The Education Program at the
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Microplastics in the Marine Environment

OVERVIEW

In this activity, students will identify the six basic types of plastics (based upon the designated recycling codes printed on them) and learn about how their various densities cause them to either sink or float in the oceans. Students will learn how long it takes to completely degrade various types of plastics, and how they break down into various sizes of plastics and microplastics in the ocean. Using a simple ultraviolet light technique, students will examine samples of sand/sediment and water to discover whether there are microplastics in the samples. Activities illustrating various aspects of plastics are designed for grades 2-12, and may be done either as a class or by dividing students into small teams to enable all team members to fully participate in the hands-on activities.

OBJECTIVES

Following completion of this lesson, students will be able to understand what plastics are; identify different types of plastics and their common usages; discover how long it takes plastics to degrade completely; learn how plastics degrade into microplastics that impact marine life and detect them in sediment; see how due to different polymer densities, some plastics float and some will sink; and recognize the ubiquitous nature of microplastics in our environment.

GRADE LEVEL: 2nd – 12th

NGSS STANDARDS

K-ESS3-3. Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.* [Clarification Statement: Examples of human impact on the land could include cutting trees to produce paper and using resources to produce bottles. Examples of solutions could include reusing paper and recycling cans and bottles.]

MS-ESS3.C: Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

ESS3.C: Human Impacts on Earth Systems Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.

5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

MS-PS1-3: Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

MATERIALS

A variety of clean consumer recyclables for the Timeline (plastic bottles, monofilament, foam cup, plastic grocery bag, straws, glass bottle, disposable diaper, aluminum can, 6-pack rings, etc.)

Marine Debris Timeline (template link included after References)

Beakers

Cups to scoop sand

“Contaminated Sand” (made from ordinary beach sand mixed with cut-up pieces of straws, grocery bags, plastic bottles, glitter, buttons, plastic diapers, plastic craft items like beads, nylon or vinyl string, Beanie Baby beads, etc.)

Flat pans and forceps

Ultraviolet light flashlights

Soil Sieves or screens in graduated sizes (about 3 sieves, various size screens, one 5 mm)

Microscope and glass dishes or slides

Samples of plastics, types 1, 2, 3, 4, 5 & 6 (cut into 0.5” squares), in separate containers

BACKGROUND

Consumer plastics are made from petroleum and natural gas into polymers. These are long chains of hydrocarbons, which are made up of repeating units of monomers (2 or more carbon atoms bonded with hydrogen; some also contain fluorine or nitrogen). Polymers have different densities which result in different characteristics; some types float, some degrade in heat, wind, or sunlight and some are more durable. The characteristics help identify the type of polymer used to manufacture the plastics.

For recycling purposes, consumer plastics are categorized into 6 primary types. One of the most prevalent is polyethylene terephthalate (PET/PETE, designated as #1), which is used to make soda & water bottles, clothing, and meat-wrappers. Trash cans, squeeze bottles, and filmy garbage bags derive from low-density polyethylene (LDPE, designated as #4). High-density polyethylene (HDPE, designated as #2) is used to make bottles for detergent, shampoo, or milk, and grocery bags. Polyvinyl chloride (PVC designated as #3) is used for plumbing pipes and blister packs. Straws, bottle caps, yogurt containers, and chip bags are made from Polypropylene (PP, designated as #5). The manufacture of takeout food boxes, meat packing trays, and plastic cups uses polystyrebe (PS, designated as #6). The industry uses Polymer identifications for classifying plastics, and the symbol is the single-digit number within a tiny triangle stamped into the plastic itself.

Polymer products differ in the amount of time required to completely degrade in the marine environment. The chart here entitled Marine Debris Decay Timeline lists various biodegradation times for common consumer products. As can be seen from the chart, a plastic grocery bag takes 20 years to break down; nylon fabric takes 30-40 year; foam plastic cups take 50 years; disposable diapers and disposable water bottles take 450 years; and monofilament fishing line takes 600 years. So once plastic has entered the marine environment, it will be there for a long time. Eventually plastics will degrade into tiny pieces known as microplastics, which are 5 mm or smaller in size.

Plastics enter the waterways from land or ocean. While some plastics come from boats (lost fishing gear, garbage dumping), most of the marine debris found in our oceans originates on the land, entering waterways via rainwater runoff. This is the process by which street litter, trash, and plastics from contaminated soils enter the marine environment. Once in the ocean, plastics take a long time to biodegrade, so they can travel far before they break down. Wind and ocean currents are common conveyance methods. The enormous Pacific Ocean Garbage Vortex is the size of Texas and contains hundreds of square miles of plastic waste that is trapped there by currents.

