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It's All about Plastic, Everywhere...

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Introduction

Plastics, Plastics and more Plastics! Over the course of my lifetime I have observed that virtually everything is now made of plastic: our rugs, our toys, our cars, our phones, and even our clothes. A startlingly high percentage of our foods and beverages are packaged, stored and served in plastic. Contact lenses, artificial joints, disposable diapers, and iPods were not imaginable to most of us five decades ago. In a single generation, plastics have revolutionized the modern world and have made an enormous impact on our everyday lives.

The versatility of plastics enables them to fill almost every product niche in our modern lifestyles. The enormous size and flexibility of synthetic plastic polymer chains, how the monomers are bonded together, and chemical structure of the monomer (repeating unit) are what provide unique chemical and physical properties. The various properties we depend on and enjoy relate to the unique chemistry of these synthetic polymers.

So, how did so much plastic infiltrate our lives in a single generation? How is it made? What is the chemistry behind our dependency on this synthetic polymer based on organic compounds? Which plastics are recyclable and which are not? What happens to plastics as they enter the waste stream? Are there severe negative impacts on the environment with all this plastic waste being discarded?

Will Green Chemistry have any solution for the controversy over the abundant use of fossil fuel-based plastics? Will fossil fuel-based plastics be available in the future, or will we have to look for other sources such as corn to make our plastic? Will the high oil prices we have seen trigger a resurgence of interest in bioplastics made from renewable biomass such as cellulose and starch?

In my unit, I intend to have my students investigate the birth and life cycle of plastic. If plastics have a negative impact on the environment and/or can no longer be made from fossil fuels, then what are the alternatives?

Rationale

This unit is designed with high school biology or high school environmental students in mind. My school is in a nearby suburb of San Francisco, yet we are physically and culturally isolated. Science education has never been a focus in the district. About half of the students are Caucasian with a balance of Asian, African American and Latino students. Economically, they range from families struggling financially to the lower end of middle class. There are many single parent families and many students raised by grandparents. Drugs and alcohol use are an underlying community issue.

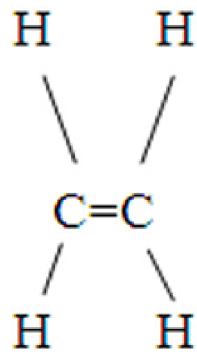
Students in the United States are struggling with motivation, confidence and thinking skills, especially in the Sciences. I have chosen this focus topic with the intent that it will be engaging, relevant, and useful for future decision making at both the individual and civic levels. I desire to give my suburban, and thus isolated, teenage students something global and holistic to focus on. One of the more difficult challenges for any high school teacher is convincing students of the importance and applicability of science to their current and future world. Conveying this message to students is essential, since it is virtually impossible to teach them anything if they do not care or understand how the topic relates to them. By presenting them with topics that are timely and relevant to their own lives I hope they will have the motivation to sustain a curiosity for the subject material. As they can see evidence of plastic products almost everywhere they look, students might perceive the topic as relevant. Students are very interested about educating themselves about topics relevant to them, sharing their knowledge through various means and becoming motivated to improve conditions. My high school students have concerns over the environment and they wish to make a positive impact. In this unit, the focus is on chemistry and the environment.

As the third largest industry in the United States after automotive and steel, plastics seem to be invading every single aspect of our modern lives. According to the American Chemistry Council the average American consumes three hundred pounds of plastic a year. Their uses are not always obvious or visible to the general public. For example, hundreds of thousands of hectares (10,000 square meters) of plastics are used in agriculture every year (a hectare is about the same size as football field). Many plastics are used in health care, i.e. intravenous bags. Innumerable plastic water bottles are used daily. I think we should be conscious of this phenomenon for the impact of plastics will continue to drastically impact our lives and the state of the environment.

