# Drastic Plastic Measures
# Facilitator's Version

## Pre-made Materials

- Example films: Ask Connor for pre-made examples that can be used for comparison to show color, clarity, stretch, twist, and fold.
- Plasticizers
    - 1,3-Propanediol
    - Glycerol
    - Xylitol
    - Mannitol
    - Sorbitol
- Dilute acetic acid
- Chitosan
- 6 boxes with materials
    - Protocol and data analysis sheet: 4 sets. We will have three extra for groups of more than 24 students.
    - 8 syringes: One for Chitosan (1), one for each plasticizer (2) , one for dilute acetic acid (1) and one for each the four final film solutions (4).
    - 4 Scintillation vials (one for each of the pre-made plasticizers, dilute acetic acid, and chitosan)
    - Four 50 mL beakers
    - Four magnetic stir bars
    - Four silicon molds
- Have 400-600ml beakers of water on table for practicing syringe use, sharpies, and tape.
- Prepare excel sheet

## Set-Up

6 groups of 4-5. Facilitator will randomly assign group numbers.
Each group will make 4 films (2 plasticizers at 2 concentrations. The controls will already be prepared.

- Group 1: 1,3-Propanediol, Glycerol
- Group 2: Glycerol, Xylitol
- Group 3: Xylitol, Mannitol
- Group 4: Mannitol, Sorbitol
- Group 5: 1,3-Propanediol, Sorbitol
- Group 6: Xylitol, Sorbitol

## Safety Guidelines

- Shellfish allergy
    - In the event of a shellfish allergy gloves will be available to students

# Protocol:

## Part I: Making the Biofilms

You will be testing the effect of plasticizer on the physical properties of chitosan films. Each group will test two different plasticizers and at two different concentrations, 30% and 50%. The control films (0% plasticizer) have already been prepared for you. See Table 1 below.

1. Write the names of the plasticizers you will be in the blue rows in Table 1
2. Decide within your group how you are going to divide the work of preparing 4 different solutions and write the name of the person making each film in the white cells of the first column.
3. Using the large beaker of water on your bench to practice using your 5mL syringes
    a. Flush the syringe 3 times by pulling water up by pulling up on the plunger and push the water out by pushing down on the plunger
    b. Pull up 5ml of water and check: Invert syringe so open end pointed up. Look for an air bubble in the barrel; if you see one, slowly push the plunger until it is released.
        i. Make sure your liquid measures to the 5ml mark on the syringe. If not, add more and check again for bubbles.
4. Using lab tape and a sharpie, label each 50mL beaker with the film number as shown in Table 1.
5. Using a different 5mL syringe for each solution, add the appropriate volumes of chitosan, plasticizer, and dilute acetic acid to the appropriate beaker to make your four solutions as shown in Table 1.
    a. You can label the syringes using your sharpie.

Dispose of syringes in the designated waste basket when finished

Table 1. Volume Guide for Chitosan Films

| **Name of person in group preparing the film** | **Film #** | **Volume of Chitosan (mL)** | **Volume of Plasticizer (mL)** | **Volume of Dilute Acetic Acid (mL)** | **Final Volume (mL)** | **Final Concentration of Plasticizer (%)** |
|---|---|---|---|---|---|---|
| | Plasticizer 1: ______________________ | | | | | |
| | 1 | 5 | 3 | 2 | 10 | 30 |
| | 2 | 5 | 5 | 0 | 10 | 50 |
| | Plasticizer 2:______________________ | | | | | |
| | 3 | 5 | 3 | 2 | 10 | 30 |
| | 4 | 5 | 5 | 0 | 10 | 50 |

6. Add a magnetic stir bar to each beaker and place on the stir plates located in the hood.
    a. Place the beakers as close to the center of the plate as you can. The stir bar should be in the center of the beaker

7. Set the **LEFT** dial to 7.

   a. **DO NOT** turn the dial on the right- this will heat the plate which you don't want yet.
8. While your solutions are mixing, prepare your silicon molds by using the sharpie and label tape to mark with the film number
   a. Place the labels on the **outside** (*not* bottom or inside) of the mold.
9. Turn off the stir plate *before* removing the beakers
10. At this time, volunteers will set plates to 85°C (Setting 2).
11. Use the syringes to **add just enough of the solution into the molds to form a thin layer along the bottom**. If you are using the small, square molds, this should be approximately 2ml. If you are using the larger circular molds, this should be approximately 7ml. If you add too much, they will not dry in time.
12. Place molds on the hotplate (or bench, TBD) for 60 minutes.
    a. During this time, we will do Part II.
13. Once films are dry, invert them onto a labeled paper towel for testing.

## Part 3: Testing the Biofilms

1. Examine your films for color, clarity, fold, twist, and stretch to get a sense of the variation between the control, two plasticizers and the two concentrations of each plasticizer films.
   a. Be careful not to break them.
2. Develop with a method to **quantify** each of the 5 physical properties and describe it in Table 2 below. Recall that **quantitative data** refers to numerical data.
   a. First decide on a numerical scale (i.e. 1-5, 1-10)
   b. Then assign a number for each test that represents the variation between the physical properties of the films.