Nurdles are resin pellets of plastic material. Typically, recycled plastic is cleaned and then reformed into long thin rods which are then cut into tiny pieces called nurdles; these pieces are then processed into various products by manufacturers. Nurdles can be found on beaches and in waterways in many colors, and often exhibiting signs of significant abrasion or wear. Pathways to the beach can vary, but nurdles may be lost in transport, or not removed during wastewater treatment before the effluent is discharge to receiving waters.

Microplastics are really tiny pieces of plastic (5mm or less in diameter), and are generated in several ways. Polyethylene microbeads were created as microplastics, for use in toothpastes, facial scrubs and many other personal-care products. These are ubiquitous in the ocean because many water-treatment facilities are unable to filter the tiny pieces out, and the plastics take a long time to degrade. While the use of microbeads is prohibited by law now, they still exist due to the long life of plastics. Microplastics can also result from plastic "dust" from construction or industrial processes that is carried to the ocean by wind or water. In addition, large plastic objects will break down into smaller and smaller pieces, because once plastic is in the ocean, wave action, heat, and sunlight can weaken the structure and break it into ever smaller fragments which do not biodegrade quickly.

World-wide plastics are a boon and a problem. Plastics are universal in our cultures, used in clothing (polyester since the 1950s), for containers, consumer and household products, medical items, disposable products like diapers, as well as manufacturing processes. However, since plastics are so long-lived, they do not just disappear once discarded. Over 5.25 trillion plastic marine debris pieces are found in the ocean either on the surface, benthos or water column. Plastics do not degrade quickly, and mineralization takes years to break it down into CO_2, water, and inorganic molecules. Plastics on the ocean surface that are exposed to sunlight and wind/wave action break down into smaller fragments more quickly.

Plastics affect marine life in various ways. Marine animals caught in plastic netting or consumer products are directly affected as they become trapped in the debris, with decreased mobility and function. With plastics found in the benthos, water column, and water surface, as well as throughout the food chain, it's difficult to avoid consuming plastic. Ingesting plastics leads to blocked digestive systems, which results in malnutrition and starvation. Ocean toxins such as mercury, polychlorinated biphenyls (PCBs), nonylphenols (NP), DDTs, and dichlordiphenyldichloroethylene (DDE) adsorb and bind to plastics, which increases the toxic effect when ingested.

Through biomagnification, the impact of plastics in the aquatic environment increases. The impact of microplastics consumed by organisms low on the food chain (plankton, isopods, filter feeders like oysters or sea cucumbers, etc.) is magnified when lower-order animals are consumed in large quantities by higher-order feeders and predators. The impact of the adsorbed toxins has not been fully studied yet.

Various solutions are available and should be evaluated for use either individually or combined effectiveness. Recycling of plastics into other polymer items, insulation, furniture, clothing, etc. has been a viable option for controlling discarded plastics, although success rates vary widely (some estimates are that only 9% of our trash is recycled due to contaminants and neglect). Refusing to use disposable plastic products such as straws, wrap, or bottles in the first place, is a behavioral change that may ultimately have more impact, as would the reuse and re-purposing of plastics. Creative and effective engineering and chemical solutions are being developed to remove plastics directly from the water, or to reformulate polymers for faster degradation. PrimaLoft Bio has added a simple sugar to the recycled plastic polymer that attracts bacteria to eat it, unlike standard polymers, so that the "sugared" polymer degrades in under two years instead of in decades. There are new local and state regulations being passed or proposed, such as NJ Senate Bill S2776, which will limit use of consumer plastics such as straws, grocery bags, and foam containers. Education in schools, colleges, and through environmental groups promotes awareness of the plastic problem and advocates solutions, and strives to inspire responsibility and stewardship for the environment and the ocean.

PROCEDURE

Begin by using the background information in this lesson plan to discuss plastics in general. Ask students what they might already know about plastics as well as their everyday use of plastic products, and have students bring in clean recyclables from home to use in this activity. Identify the type of common consumer plastics students mention or bring in, using the information here and the designated recycling category number stamped on actual plastic products.

Explain that plastics are made of polymers from petroleum and natural gas products, and that because plastics typically take decades or even centuries to completely degrade in the marine environment, the resulting persistent microplastics will have a detrimental effect on marine life.

