The Education Program at the
NJ Sea Grant Consortium
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Magnifying Plastics

OVERVIEW

In this lesson, students will discover the basic elements of plastics including raw material sources, the various types of polymers, how they degrade into microplastics, and how these ubiquitous plastics enter and affect waterways and our oceans. Biomagnificaiton exacerbates the marine impact of plastics. A variety of solutions are reviewed including engineering, education, behavioral, and legislative.

OBJECTIVES

Following completion of this lesson, students will be able to understand what plastics are; different types of plastics and their common usages; how plastics degrade into microplastics that impact marine life; and the effect of plastic biomagnification. Students will be presented with an array of solutions they can evaluate based on their understanding of the plastic issue. Interactive demonstrations and activities reinforce concepts learned here.

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.]

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

MS-ESS3.C: Apply Scientific Principles to design a method for monitoring and minimizing a human impact on the environment.

ESS3.C DCI: Human Impacts on Earth systems. 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. 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.

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

Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]

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.]

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

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).]

PROCEDURE

Begin by using the background information in this lesson plan, and start with a general discussion about plastics and how it affects marine contamination. Ask students what they might already know about plastics as well as their everyday use of plastic products. Identify the types of common consumer plastics the students mention, using the information here and the 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. Students may observe actual microplastics, such as microbeads found in cosmetics, under the microscope. With these concepts established, discuss the process of biomagnification. Include the impacts of plastics on the marine food chain and how adsorption of some aquatic toxins to plastic exacerbates this effect. The accompanying interactive activities should be used to help students fully comprehend the various concepts. The mockumentary video "The Majestic Plastic Bag" may also help students understand how plastics move from land to water.

A discussion about the solutions to the plastic problem should also follow. References are given for each type of solution such as engineering, education, behavioral, and legislative for students to become aware of and possibly take action on.

Activities illustrating various aspects of plastics are designed for grades 2-12. They 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.

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. Garbage cans, squeeze bottles, and filmy trash 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 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 10-20 years to break down; nylon fabric takes 30-40 years; 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 length.

Plastics enter the waterways from land or ocean. While some plastics come from boats (lost fishing gear, garbage dumping, chipped boat paint), 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's 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 exhibit 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 discharged to receiving waters.

Microplastics are really tiny pieces of plastic (5mm or less in length), 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 use of such microbeads 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's 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 plastic is so long-lived it does not disappear once it is 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 CO2, 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 biomagnifications, the impact of aquatic plastics is increased. The impact of microplastics consumed by organisms low on the food chain (plankton, isopods, filter feeders like oysters or sea cucumbers) is magnified when those lower-order animals are consumed in large quantities by higher-order feeders and predators. The impact of the adsorbed toxins has not fully been studied yet, however.

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 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.

ACTIVITIES

We offer a variety of interactive activities for grades 2-12 to demonstrate the various aspects of the plastics issue.

Join us at the ANJEE Conference or Barnegat Bay Environmental Educators Roundtable to receive complete details and demonstration of the activities and microplastics lesson plan.

Activity 1. Identifying Plastics

Identifying different types of Plastics (see Florida Sea Grant info). Look for the identifying number within the triangle on plastic products, and discuss what type of plastic it is and what it's used for.

Activity 2. Plastic Characteristics

Discover characteristics of various types of plastics by studying its density. Using small pieces of plastic from categories 1-6 (ideally cut it out of the container, leaving the ID number within the triangle intact), put first in a container of tap water, then in a container of salt water, and record what floats and what sinks. LDPE, PP, and EPS should float. PET, PVC, PS, and Nylon should sink. See **Florida Sea Grant** for complete lesson plan.

Activity 3. Marine Debris Decay Timeline.

Teach students how long various plastics take to degrade in the ocean.
(Lesson plan: http://njseagrant.org/wp-content/uploads/2018/02/MarineDebris.pdf).

Activity 4. One Bottle = Many Microplastics

Fill a plastic bottle full of small plastic beads - use to demonstrate how one bottle breaks up into many smaller pieces of plastic in the ocean. For older students - use a bigger cube full of smaller cubes to measure the increase in surface areas when plastics break down; more surface area may attract more toxins like PCBs, mercury, etc.

Activity 5. Biomagnification / Snow Globe

This is a visual for biomagnification. We use glitter to represent plastic percentage content in marine life, and how it's magnified up the food chain, from plankton to Apex predators.

Use several small plastic 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 plankton. Using additional bottles of water, add various amounts of glitter 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" who ate 10 planktonic algaes and would have 10 pieces of glitter. The next bottle might be labeled "Crab" who ate 10 mollusks and would have 100 pieces (estimated) of glitter. The last bottle might be labeled "Osprey" who ate 10 crabs and would have 1000 (estimated) pieces of glitter.