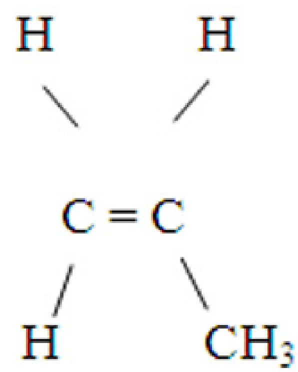
History and Background

Since the 1950s, the United States has been looking for other alternatives to important natural products. People have been using natural polymers such as silk, wool, cotton, wood, horn, and leather for hundreds or in some cases thousands of years; however, the demand for natural products could not keep up with the population increase after WWII. This consequently inspired chemists to create synthetic counterparts, which they have done with amazing success, filling almost every product niche in American society.

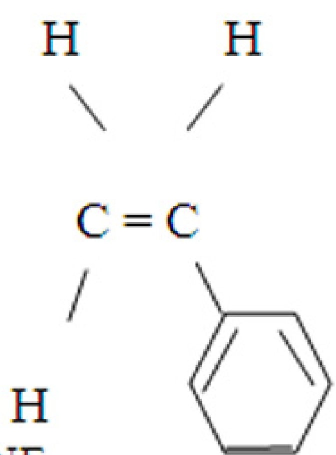
The American Chemistry Council estimates the world consumption of plastic at six hundred billion pounds. In the United States alone, plastic generates three hundred billion dollars in sales. [1] These inexpensive moldable substances seem to be able to accomplish almost any desired function of a product or material. The majority of plastic items and products are manufactured from byproducts of petroleum refining or from natural gas processing such as ethylene ($CH_2=CH_2$), propylene ($CH_2CH=CH_2$) and styrene ($C_6H_5-CH=CH_2$) shown below. [2]



ETHYLENE



PROPYLENE



STYRENE

Plastics are synthetic materials, meaning they are artificial or manufactured. The Greek word *plasticós* means, "to mold." Plastics begin their life as a little round nugget of plastic called nurdles. Nurdles can be made into any kind of product. Nurdles are the easily transportable raw material for almost every plastic product on our Earth, from the dashboard on your car to the soda bottle in your refrigerator. They are also referred to as pre-production plastic pellets, referencing the fact they are a raw material, or "plastic resin pellets." Basically, nurdles are tiny pellets of plastic that can be melted down and formed into new shapes in various colors, densities, thicknesses and sizes.

To process nurdles, manufacturers feed the plastic pellets into hoppers which melt them down, allowing the manufacturer to make plastic products. After melting, nurdles can be injected into molds, extruded by machines, or shaped in specialized presses, which are designed to make specific products. Nurdles come in a variety of types, allowing people to make a range of plastic products. They can be clear or colored, allowing manufacturers to color their own plastics or utilize pre-mixed colors for their products.

It is estimated that more than 250 billion pounds (113 billion kilograms) of nurdles are manufactured and shipped globally every year. [3] Nurdles are typically shipped via tanker truck, with each tanker being loaded to the brim with nurdles. [4] Unfortunately some nurdles end up on beaches and in the ocean. Are these plastics accumulating toxins in the environment that biomagnify in the food chain? Captain Moore in California has received a grant from the state to figure out how nurdles are getting into the Pacific Ocean. Charles Moore: "They are becoming the most common pollutant on our beaches. A three month study of Orange County beaches found three and a half million of these little plastic pellets." He also concluded, and published in the *Marine Pollution Bulletin* in 2001, that there is more plastic in the North Pacific subtropical gyre that zooplankton. [5]

According to the Environmental Protection agency, plastics were estimated to account for 390,000 tons of municipal solid waste in the United States. As of 2009, that figure has risen to 29.8 million tons. This figure represents an increase from less than one percent of our waste to slightly over twelve percent for that time period. About seven percent was recovered and reused in 2009. [6]

Petroleum to Plastics Overview

First, petroleum is drilled, extracted and then transported to a refinery. Most, about ninety percent, is processed for fuel. Crude oil and natural gas are refined into ethane, propane, or hundreds of other petrochemical products. A small percentage of these are diverted for other uses such as polymer production. Ethane and propane are "cracked" into ethylene and propylene, using high-temperature furnaces. *Cracking* is the process where complex organic molecules are broken down into simpler molecules such as light hydrocarbons, by the breaking of carbon-carbon bonds in the precursors. The end products are strongly dependent on the temperature and presence of catalysts. Hydrocarbon cracking is the process of breaking long-chain hydrocarbons into short ones.

