MICROPLASTIC MAYHEM!

EXPLORING THE EFFECTS OF WASTE MANAGEMENT ON MICROPLASTIC POLLUTION

Liam Green
Virginia Institute of Marine Science

Grade Level
High School

Subject Area
Environmental Science

The Virginia Scientists & Educators Alliance (VA SEA) is a project of William & Mary's Batten School & VIMS Office of Outreach and Engagement. The VA SEA project is made possible through funding from VIMS, Virginia Sea Grant, the National Science Foundation, and the MacWhorter Family.

VIMS | William & Mary
Virginia Institute of Marine Science

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Sea Grant
Virginia

Title: Microplastic Mayhem! Exploring the Effects of Waste Management on Microplastic Pollution

Focus: Exploring how environmental weathering and waste-management practices affect plastic pollution through a competitive card game resulting in collaborative dataset generation and interpretation.

Grade Level: High School Environmental Science

Virginia Standards of Learning:

ENV.1 - The student will demonstrate an understanding of scientific and engineering practices by

A) asking questions and defining problems.
C) interpreting, analyzing, and evaluating data.
D) constructing and critiquing conclusions and explanations.
E) developing and using models.
F) obtaining, evaluating, and communicating information.

ENV.7 The student will investigate and understand that pollutants have physical, chemical, and biological consequences at the local, regional, and global level.

A) Use data to identify a land, water, or atmospheric pollutant in the local community and determine possible sources and effects on the environment.
B) Debate advantages and disadvantages of solutions to safely reduce, eliminate, or remediate a land, water, or atmospheric pollutant.
C) Compare the benefits and limitations of remediation methods used with land, water, and atmospheric pollutants.

ENV.9 The student will investigate and understand that individual and collective actions influence environmental sustainability and policy at local, national, and global levels.

A) Make, support, and evaluate a claim about how consumer, corporation, and government choices can affect the environment.
B) Debate advantages and disadvantages of possible solutions to an environmental problem.

Learning Objectives:

Students will...

- Identify different types of environmental weathering and discuss how they exacerbate plastic pollution
- Participate in a semi-competitive game that demonstrates environmental weathering and microplastic shedding

- Balance winning against their peers while trying to collectively minimize their impact on the environment
- Generate data each round by counting their total number of microplastics introduced into their "environment" zone

Total length of time required for the lesson:

Preparation of Materials: ~60 minutes

Actual Lesson: ~75-120 minutes

- 15-20 minutes of introduction
- 10 minutes to explain rules of the game
- ~50 minutes of gameplay – 4 rounds of play, with each round being ~3-4 minutes in length with a group of 5-6 students.
    - Each student takes 2 turns, approximately 30 seconds for each turn. ~30 minutes of total play time.
    - ~3-4 minutes between rounds to count beans, record data, and shuffle the deck. ~20 minutes.
- 10 minutes of debriefing – asking the whole class about observations and comments on weathering and waste management
- 20-30 minutes for worksheet / graphing activity (may be provided as homework)

Vocabulary:

Mechanical Abrasion Physical weathering of a material when it is scraped, ground, or rubbed against other surfaces, which leads to it breaking down into smaller pieces.

Microbial Degradation Chemical weathering caused by microbes, where digestive enzymes break down larger materials into smaller pieces that bacteria and other microorganisms can eat.

Microplastic A plastic particle ranging in size from approximately 1 micrometer (µm) to 5 millimeters (mm), often produced through the fragmentation of larger plastic debris or directly manufactured at that scale.

Monomer A single molecular unit of a polymer.

Polymer A large molecule composed of repeating subunits known as monomers, covalently bonded in long chains or networks. There are both natural (cotton or wool) and synthetic polymers (plastics).

Thermal degradation Chemical weathering of a material through providing enough thermal energy to break the bonds between molecules

Upcycling The process of reusing discarded materials or products in a way that creates something of higher quality, value, or usefulness than the original item.

