical groupings according to their BPA levels and found that those in the quartile with the highest concentrations were nearly three times as likely to have cardiovascular disease than those with the lowest levels, and 2.4 times as likely to have diabetes. Higher BPA levels were also associated with abnormal concentrations of three liver enzymes.

Although the researchers described them as preliminary, the findings were the buzz of a public hearing the Food and Drug Administration held yesterday to discuss whether BPA is safe for continued use in food packaging and liquid containers.

"This is the nail in the coffin," Frederick vom Saal, a reproductive scientist at the University of Missouri at Columbia and one of the first to document evidence of health problems in rodents exposed to low doses of BPA, said outside the FDA meeting in Rockville. "This is a huge deal."

On Capitol Hill, Sen. Charles E. Grassley (R-Iowa) cited the study as he opened an investigation of the way the FDA has regulated the chemical, joining several Democrats, led by Rep. John D. Dingell (Mich.), who have been looking into whether chemical manufacturers unduly influenced the agency's stance.

One of the authors of the new study, David Melzer of the Peninsula Medical School in Exeter, England, briefed the FDA gathering about the research.

He said that the study did not prove that BPA causes health problems and that additional studies are needed. "This needs to be replicated as soon as possible, and we need to understand the mechanism," he said.

Data on the health status of the study subjects, who ranged in age from 18 to 74, came from the Centers for Disease Control and Prevention. The BPA levels in the study were below those the government deemed safe.

Trade groups representing the chemical industry and metal can producers dismissed the results.

"Due to inherent limitations in study design, this new study cannot support a conclusion that bisphenol A causes any disease," Steven G. Hentges of the American Chemistry Council said in a statement. "The weight of scientific evidence continues to support the conclusion of governments worldwide that bisphenol A is not a significant health concern at the trace levels present in some consumer products."

The FDA regulates the compound's use in plastic food containers, bottles, tableware and the plastic linings of food cans. In light of the controversy surrounding the chemical, the agency is reviewing its policy. It issued a draft statement last month that repeated its position that BPA is safe for food and beverage packaging, but it also tapped six outside scientists to review the scientific literature and make a recommendation to agency officials, who are expected to make a final decision on BPA next month. Yesterday's hearing before the six scientific advisers was the public's chance to offer testimony.

Laura Tarantino, director of the FDA's Office of Food Additive Safety, said her agency has no reason to think that BPA in food packaging and liquid containers is unsafe. "We have confidence in the data we've looked at to say that the margin of safety is adequate," she said, adding that consumers can take steps to reduce their exposure to the chemical.

More than 100 studies have linked BPA exposure to health effects in animals. The FDA maintains that BPA is safe largely on the basis of two studies funded by the chemical industry, a fact that was repeatedly cited at yesterday's forum.

"We're concerned that the FDA is basing its conclusion on two studies while downplaying the results of hundreds of other studies," said Amber Wise of the Union of Concerned Scientists. "This appears to be a case of cherry-picking data with potentially high cost to human health."

The FDA's position on BPA runs counter to a report by another federal agency, the National Toxicology Program, which found "some concern" that BPA may cause developmental problems in the brains and hormonal systems of children.

Bioplastics: Advanced Level Instruction

Materials

Corn starch
Water
Corn oil
Ziploc Bag
Food Coloring (optional)
Dropper
Balance
Microwave oven

Pre-Lab

1. Use the Internet to research bioplastics. What makes a substance a *bio*plastic, as opposed to a regular plastic? What are the environmental advantages of bioplastics? What are the limitations?
2. Find at least 3 samples of materials you believe are bioplastics at home, in school, or from a local business. Bring these materials in to school. You will use them in your experiments.

Procedure:

Part 1: Your task is to use the available materials and equipment to design and produce a usable bioplastic material. Keep track of all trials including proportions of ingredients used, cook times, and results. Make a conclusion about which trial was most successful, and cite specific results to support your conclusion.

Part 2: Design a long-term study to determine how biodegradable your produced bioplastic is. Compare your material to the materials you brought in from home. Be sure to identify the criteria used to determine how biodegradable the materials are. Your study should include multiple environmental conditions.

Discussion Questions:

1. Review the Washington Post article[16] at the end of this packet and discuss the evidence that BPA is safe or unsafe to use. Would your family be willing to spend an extra $10 per month to buy products free from BPA?[17] Use the internet to research what alternatives may (or may not) be available.

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[16] Layton, Lindsey (September 16, 2008). "Study Links Chemical BPA to Health Problems". Washington Post. pp. A03. retrieved January 22, 2010.

[17] This is an arbitrary figure for discussion only; the added cost will vary greatly from family to family.

Questions:

1. Describe the polymerization process used to make plastics. How is the bioplastic you produced different than traditional plastics such as polyethylene?
2. Compare the composition of your bioplastic material before and after cooking. What changes took place during the cooking process? How do these changes explain the final properties of the bioplastic material?
3. What characteristics of your material should be improved in order to make it a useful commercial product? What process improvements do you think would accomplish these improvements?

Extension Activities:

As a class, organize a field trip to a recycling plant, or invite a guest speaker in if a field trip is not feasible. Based on the information obtained from the speaker or field trip, prepare a report on the process of plastics recycling. Be certain to consider the environmental as well as the economic considerations of plastics recycling. In the current economic conditions, is plastics recycling a reasonable venture to pursue? Support your conclusions with specific data.

Report:

The lab report should consist of an introduction, answers to pre-lab questions, brief description of procedures, and a data table showing all measurements and observations. Be sure to include answers to the Questions (including calculation of percent yield) and the Extension activities.