Using the Marine Debris Timeline (template link provided), have the students each place a few plastic items on the Timeline based upon how long they guess it will take to degrade. Once all students have placed their items on the Timeline, use the Degradation Chart to determine if the guesses were correct. Have the students move their incorrectly-guessed plastics to the correct place on the Timeline, to reinforce that the item takes more (or less) time to degrade.

After students become aware of how long-lasting plastics are in the environment, discuss how wind, sun and water break down plastics, and explain that even though plastics break down into smaller and smaller pieces, they will not degrade any faster. So a plastic bottle that begins to break down will eventually break down into hundreds of tiny pieces that each still take 450 years to break down.

Using your homemade contaminated sand (a mix of ordinary beach sand that also contains cut-up straws, grocery bags, single-use plastic bottles, glitter, plastic buttons, caps, Beanie Baby beads, nylon string, etc), have students scoop a few cups into a flat pan. Using forceps or their fingers, have the students “mechanically clean” the sand by picking out the bigger pieces of plastic (e.g. the grocery bag strips, quarter-size pieces of plastic bottles, plastic buttons, caps, etc.). After about four minutes, ask the students if the sand is now cleaner and why. Take the “clean sand” and pour it into the graduated-size soil sieves or screens. The sieves should be arranged in size from sieves with the largest screen holes on top to sieves with the smallest screen holes on the bottom. Ideally the bottom sieve or screen will have holes about 5mm, which is the minimum size for microplastics, so the students can actually see how small microplastics are. You may want to place the sieves over a bucket or pan to catch the remaining sand that passes through all of the sieves. Have the students gently shake the sieves to allow the sand to move all the way through. When done, take the sieves apart and examine what type and size of plastic remains in each level. Explain that they can see how plastics break down by looking in the sieves and seeing the various sized particles there; and that eventually in the ocean even these bigger pieces will become microplastic size. This also demonstrates how hard it is to clean up the plastic in the environment, since even though the biggest plastic pieces are removed, there are still smaller pieces remaining.

Take a small amount of this sieved clean sand and look at it under the microscope. Using an ultraviolet flashlight, illuminate the sand sample and observe if there are any florescent specks in your sample. The ultraviolet light will cause plastic bits to glow neon orange, yellow, tan, pink, and green, and these can be easily seen. Tiny plastic microfibers and threads will also florescence. Carefully stir the sample while under the microscope to expose any additional plastic bits to the ultraviolet light. Explain to the students that these tiny microplastics are found everywhere, in all bodies of water and throughout the water column too - in the benthos, and in the water surface, which is why plastics are so easily consumed by marine creatures living there. Discuss biomagnification and the food chain to illustrate how smaller organisms that consume microplastics are eaten by larger animals up the chain, so that ultimately plastic can be found in all animals and in humans too, because we drink the water and consume animals that have eaten plastic.

Using the contaminated sand again, pour one or two cups into a beaker of water so that the there is about an inch or two of sand on the bottom of the beaker. Let it sit undisturbed for a minute or two, so you can see that some plastic will stay on the bottom, some will float on the surface, and some plastic will remain suspended in the water column. Show the students how plastic is found throughout the ocean, from top to bottom, so that all marine creatures are exposed to it. Also explain that since denser plastics sink to the bottom, it makes cleanup of polymers more difficult, because we may not even know that some tiny plastics are there.

Using a spoon, gently stir the water to release additional plastics that have settled to the bottom, so students can see that even plastics which had settled out can start floating around again due to storms, currents, and temperature changes. Explain that natural ocean processes cause plastics to be consistently present in all parts of the ocean, making it difficult for sea creatures to avoid ingesting or entanglement.

For further investigation, you can help students identify the plastics they see in the contaminated sand by determining which plastics float and which sink. Plastics are made of various polymers so they have different densities, which is a characteristic that helps identify them. You will need small pieces of plastic from categories 1-6 (ideally cut it out of the plastic container leaving the ID number within the triangle intact). For this exploration, set out containers of water and allow the students to put different types of plastic in the water to see if it sinks or floats. Remember that surface water tension might suspend some pieces on the surface, so you may need to gently push the piece of plastic under the surface for an accurate determination. Students should record which types of plastic sink and which float. Once they have their data, they can again inspect the beaker of contaminated sand water to try and identify the type of plastics that are floating, and the type of plastics that have sunk. Generally, type 1, 3, and 6 plastics (PET, PVC, PS, and Nylon) sink; type 4, 5 and 6 float (LDPE, PP, and EPS). Type 6 plastics like meat trays float; type 6 plastics like coffee lids sink. Encourage students record their observations and discuss as a class afterwards.