UV Weathering The process where sunlight, particularly ultraviolet (UV) light, breaks chemical bonds in the polymer chains of plastics, causing the material to weaken and fragment into smaller pieces.

Weathering The suite of physical, chemical, and biological processes that alter or break down materials, including rocks and synthetic compounds like plastics, into smaller fragments or chemically transformed products.

Background Information:

Plastics have become one of the most widely used and produced materials on Earth because they are lightweight, durable, and inexpensive to manufacture. Plastics are chemically known as synthetic polymers. They are organic molecules that consist of repeating structures called monomers. Many monomers make up a polymer chain. These chains aren't very dense, but are very strong, allowing plastics to exhibit amazing durability while still being lightweight. Global plastic production has escalated dramatically in recent decades. In 1950, the world produced only about 2 million tons of plastic; by 2019, *annual* production had climbed to approximately 460 million tons. As of 2015, around 6,300 million tons of plastic waste had been generated globally, and of that, only about 9 % was recycled, 12 % was incinerated, and 79 % accumulated in landfills or the natural environment. The sheer volume of plastic entering ecosystems today, combined with low disposal and recycling rates, means that plastic pollution has reached a scale threatening water bodies, soils, wildlife, and humans alike.

Once plastics enter the environment, a variety of weathering processes begin to degrade them into smaller fragments, commonly referred to as microplastics (typically 1 µm to 5 mm) and even smaller nanoplastics (<1 µm). These fragments are especially problematic because their small size enables them to be ingested by organisms and transported around the body to areas where they may cause harm. These small pieces, like their larger counterparts, are also very resistant to many forms of degradation, allowing them to persist in the environment for long periods of time. Every year, more studies are released about harmful effects of microplastics in our environments and our bodies, highlighting the need to address the issue.

To reduce the environmental and health impacts related to microplastics, proper waste management practices and effective policies are critical. We greatly reduce the likelihood of larger plastics becoming microplastics by removing those large pieces from the environment, or by keeping them from getting there in the first place. Improving recycling infrastructure, reducing plastic production, banning or restricting single-use plastics, and improving community waste collection are a few examples of strategies we can take as a society to keep large plastics out of our environments, and reduce the production of microplastics.

This game simulates the effects of environmental weathering and waste-management practices, allowing students to experience how plastics fragment into microplastics and how management strategies can reduce environmental accumulation over time. By collecting and graphing data from gameplay, students can connect this lesson to real-world challenges, reinforcing both the science of environmental degradation and the importance of human decisions in protecting ourselves and the environment from our waste production.

Materials & Supplies:

- One to two large bags of dried beans. Any size will work! Approximately 1lb of dried beans should be plenty for the whole class. (Each group will receive a heavy handful of beans placed in their "Plastic Factory" cup)
- Small cups. Dixie cups, small paper cups, or small trays will work. (One per person in each group, e.g. 24 cups for 24 students)
- Large cups. These will serve as the "Landfill" and the "Plastic Factory" reservoirs in each group. (2 per group)
- Game cards. These must be printed, cut, and laminated if you intend to reuse them. (One set of cards for each group)
- Envelopes or small paper bags. These will be used for delivering new cards as new waste-management practices are introduced. (3 envelopes per group)
- Small plastic bags. These will be used for storing game cards. (One plastic bag per group)

Optional:

- A golden spray-painted plastic water bottle given to the student or group with the least microplastic shedding (The "Golden Upcycle")
- Laminator for reuse of game cards / rule cards

Teacher Preparation:

Example set-up for a class of 24 students (6 groups of 4 students each)

1. Print and cut out game cards for each group. Cards are separated by their color. Optionally Laminate before cutting.
    - Red = "Weathering" Cards (18)
    - Purple = "Clean-Up" Cards (6)
    - Blue = "Preventative Action" Cards (6)
    - Green = "Recycling" Cards (6)
2. Provide each group with an "Environment" sheet (no cut-out required). Place this in the center of the table. Optionally Laminate.
3. Separate the game cards that will be added during the waste-management rounds into labeled envelopes.
4. Shuffle each group's remaining cards
5. For each group, label one large cup as the "Plastic Factory" and fill it with dried beans.
6. Label the other large cup as the "Landfill"
7. Provide each table with a number of small cups equal to the number of players in that group.
8. Provide each student with their own worksheet.