For production of a polymer, a catalyst is combined with a monomer such as ethylene or propylene in a reactor, resulting in "fluff," a powdered material (polymer) resembling laundry detergent. Fluff is combined with additives in a continuous blender. The polymer is fed to an extruder where it is then melted. Melted plastic is cooled and then fed to a pelletizer. This cuts the product into small pellets called nurdles. These pellets, or nurdles, are shipped to manufacturers. Using processes such as extrusion, injection molding, and blow molding, plastic is shaped into products. [7] See appendix for a flow chart summary of the overall process.

Chemistry of Plastics

The molecular building blocks of plastics are small organic units called monomers. Organic molecules contain carbon along with other elements. They are usually derived from oil (petroleum) or natural gas, but they can also come from other organic materials such as wood fibers, corn, etc. Each repeating unit of these small molecules is known as a *monomer* ("one part or unit") because it's capable of joining with other monomers to form a very long molecule chain called a *polymer* ("having many parts/units") during a chemical reaction known as *polymerization*. Students have learned or will learn that DNA is also a polymer with repeating units. The structure of different polymers lend to their special unique physical properties. Chemists combine various types of monomers in many different arrangements to make an almost infinite variety of plastics with an enormous array of chemical properties.

Many common classes of polymers are composed of hydrocarbons. These polymers are specifically made of small units bonded into long chains. Carbon makes up the backbone of the molecule. Hydrogen atoms are bonded along the backbone. Below is a diagram of polyethylene, the simplest polymer structure.

$$H - (CH_2 - CH_2)_n - H$$

There are other plastic polymers that also contain only carbon and hydrogen such as polypropylene, and polystyrene. Many basic polymers consist of only carbon and hydrogen but other elements can also be present. For example, polyvinyl chloride (PVC) contains chlorine, nylon contains nitrogen and oxygen, Teflon contains fluorine, and polycarbonates contain oxygen. Vulcanized rubber contains sulfur. There are also polymers that have silicon or phosphorous backbones. These are considered inorganic polymers. A familiar silicon-based polymer is Silly Putty ™ .

Two main processes can form polymers. Addition polymerization is the process of "monomers" joining by each one adding on to the end of the last. A simplified model would be paper clips joined together to create a long chain. The other group of polymers is formed by condensation polymerization**:** a process by which two molecules join together, resulting in a loss of molecules i.e. water. The most commonly known condensation polymers are proteins and fabrics such as nylon, silk, or polyester.

Thermoplastics vs. Thermosets

Plastics fall into two categories: thermoplastics (which can be melted and remolded) and thermosets (which are permanently set once formed). When the connection of carbon atoms forms two and three-dimensional networks or cross-links rather than one-dimensional chains, the polymer will be a thermoset plastic.

Thermoset materials will not melt after being molded into shape. They will either crack or become charred when exposed to extreme heat. Materials classified as thermosets include polyester fiberglass, vulcanized rubber, epoxy resins, Bakelite, urea aldehyde, silicones and polyimides. Due to molecular cross-linking, thermosets tend to be stronger than thermoplastics. Thus, thermoset plastics are traditionally used in products requiring stiffer and longer-lasting materials, such as computers, refrigerators, and electrical insulation. Since the strong cross-links in these polymers generally decompose when heated to high temperatures, the thermoset material is almost impossible to recycle. The majority of end products go to landfill.

Polymers formed by addition polymerization are often thermoplastic in nature. When subjected to sufficient heat, thermoplastics will become pliable and/or melt. Thus, they can be reformed and recycled if there are the logistics, facilities and the resources to do so. Thermoplastics include a long list of such common everyday materials such as: polyethylene, polypropylene, polystyrene, and polyvinyl chloride.

Elastomers are another kind of polymer. Possessing fewer cross-links than other thermosets, they are amazingly flexible. Automobiles tires and Neoprene used in wetsuits are examples of elastomeric polymer products.