VOCABULARY

Microplastics - tiny pieces of plastic 5mm or less in length.

Degrade - To break down, deteriorate, or decompose.

Polymers - long chains of hydrocarbons, which are made up of repeating units of monomers (2 or more carbon atoms bonded with hydrogen; some also contain fluorine or nitrogen).

Nurdles - resin pellets of plastic material.

Polyethylene terephthalate (PET/PETE, designated as #1) - used to make soda & water bottles, clothing, and meat-wrappers.

Low-density polyethylene (LDPE, designated as #4) - used to manufacture garbage cans, squeeze bottles, and filmy trash bags.

High-density polyethylene (HDPE, designated as #2) - used to make bottles for detergent, shampoo, or milk, and grocery bags.

Polyvinyl chloride (PVC designated as #3) - used for plumbing pipes and blister packs.

Polypropylene (PP, designated as #5) - used to manufacture straws, bottle caps, yogurt containers, and chip bags.

Polystyrebe (PS, designated as #6) - used to make takeout food boxes, meat packing trays, and plastic cups.

EXTENSIONS

Activity 1. Identifying Plastics
This is an introductory activity used to help students learn how to identify different categories of plastics. First, using the information from the Background section, explain to the students that there are six basic recycling categories, and they are displayed on plastics (usually on the bottom of the item) as numbers within a triangle. Using a variety of clean consumer recyclables (plastic bottles, foam or plastic cups, plastic bags, milk jugs, shampoo bottles, yogurt cups, glass bottle, foam takeout containers, plastic clamshell food containers, detergent bottles, etc.), have students look for the identifying number within the triangle on all of the plastic products. Discuss what type of plastic it is and what it's used for. This activity can be paired with further identifying plastics by their density, using the sink-or-float experiment as detailed in the Procedures section.

Activity 2. One Bottle = Many Microplastics
Fill an empty plastic bottle full of small plastic beads. The beads represent the many tiny microplastic pieces that a single bottle will mechanically degrade into. To visually demonstrate how one bottle breaks up into many smaller pieces of plastic in the ocean, pour the plastic beads out of the bottle into a flat pan, so students can see that one piece of plastic disintegrates into many smaller pieces. Explain that this effect is multiplied by the millions of plastics in the oceans which will each break down into smaller and smaller pieces.

Activity 3. Biomagnification
This is a visual to demonstrate the concept of biomagnification. Glitter is used to represent the percentage of plastic content in marine life, and how it's magnified up the food chain, from plankton to Apex predators. Start by using several identical small plastic bottles (such as disposable water bottles) filled with tap water. Put one piece of glitter in one bottle, and label it "Plankton." This represents the amount of plastic found in tiny plankton. Add various amounts of glitter to the remaining bottles of water to demonstrate that higher food chain animals end up with greatly increased amounts of plastic due to biomagnifications. For example, the next bottle might be labeled "Mollusk" and would have 10 pieces of glitter. The next bottle might be labeled "Crab" and might have 20 pieces of glitter. The last bottle might be labeled "Osprey" and would have 40 pieces of glitter. This is not intended to be a precise magnification calculation, but rather to visually reinforce how plastic accumulates up the food chain.

REFERENCES

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https://oceanservice.noaa.gov/hazards/marinedebris/plastics-in-the-ocean.html

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DEBRIS TIMELINE

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DEGREDATION CHART OF TIME REQUIRED FOR TRASH TO DECOMPOSE IN THE ENVIRONMENT:

Glass Bottle.......................... 1 million years

Monofilament Fishing Line… 600 years

Plastic Beverage Bottles…….. 450 years

Disposable Diapers……………. 500 years

Aluminum Can...................... 200-500 years

Foamed Plastic Buoy…………. 80 years

Foamed Plastic Cups…………. 50 years

Rubber-Boot Sole................. 50-80 years

Tin Cans……………………………. 50-80 years

Leather................................ 50 years

Nylon Fabric......................... 30-40 years

Plastic Film Container.......... 20-30 years

Plastic Bag.......................... 20 years

Cigarette Butt...................... 10 years

Wool Sock........................... 1-5 years

Plywood……………………………. 1-3 years

Waxed Milk Carton…………… 3 months

Apple Core……………………… 2 months

Newspaper………………………. 6 weeks

Orange or Banana Peel......... 2-5 weeks

Paper Towel……………………… 2-4 weeks

Information Source: U.S. National Park Service; Mote Marine Lab, Sarasota, FL.