Activity 6: Microplastics Biomagnification Board Game

Microplastics Biomagnification Game: This board models the aquatic bay ecosystem with a simple food chain of plankton, silversides , striped bass, shark, and humans. With 5-7 players representing the different marine life, players see how trophic levels interact and how consumption results in biomagnifications.

Activity 7. Pervasive Plastics in the Ocean

Mix up contaminated sand that consists of big and small plastics (e.g. cut up water bottles/grocery bags/straws – different densities), glitter, etc. Divide into 2 containers. Using tweezers, mechanically remove bigger pieces from the first container, then put the "cleaned" sand through a sieve to see what size pieces are left. Using the mechanically-removed bigger pieces and the ones in the sieve, see if you can identify the type of plastic using the **Florida Sea Grant** activity (basically floating it in water/salt or water/rubbing alcohol).

Next, put the second container of contaminated sand into a clear beaker of water to see what floats on the surface, what stays in the water column, and what sinks to the bottom. Discuss how plastic now infiltrates all marine life whether they are benthic, pelagic, or surface (even plankton!). Plastic beads from Beanie babies can represent microbeads.

Activity 8. Plastics to Microplastics Multimedia

"The Majestic Plastic Bag - A Mockumentary" –
https://www.youtube.com/watch?v=9pi_45f1uX8.
Visually explains how plastics move from land into the waterways and oceans.

Salt Marsh in a Pan – Create a simple watershed model to demonstrate how pollution and debris (such as plastics) runoff into our waterways.
(Lesson plan: http://njseagrant.org/wp-content/uploads/2014/03/salt_marsh_in_a_pan.pdf).

Plastic Adrift – Track where plastic goes when it reaches the ocean (http://plasticadrift.org/).

See how much microplastic has been collected from water samples from around the world (https://www.adventurescientists.org/microplastics.html).

Activity 9. Solutions to Plastics and Microplastics Pollution

Helpful links to help students become aware of, understand, and take action on possible solutions from educating others, changing behaviors, engineering solutions, and legislative initiatives. Older students may choose a solution to look further into, including the costs and benefits of this solution. Oregon Sea Grant has a fantastic "Designing Solutions to Microplastics" lesson plan for students to follow.

Education and Behavioral Change

https://oceanservice.noaa.gov/hazards/marinedebris/plastics-in-the-ocean.html.
https://www.scientificamerican.com/article/solving-microplastic-pollution-means-reducing-recycling-mdash-and-fundamental-rethinking1/
https://www.plt.org/educator-tips/reduce-single-use-plastic
https://blogs.ei.columbia.edu/2018/05/11/can-fight-plastic-pollution/

Engineering

https://interestingengineering.com/how-to-eliminate-plastic-waste-and-plastic-pollution-with-science-and-engineering,
https://www.googlesciencefair.com/projects/2018/2c3f6207b15f46cb4bb66a56095bd6d901ccfa42e7e51600c766df7856590c4e
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https://www.imaginationstationtoledo.org/educator/activities/plastic-milk
https://www.ispo.com/en/trends/fighting-microplastics-primaloft-develops-first-biodegradable-synthetic-fiber
http://primaloft.com/primaloftbio
https://cen.acs.org/environment/pollution/Chemistry-solutions-plastic-trash-problem/96/i25

Legislative

https://www.congress.gov/bill/114th-congress/house-bill/1321/text,
http://www.ncsl.org/research/environment-and-natural-resources/plastic-bag-legislation.aspx
https://www.usnews.com/news/best-states/new-jersey/articles/2019-12-05/new-jersey-considers-bill-to-ban-single-use-plastic-bags,
https://www.biologicaldiversity.org/campaigns/ocean_plastics/pdfs/CWA-Petro-Plastics-Petition-to-EPA-6-23-19.pdf, https://www.whitehouse.senate.gov/news/release/save-our-seas-20-act-advances-through-final-senate-committee

REFERENCES

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https://www.scienceinschool.org/content/microplastics-small-deadly

https://www.teachengineering.org/lessons/view/uok-2116-plastisphere-microplastics-pollution-wastewater-treatment#

https://seagrant.oregonstate.edu/sgpubs/mitigating-microplastics-teacher-lesson-plans-curriculumhttps://sfyl.ifas.ufl.edu/flagler/marine-and-coastal/microplastics/k-12-resources/

http://phytoheroes.com/wp-content/uploads/2018/05/Lesson-plans-3-micro-plastics-final.pdf

http://plasticadrift.org/

https://oregoncoaststem.oregonstate.edu/marine-debris-steamss/

HHS Public Access: The Bio Bay Game: Three- Dimensional Learning of Biomagnification:

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

Next Generation Science Standards: https://www.nextgenscience.org/search-standards

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