Procedure:

Set up. Shuffle the starting deck and place it in the center of the table alongside the environment board, the plastic factory and the landfill. Each student gets a small cup with 10

beans representing their piece of plastic waste. Each student will draw one card, and the starting player will draw two.

Gameplay:

- **Round 1 – No waste management!**
    - On their turn, students will choose one of the two cards at their disposal and play it on a target player, themselves, or the group as a whole. The ability of each card is clearly described in its text box.
        - Any time a card would "Fragment" a target player, that player places the specified number of microplastics onto the Environment Board.
    - After 2 turn cycles, students will record the total number of microplastic particles that made it onto the Environment Board on their individual worksheet, as well as their remaining number of plastic particles in their personal cups.
    - Everyone shuffles their cards back into the deck.
    - Everyone refills their individual cups back to 10 dried beans from the plastic factory.
    - Beans do NOT get retrieved from the environment after the end of each round. The purpose of this is to demonstrate plastic persistence in the environment.
- **Round 2 – First wave of waste management! The mayor of your town now requires street clean-up crews to collect trash once a week.**
    - Shuffle 5 "Clean-up" cards into the center deck. Deliver these to the students in an envelope or paper bag.
    - Students will play another 2 turn cycles and then record the total number of microplastic particles that made it onto the Environment Board on their individual worksheet, as well as their remaining number of plastic particles in their personal cups.
    - Everyone shuffles their cards back into the deck.
    - Everyone refills their individual cups back to 10 dried beans from the plastic factory.
- **Round 3 – Second wave of waste management! The mayor of your town wants to introduce measures to keep plastic from getting into the environment.**
    - Shuffle 6 "Preventative-Measures" cards into the center deck
    - Students will play another 2 turn cycles and then record the total number of microplastic particles that made it onto the Environment Board on their individual worksheet, as well as their remaining number of plastic particles in their personal cups.
    - Everyone shuffles their cards back into the deck.
    - Everyone refills their individual cups back to 10 dried beans from the plastic factory.
- **Round 4 (Final Round)- Third wave of waste management! The local landfill and the city government have teamed up to fund a recycling facility.**
    - Shuffle 6 "Recycling" cards into the deck. Deliver these to the students in an envelope or paper bag.

    - Students will play another 2 turn cycles and then record the total number of microplastic particles that made it onto the Environment Board on their individual worksheet, as well as their remaining number of plastic particles in their personal cups.
    - Everyone shuffles their cards back into the deck.
- **OPTIONAL – Have the students clean up the game and reorganize the cards into their envelopes!**
- **Final Remarks**
    - Engage in a full-class discussion, calling on students and asking them:
        - How did microplastic pollution in the environment change in response to waste management practices?
        - Which waste management practices were the most effective?
        - How did some of the waste management cards interact with one another?
        - Which of these waste-management practices do you see in your own life?
        - What barriers might prevent some of these practices from being implemented?
- **Optional: Find the student with the lowest number of microplastics shed to the environment and gift them with the "Golden Upcycle"**

Assessment:

On the back of the provided data sheet, students will complete four short-answer questions and one graphing task. They will construct a graph of their choice using the data generated within their individual groups, and the first short-answer question will ask them to interpret the trends shown in their graph.

The assessment can be given at the end of the class for homework, or as an in-class assignment.

References:

Andrady, A. L. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin, 62*(8), 1596–1605. https://doi.org/10.1016/j.marpolbul.2011.05.030

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances, 3*(7), e1700782. https://doi.org/10.1126/sciadv.1700782

Organisation for Economic Co-operation and Development (OECD). (2022). *Global plastics outlook: Policy scenarios to 2060*. OECD Publishing. https://doi.org/10.1787/aa1edf33-en

Ritchie, H., & Roser, M. (2018). *Plastic pollution*. Our World in Data. https://ourworldindata.org/plastic-pollution

Microplastic Mayhem!