Regardless of whether they are thermoplastic or thermoset, manmade polymers have a number of things in common. Plastics are synthetic organic molecules generally having molecular weights in excess of 20,000, consisting of long chains, or polymers, of the individual units known as monomers with an amazing array of versatile qualities.

Waste

Many plastic products are used for a relatively short time before being discarded. Although some recycling programs have been in place for years, many would be surprised to learn that not all plastics are recyclable. Many urban areas have active

recycling programs for plastics numbered 1 and 2. Even those that are recyclable don't always find their way to the recycling bin as there may not be facilities nearby to collect, sort and process the plastic for recycling.

According to a 2009 report from the EPA (Environmental Protection Agency), plastics are a rapidly growing source of waste. Weighing in at 12.5 million tons in 2009, containers, bags, sacks, wraps, other packaging, polyethylene terephthalate (PET) bottles, jars and high-density polyethylene (HDPE) natural bottles represented the largest group discarded. PET bottles and jars were recovered at the most successful rate of all the plastics at 28.0 percent in 2009. [8] China processes about seventy percent of the waste plastic that is recycled, mostly PET bottles (number 1) from around the world, most of which is made into polyester fiber. [9] India is also an importer of plastic waste material.

Because many types of plastic do not chemically react with most other substances, do not decay, and can stay in the environment for centuries, plastic disposal poses a difficult and significant environmental problem. I highly suspect that much of what is put in a recycling bin is in fact never processed at all. There are many rumors that some material is dumped in landfills or the ocean. I plan on having students do research on what percentages of plastic bottles are being recycled, focusing on where, how, and into what.

There are numbers imprinted on the bottom or top of some plastic items. You may have noticed them on bottles or food containers. These numbers, with a recycling arrow in the shape of a triangle surrounding them, refer to the chemical composition of the container. In theory, this identification means they are recyclable. The ones that are more commonly collected and recycled are #1 and #2. Not all numbered plastics are collected and/or processed in all areas. Actually, few are collected and processed at all. If you want to be environmentally responsible severely reduce or try to eliminate your use of plastics.

The following descriptions of each of the numbers for plastic types were obtained from the American Chemistry Council. [10]

PET #1 (Polyethylene Terephthalate) is the plastic used in soda bottles. It is tough and clear. Because it has a high use temperature it can be used in microwavable trays. It may also be found in carpets, clothing, and precision molded parts.

HDPE #2 plastic is High Density Polyethylene. It is sometimes used to package items such as snacks and margarine. Because of its chemical resistance, HDPE is also used for household chemicals such as detergents and bleach. The common grocery bag is made of HDPE.

PVC #3 (Polyvinyl Chloride) is not usually recycled. We see vinyl used in synthetic leather, blood bags and medical tubing as well as in windows, flooring, pipes and fittings. Vinyl can be made rigid or flexible. Its strength and resilience make it highly useful.

LDPE #4 Low Density Polyethylene is also tough and flexible. Because of its transparency and/or low melting point makes it popular for dry cleaner garment bags, flexible lids and bottles, and ever-abundant produce bags. LDPE is used also in wire and cable applications due to stable electrical conduction and processing characteristics. LDPE is not usually recycled.

PP #5 Polypropylene is sometimes recycled. Polypropylene is found in everything from cups, packaging and fabric fibers used in carpets. It is also used for large molded parts for the automotive industry. Polypropylene is chemical resistant and thus used for automobile battery casings. Other applications include containers for ketchup, yogurt, medicine, and pancake syrup.

PS #6 Polystyrene is widely used and inexpensive. Some polystyrene is clear, hard and brittle. This type is used for food packaging, and in laboratory ware. In contrast, there is foamed polystyrene often used for protective packaging of electronics such as televisions and computers. It is also used in packing peanuts. Styrofoam is extremely lightweight as solid foam. It serves as an excellent thermal insulator. There is also Expandable Polystyrene (EPS), which can be thermoformed into trays for meat etc and into other items such as egg crates. EPS is also formed into cups and tubs for dry foods such as dehydrated soups, i.e. Cup of Noodles. Polystyrene is used extensively for take-out containers because it is lightweight, stiff and cheap.