Name: _____ Date: _____

Group Members: _____

Part 1. Data Collection

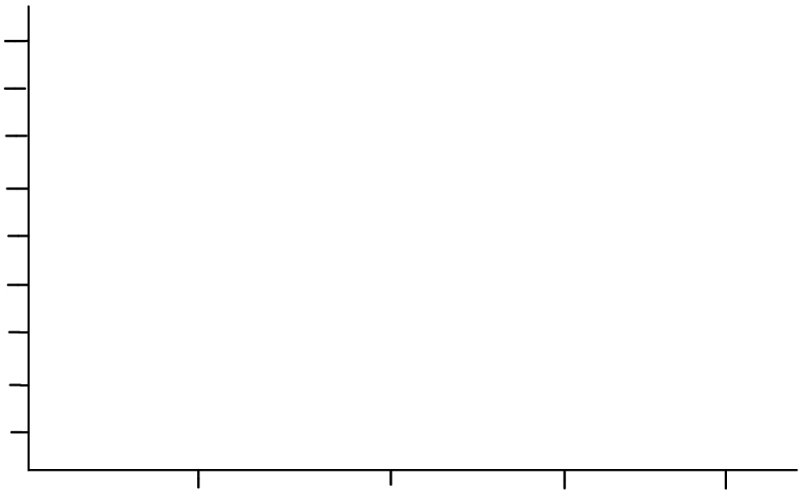
Record the following data at the end of each round.

Round / Waste Management Policy	Microplastics Remaining in YOUR cup	Total Microplastics in Environment Board

Who in your group is the microplastic pollution prevention champion?!

Part 2. Graphing

Create a graph of the data below. On the x-axis, label the round number (1–4). On the y-axis, provide the number of microplastics in the environment. Choose a graph type to best represent the data. Add a Relevant Title to your graph!



Part 3. Short Answer Questions

Answer the following in complete sentences.

From your graph, what trend do you notice in the number of microplastics ending up in the environment across rounds? What caused this trend during gameplay?

Which waste management practices seem to have the most impact on gameplay? How does this relate to the real world?

Why is it important to remove or prevent large plastics from entering the environment? Use evidence from your graph and gameplay to explain your answer.

What barriers might exist in the real world when trying to implement waste management practices?

Answer Keys:

Microplastic Mayhem!

Name: _____Liam Green_____ Date: _____December 15th, 2025_____

Group Members: ___Know-it-all Nancy, Chill Chad, Tiny Tina, Opulent Oliver_____

Part 1. Data Collection

Record the following data at the end of each round.

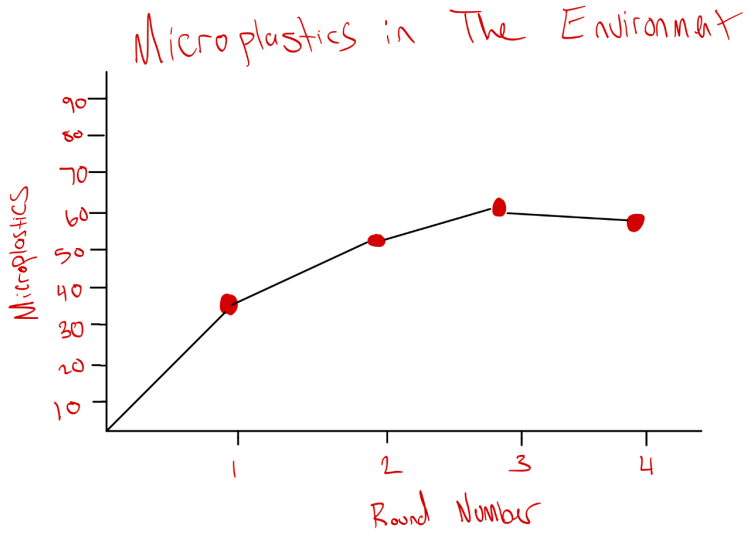
Round / Waste Management Policy	Microplastics Remaining in YOUR cup	Total Microplastics in Environment Board
Round 1 - None	2	35
Round 2 – Clean-Up	5	50
Round 3 – Preventative Measures	6	59
Round 4 - Recycling	6	55

Who in your group is the microplastic pollution prevention champion?!

Know-it-all Nancy ☹

Part 2. Graphing

Create a graph of the data below. On the x-axis, label the round number (1–4). On the y-axis, provide the number of microplastics in the environment. Choose a graph type to best represent the data. Add a Relevant Title to your graph!



Part 3. Short Answer Questions

Answer the following in complete sentences.

From your graph, what trend do you notice in the number of microplastics ending up in the environment across rounds? What caused this trend during gameplay?

The amount of microplastics being added to the environment decreased as we introduced waste-management practices. Microplastics still remained in the environment, and some were still added, but fewer and fewer each round. When we added recycling cards, the number of plastics went down!

Which waste management practices seem to have the most impact on gameplay? How does this relate to the real world?

The recycling cards allow the students to directly increase the number of beans in their own cups, incentivizing them to help the environment rather than fragment any of their neighbors. This should be the most powerful mechanic, but other practices can be justified based on the student's observations.

Why is it important to remove or prevent large plastics from entering the environment? Use evidence from your graph and gameplay to explain your answer.

Removing larger plastics from the environment will keep them from being exposed to environmental weathering, reducing microplastic production. The best way to start working on the problem is to cut off the source.

What barriers might exist in the real world when trying to implement waste management practices?

There are many different answers here. The big one is money. The in-class discussion will offer the opportunity for the teacher to discuss the balance between funding and sustainability practices like waste management. Other answers can be correct if they are well-justified.

Microplastic Mayhem!

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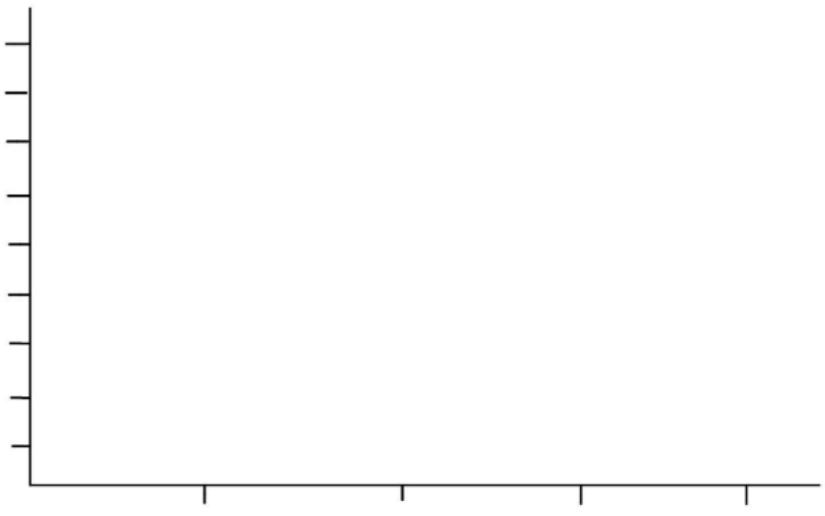

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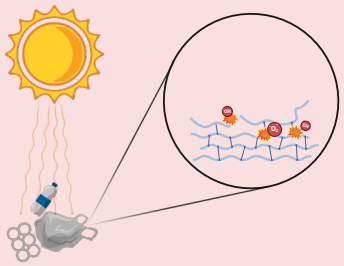
UV-Weathering

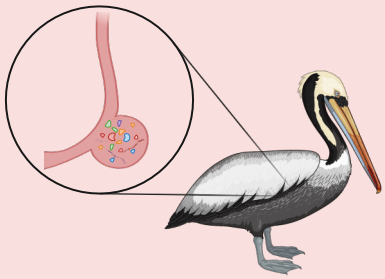


The bright sun bombards your plastic with UV light. Reactive Oxygen Species attack the surface of your polymer chains. **Fragment 1 microplastic, and the next time you fragment, instead fragment twice as many. Give this card to your target as a reminder!**