#7 includes multiple plastics including PC, or polycarbonate. Discovered to leach bisphenol A, a hormone disruptor that mimics estrogen, this plastic is no longer used in reusable water bottles. Bioplastics are also labeled with #7 including PLA, or polyactide, typically made with corn. Not easily recycled, it can be composted in industrial composting operations, which provide enough heat to break it down. [11]

Plastic is a contributor to the filling up of landfill areas at an increasing rate. It does not compress well or decompose. There are gyres of plastic in all major oceans and it has been estimated that there is now more plastic in the oceans than krill. [12] Plastics are being found in the gullets and stomachs of fish, birds, turtles and even jellyfish. It is washing up on beaches far from human populations. What is the future of marine wildlife if plastic continues to find its way into the oceans of the world?

I will introduce the concept of the Tragedy of the Commons in relation to the resources of the oceans. Garrett Hardin first published this concept in an article in *Science Journal* in 1968. [13] It describes a type of situation involving group responsibility for a shared or common resource. Conflict arises because each of the interested groups selfishly overuses the resource with no regards to the others. Eventually, this behavior depletes the resource, making it unavailable to all. Whose responsibility is it to keep ocean ecosystems healthy so that its beauty and resources are available to everyone now, and in the future?

Alternatives to Petroleum Based Plastics

Bioplastics have been around for a long time, and were in fact, the first type of plastics. Bioplastics, meaning plastics derived from renewable biomass sources such as soy bean, vegetable oil, sugar cane, corn starch and pea starch etc, seem to be very promising in certain areas; however, there is a concern that they are not as ecologically friendly as they might seem.

John Wesley Hyatt Jr. created a plastic from cotton cellulose in 1869 to use as a substitute for ivory in billiard balls. He also invented celluloid, a material still used in photographic and movie film. [14]

An additional bioplastic still in common use today is cellophane, which was created at the turn of the century by Jacques E. Brandenberger for commercial use. [15] Whitman Chocolates was an early user of cellophane. It is extremely thin and transparent and often used to package candy, cigarettes and other items. Cellophane is derived from cellulose. It can be made into very thin, transparent sheets of film, which have very low permeability to air, oils and bacteria. These properties make it extremely useful for packaging food items. Cellulose can be derived from wood, cotton or hemp among others. Cellophane has a number of industrial applications as well. It is used for the backing of adhesives like Scotch Tape, dialysis tubing, as a semi permeable membrane in a particular type of battery. Chemically cellophane is a polymer of glucose molecules ($C_6H_{12}O_6$) containing carbon, hydrogen and oxygen .

Another agriculture biomass pioneer was George Washington Carver. He did much of his research investigating the use of soybeans, as well as peanuts, in the development of hundreds of products and applications ranging from clean-burning biofuels to plastics, paint, and food products.

George Washington Carver and Henry Ford shared a vision of a future in which agricultural products would be put to new uses to create products and industries. By the late 1930s, Carver and Ford were investigating new industrial uses for soybeans and other plants. [16] Carver, born a slave in Missouri during the Civil War, had become a world-famous botanist by the 1930s, famed for his research into the many uses of soybeans, peanuts and other plants. Carver promoted the concept that plant matter could be turned into plastics, paint, fuel and other products.

In the 1920s, Henry Ford made advances using soybean bioplastic as a new material for automobile parts such as steering wheels, siding and dashboards etc. [17] By 1941, he had an exciting car prototype to share with the public. With the advent of World War II, the focus was on war-related national pursuits, which were understandably a high priority, and so development of soybean bioplastics was not given the funding and attention it might have had otherwise. Today plastic automobile parts are common. If WWII had not sidetracked the United States, we might have more soybean bioplastics in our cars. The Ford Company still uses bioplastics in its models to this day.

One of the advantages of bioplastics is that they degrade. But not all are biodegradable under normal situations, like sitting in a landfill or tossed in the environment. Often there are specific conditions in which they are degradable. They require various amounts of heat, moisture and available microbes.