Microbial Digestion

You develop a biofilm crawling with bacteria and other microbes. Their digestive enzymes break apart the surface of your polymer into tasty chunks. **Fragment 1 microplastic.**

Animal Consumption

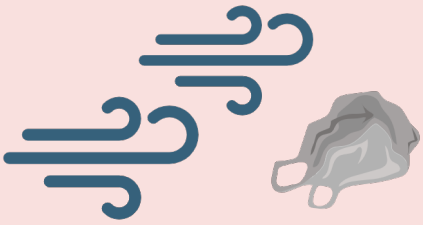


You've been munched on by an animal! You get chomped by the animal's mouth and then experience some powerful digestive enzymes in the animal's stomach. **Fragment 2 microplastics.**

Mechanical Abrasion

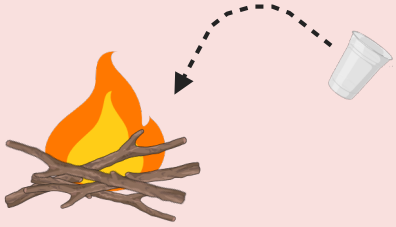
You get tossed into a nearby river. It is a VERY windy day, and the waves crash on the surface of your plastic. **Fragment 1 microplastic.**

Mechanical Abrasion



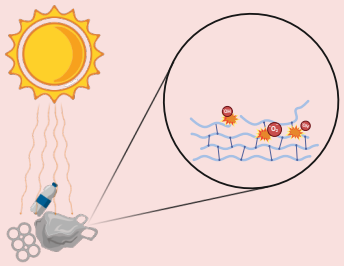
Your plastic pretends to be a tumbleweed in the heavy wind. You scrape against the roadside as you're blown from one place to another. **Fragment 1 microplastic.**

Thermal Degradation



Someone accidentally threw your plastic into their bonfire. You're pulled out before you completely melt, but you definitely felt the heat. **Fragment 2 microplastics.**

UV-Weathering



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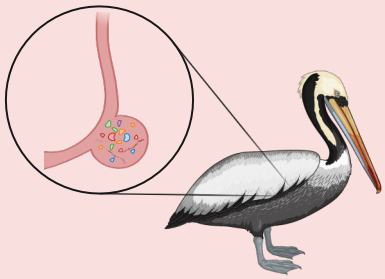

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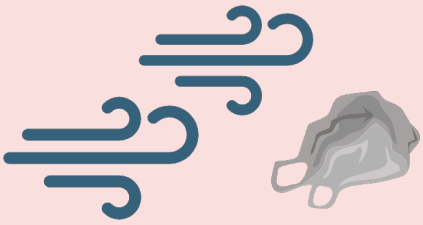

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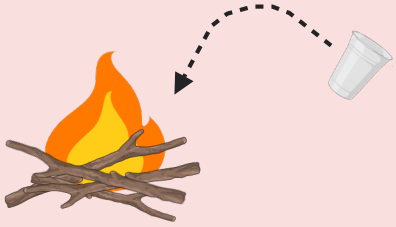

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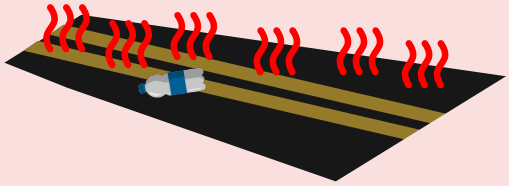


It is a HOT summer day and your plastic is left out on the blacktop and exposed to the heat. **Fragment 1 microplastic.**

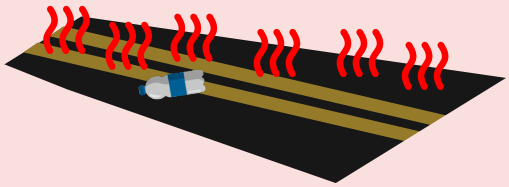
HURRICANE!

PLAY THIS CARD AS SOON AS YOU DRAW IT. A hurricane blows through the coastal city! Trash cans get knocked over! Flood water washes waste all around the city! **Everyone fragments 2 microplastics.**

Urban Runoff

It's a particularly rainy day. Water flows off the streets of the city, washing away plenty of plastic along with it. **Everyone fragments 1 microplastic.**

Thermal Degradation



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River Boom

The city installs a boom, or a floating waste filter, in the local river. Now, floating plastics get removed before they wash out into the bay! **Prevent the next fragmentation from any source.**

Single-use Plastic Boycott

People of the city embrace re-using their single-use materials. Your plastic is re-used again before it enters the waste stream. **Prevent the next fragmentation from any source**.

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Improved Access to Waste Storage

The city has provided new trashcans with built-in compactors on every corner. **Prevent fragmentation the next time you're targeted by another player.**

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The city has provided new trashcans with built-in compactors on every corner. **Prevent fragmentation the next time you're targeted by another player.**

Green Infrastructure

The city has begun planting roadside vegetation to catch urban runoff before it gets released into the bay. **Prevent the next fragmentation from any weather or runoff related source.**

River Booms - River Vectors by Vecteezy

Single Use Plastic - https://www.vecteezy.com/vector-art/20862649-no-plastic-bag-illustration-concept-on-white-background

Green Infrastructure - https://www.vecteezy.com/vector-art/56698457-an-illustration-of-a-city-with-green-trees-and-buildings-on-a-white-background

Big Belly Trash Compactors - Photo by Bailey Stewart (@alwaysangstyyy)

Created in BioRender. Green, W. (2025) https://BioRender.com/mrujy0h

Single Stream Recycling

A convenient way to dispose of recycling, but not very efficient in the waste management world. **Take one microplastic from the Environment and add it back to your personal cup.**

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A convenient way to dispose of recycling, but not very efficient in the waste management world. **Take one microplastic from the Environment and add it back to your personal cup.**

Plastic-Sorted Recycling Dropoff

Special bins located outside the recycling facility allow citizens to sort their plastics to increase recycling efficiency. **Take two microplastics from the environment and add them back to your cup.**

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Single stream recycling (CC) - https://commons.wikimedia.org/wiki/File:Single_Stream_Recycling.JPG

Plastic-Sorted Recycling Dropoff - https://www.vecteezy.com/vector-art/35999159-waste-management-concept

The Rules

1. Each player starts with one card and 10 "microplastics". The player that recycled last starts.
2. On your turn, draw one card, and play one of the two cards in your hand on your friend or yourself! Each card describes its ability.
3. Once each player plays 2 cards, the round is over.
4. Players then record the total microplastics now on the Environment Board and how many of their microplastics remain in their cups
5. Refill your plastic reservoir from the "Plastic Factory"
6. Once you're ready, raise your hand to let your teacher know!

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2. On your turn, draw one card, and play one of the two cards in your hand on your friend or yourself! Each card describes its ability.
3. Once each player plays 2 cards, the round is over.
4. Players then record the total microplastics now on the Environment Board and how many of their microplastics remain in their cups
5. Refill your plastic reservoir from the "Plastic Factory"
6. Once you're ready, raise your hand to let your teacher know!

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Beach Clean Up

A group from the local school decides to do a beach cleanup. **Everyone transfers 1 microplastic from the Environment Board to the Landfill!**

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Street Sweepers

The city's cleaning crew sweeps through the city and removes as much waste as they can from the street. **Transfer 3 microplastics from the Environment Board to the Landfill!**

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Beach cleanup - https://www.vecteezy.com/vector-art/68136623-3d-isometric-flat-illustration-of-environmental-water-pollution-volunteers-cleaning-sea-shore-from-plastic-and-other-trash

Street sweeper - https://www.vecteezy.com/vector-art/72516578-street-sweeper-efficient-city-cleaning-illustration