Bioplastics are thought to produce less CO_2 during production compared to fossil fuel based plastics. Fossil fuels used in the growth, production and transportation of the crops/biomass used for bioplastics may emit near or the same amounts of CO_2 that was thought to be originally avoided. There are also concerns over the issues of deforestation, water supply and soil erosion to grow biomass to fuel the bioplastic industry. The production cost of bioplastics is also considerably higher compared to fossil fuel plastics. [18]

Starch is used for the majority of the bioplastic-based polymers. [19] It can be found in such items as pharmaceutical capsules, starch packing peanuts and biodegradable tableware. Bioplastics hold promise since they biodegrade at a reasonable rate compared to the exceedingly longer rate of those produced from fossil fuels. The market for bioplastics is predicted to increase substantially in the near future. [20] Brazil is growing significant amounts of sugarcane for the bioplastic and biofuel industry.

Activities and Strategies

High school students are familiar with some natural polymers such as DNA, proteins, and starch, or at least they will be after they have finished biology. They will have some exposure to the general definition of a polymer: a molecule of repeating subunits. For this unit the objectives are as follows: The students will understand the basic structure of polymers, the unique properties of plastics, how plastics are manufactured, what happens to plastics as they enter the waste stream, which plastics can be recycled and the effect plastics are have on the oceans.

Investigations

Lesson one: Making GAK is a lab activity whereby students can make a synthetic polymer and have tactile experience with its mobile flexibility. Students make this synthetic polymer by adding a saturated borax solution to white glue and water solution to trigger cross linkage. They then observe, explore, and record observational data on the behavior of the polymer. Cross-linkage is discussed.

Add: 1/2 cup (or 125ml) water to 1/2 cup (or 125ml) Elmers glue. Mix. Add 3 drops of food coloring (optional). Make a borax solution by adding 2 heaping tablespoons borax (You can buy this at a grocery store or online) to 1 cup of water (or 250ml) and stir vigorously. Add 1/2 cup or 125 ml of Borax solution to the water and glue mixture. Stir. Store in a plastic bag. Students then observe, explore, and record observational data. Resource Area for Teaching has an Idea sheet with the instructions for making Gak. [21]

- 10-15 minutes Intro and lab instructions

- 15-20 minutes Students mix materials, observe and record

- 10 minutes discussion, analysis and conclusions

Lesson two: Absorption of Water by Polymers: Some polymers are super absorbers. I plan to do a demonstration of this by adding water to a small amount of Instant Snow Polymer that can absorb water many times its weight in water. Sodium acrylate is the superabsorbent polymer used in diapers. A cross-linked polymer in gel form, it can absorb more than 500 times its weight in pure water. Students can try different liquids to see if absorption is affected. Classroom sodium acrylate can be purchased at Resource Area for

Teaching in San Jose, California or through the Flinn Scientific catalogue.

Lesson three: Students will be exposed to the chemistry and early history of a man made polymer. I will make nylon by floating hexanedioxyl dichloride over diaminohexane. Where they interface is where nylon is formed and then it can be spooled out to show the class. The two chemicals must be in a 2:5 ratio. Pour the hexanedioxyl dichloride into a glass beaker. Slowly pour the diaminohexane over the layer of the hexanedioxyl dichloride. Prevent mixing. Let this solution sit undisturbed. You will be able to see two layers. Notice a small layer forming where two chemicals interface. With your tweezers, pinch and pull up a small amount of the substance. It will come out in a thread. Pull up the single thread to eye level and place the end of the thread of nylon onto a spool. As you slowly turn the spool, the nylon will thread out of the solution in a long, thin string. Continue winding the spool. A kit can be purchased from Flinn Scientific. [22]

Lesson four: Shrink Math, as it is called at Resource Area for Teaching, is a fun activity where students measure and record the area of a rectangle of #6 plastic. It is then baked in a toaster oven, designated for science activities, at 250 degrees for a minute or so. This procedure involves students using heat to distress the polymer to return it to it original state. Students will re-measure area and density. Manufacturing is discussed.