Urban Runoff - https://www.vecteezy.com/vector-art/4595893-trash-into-sewer-cause-flood-in-city-flat-illustration-vector-background

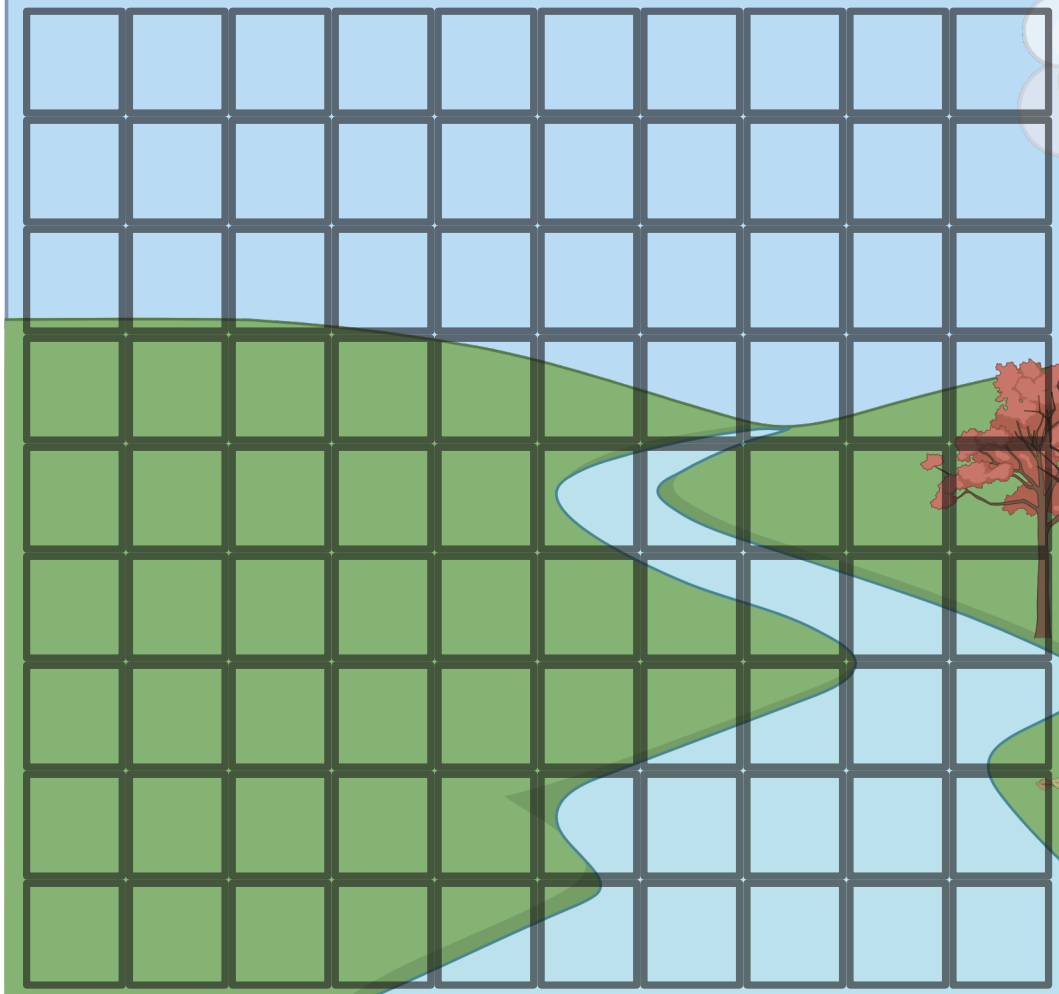
Hurricane - https://www.vecteezy.com/vector-art/372642-natural-disaster-scene-with-hurricane

Mechanical Abrasion - https://www.vecteezy.com/vector-art/73328408-abstract-blue-ocean-wave-illustration-with-splash-elements

The Environment

Whenever you "Fragment" a microplastic, it ends up here!

Place them in the box below to help you count



10 Fragments