- 10-15 minutes Intro and lab instructions, perform introduction

- 15-20 minutes Students draw, measure, heat, observe and record

- 10-15 minutes analysis and conclusions discussion

Lesson five: Jigsaw research: Students research and present a topic of interest to them such as alternatives for fossil fuel based plastic/bioplastics, plastic in the oceans/gyres, animals digesting plastic, recycling, density of plastics, recycling numbers, nurdles in the environment, plastics in agriculture etc. They must include at least five facts, a visual and a prop or realia relating to the topic.

- Day one: introduction of topics, review of expectations

- Day two: computer research on topic

- Day three and four: presentations

Lesson six: The unit will culminate in an up-cycling project to be displayed at Maker's Faire in the spring: Students design and make an item using common plastic materials. This is a creative, critical thinking and problem solving activity that is done over several weeks. They must build a prototype with instructions to share with the public.

- Day one and two: research plastic upcycle projects

- Day two: computer research on topic, students choose or design a project

- Day three and four: gather materials for project

- Day five and six: build project

- Day seven: students write share sheet that goes with project

- Day eight and nine: student share project with classmates

Lesson seven: Plastic Quilt: This activity is meant to be an aid to visual awareness of how much plastics we use on a daily basis. Students collect plastics they have come into contact with over a unit of time i.e. one week, make decorative quilt panels from the plastic collected, these are attached and displayed. Panels can be approximately 8 by 11 inches. The foundation panel might be a large plastic wrapper i.e. chip or frozen vegetables, and then students can attach other items with double stick tape or thread.

Lesson eight: Environmental Lunch is a one-week activity done outside of class. Students make a chart to record the food they consume at lunch. Emphasis is on the packaging. All packaging is recorded and sorted by type, recycle ability, reusability etc. The data are then analyzed. Students record all packaging items including plastic items from their lunch to evaluate habits and suggest ways to limit plastic waste.

Lesson nine: I will do a lab to make a bioplastic out of cornstarch, potato starch or milk. The milk-based bioplastic involves adding vinegar (2tsp) to milk (2 cups) over heat. casein is formed. The liquid can be drained off and then the polymer left can be formed like clay.

§ Day one: computer research on bio plastics topic

§ Day two: 10-15 minutes Intro and instructions

§ 15-20 minutes Students measure, heat, observe and record

§ 10 minutes discussion, analysis and conclusions

I base my lessons on the constructionist approach. Constructivism is a style of teaching and learning based on the premise that knowledge cannot be simply given by direct instruction by the teacher at the front of the room to students in their desks. Rather, students learn through active hands on approach that stimulates the mental process to construct knowledge. Students are the builders and creators of meaning and knowledge.

The labs: Making bioplastic from Starch and the demonstration of Making Nylon are appropriate for high school science lab settings, and some middle school settings as well. This must be based on judgment of the teacher. If a teacher is not comfortable doing a certain activity for safety reasons, then do not do it.

The Investigation activities: Exploring Absorbency of Polymers with diaper material, Shrink Math and Making a Polymer (GAK) may be done with students 5 th grade and up at the teacher's discretion.

Data collection assignment: Environmental lunch requires the student to record the plastic used at lunch everyday for a week. The students are asked to graph, analyze and extrapolate the data. This is appropriate for upper elementary and above.

Craft Project: Students make an artistic visual collection of plastic food packaging like a quilt to hang on the wall. This might represent a unit of time for which the plastic was collected, i.e. one week. This is appropriate for upper elementary and above. Both the environmental lunch activity and this craft project can be done in the beginning, middle or end or the unit.

Projects: The Maker's faire Up-cycle project can be applied to any secondary grade level to encourage problem solving, designing and critical thinking. Jigsaw research projects (on the recycling numbers or other areas of interest as noted above) are when a student or small group has a specific topic to research. They then do a presentation to share that information with the other students. Students must be mature enough. Teacher use your judgment weather this is appropriate for your students. This is probably appropriate for upper elementary and above.

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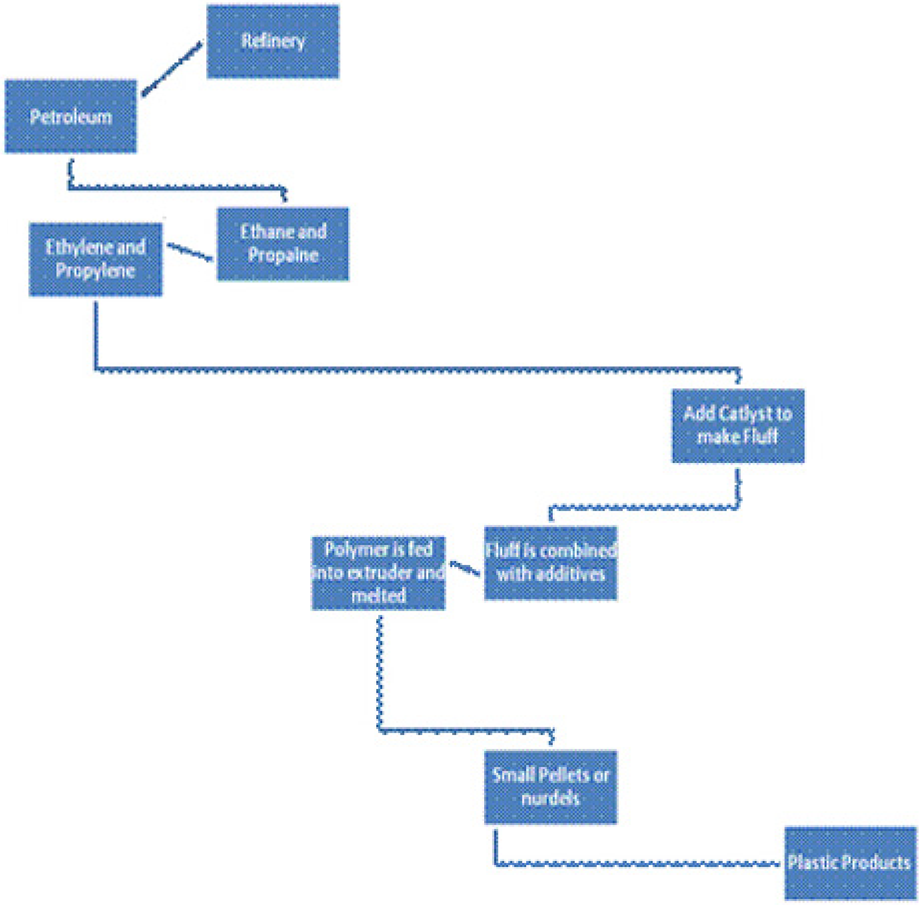
MLA formatting by BibMe.org.

Appendix item 1 flowchart

Petroleum to Plastics Overview [23]



Appendix item 2

CA State Science Content Standards

For grades 9-12:

Ecology

- Stability in an ecosystem is a balance between competing effects. As a basis for understanding this concept:

a. Students know bio diversity is the sum total of different kinds of organisms and is affected by alterations of habitats.

b. Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.

c. Students know how fluctuations in population size in an ecosystem are determined by the relative rates of birth, immigration, emigration, and death.

d. * Students know how to distinguish between the accommodation of an individual organism to its environment and the gradual adaptation of a lineage of organisms through genetic change.

Lessons three, four, five, six, and eight will address the above standards.

Investigation & Experimentation - Grades 9 To 12

- Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

a. Formulate explanations by using logic and evidence.

b. Recognize the cumulative nature of scientific evidence.

c. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.

d. Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California.

Lessons two, six, seven, and nine will address the above standards.

Organic Chemistry and Biochemistry

- The bonding characteristics of carbon allow the formation of many different organic molecules of varied sizes, shapes, and chemical properties and provide the biochemical basis of life. As a basis for understanding this concept:

a. Students know large molecules (polymers), such as proteins, nucleic acids, and starch, are formed by repetitive combinations of simple subunits.

b. Students know the bonding characteristics of carbon that result in the formation of a large variety of structures ranging from simple hydrocarbons to complex polymers and biological molecules.

Lessons one, two, and nine will address the above standards.

Endnotes

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