Table 2. Quantification of Physical Characteristics

| Physical Properties | Number Scale | Quantification Method |
|---|---|---|
| **Color** | | |
| **Clarity** | | |
| **Fold** | | |
| **Twist** | | |
| **Stretch** | | |

3. Conduct your experiments using the methods described in Table 2 and record your quantitative data in Tables 3 & 4 below.
   a. Have each group member independently examine each film for each of the 5 properties and then average your results (you may use your phone calculator).
   b.

$$Average = \frac{\sum All\ Measured\ Values}{Total\ Number\ of\ Values}$$

Table 3. ______________________________(Name of Plasticizer)

| Film Number | Concentration of plasticizer (%) | Avg. Color | Avg. Clarity | Avg. Fold | Avg. Twist | Avg. Stretch |
|---|---|---|---|---|---|---|
| **Control** | 0 (Control) | | | | | |
| **1** | 30 | | | | | |
| **2** | 50 | | | | | |

Table 4 . ______________________________(Name of Plasticizer)

| Film Number | Concentration of plasticizer (%) | Avg. Color | Avg. Clarity | Avg. Fold | Avg. Twist | Avg. Stretch |
|---|---|---|---|---|---|---|
| **3** | 30 | | | | | |
| **4** | 50 | | | | | |

## Clean up

- Syringes should be disposed in the red "sharps" box.
- All liquids can be rinsed down the sink, rinse dishes and place on rack to dry

# Drastic Plastic Measures

Investigating the synthesis and properties of chitosan films as a potential biological plastic

## Investigation Overview: Each group of 4-5 students will prepare four chitosan films to test the effects of plasticizer type and concentration on five physical properties of the film: color, clarity, fold, twist, and stretch.

## Safety Guidelines

- Shellfish allergy
    - Chitosan is derived from chitin, which comes from the exoskeleton of shrimp and other crustaceans. Notify the facilitator if you have a shellfish allergy.

## Protocol:

### Part I: Making the Biofilms

You will be testing the effect of plasticizer on the physical properties of chitosan films. Each group will test two different plasticizers and at two different concentrations, 30% and 50%. The control films (0% plasticizer) have already been prepared for you. See Table 1 below.

**Group 1**: 1,3-Propanediol, Glycerol
**Group 2**: Glycerol, Xylitol
**Group 3**: Xylitol, Mannitol
**Group 4**: Mannitol, Sorbitol
**Group 5**: 1,3-Propanediol, Sorbitol
**Group 6**: Xylitol, Sorbitol

1. Write the names of the plasticizers assigned to your group in the blue rows in Table 1
2. Decide within your group how you are going to divide the work of preparing 4 different solutions and write the name of the person making each film in the white cells of the first column.
3. Use the large beaker of water on your bench to practice using your 5mL syringes
    a. Flush the syringe 3 times by pulling water up by pulling up on the plunger and push the water out by pushing down on the plunger
    b. Pull up 5ml of water and check: Invert syringe so open end pointed up. Look for an air bubble in the barrel; if you see one, slowly push the plunger until it is released.
        i. Make sure your liquid measures to the 5ml mark on the syringe. If not, add more and check again for bubbles.
4. Using lab tape and a sharpie, label each of the four 50mL beakers with the film number as shown in Table 1.

5. Using a **different 5mL syringe for each solution**, add the appropriate volumes of chitosan, plasticizer, and dilute acetic acid to the appropriate beaker to make your four solutions as shown in Table 1
    a. You can label the syringes using your sharpie
    b. Dispose of syringes in the designated waste basket when finished

Table 1. Volume Guide for Chitosan Films

| **Name of person in group preparing the film** | **Fil m #** | **Volume of Chitosan (mL)** | **Volume of Plasticizer (mL)** | **Volume of Dilute Acetic Acid (mL)** | **Final Volume (mL)** | **Final Concentration of Plasticizer (%)** |
|---|---|---|---|---|---|---|
| | Plasticizer 1: ______________________ | | | | | |
| | 1 | 5 | 3 | 2 | 10 | 30 |
| | 2 | 5 | 5 | 0 | 10 | 50 |
| | Plasticizer 2:______________________ | | | | | |
| | 3 | 5 | 3 | 2 | 10 | 30 |
| | 4 | 5 | 5 | 0 | 10 | 50 |

6. Add a magnetic stir bar to each beaker and place on the stir plates located in the hood.
    a. Place the beakers as close to the center of the plate as you can. The stir bar should be in the center of the beaker
7. Set the **LEFT** dial to 7.
    a. **DO NOT** turn the dial on the right- this will heat the plate which you don't want yet.
8. While your solutions are mixing, prepare your silicon molds by using the sharpie and label tape to mark with the film number
    a. Place the labels on the **outside** (*not* bottom or inside) of the mold.
9. Turn off the stir plate *before* removing the beakers.
10. At this time, volunteers will set plates to 85°C (Setting 2)
11. Use the syringes to **add just enough of the solution into the molds to form a thin layer along the bottom**. If you are using the small, square molds, this should be approximately 2ml. If you are using the larger circular molds, this should be approximately 7ml. If you add too much, they will not dry in time.
12. Place molds on the hotplate for 60 minutes.
    a. During this time, we will do Part II.
13. Once your films are dry, invert them onto a labeled paper towel for testing.

## Part 3: Testing the Biofilms

1. Examine your films for color, clarity, fold, twist, and stretch to get a sense of the variation between the control, two plasticizers and the two concentrations of each plasticizer films.

    a. Be careful not to break them.
2. Develop a method to **quantify** each of the 5 physical properties and describe it in Table 2 below. Recall that **quantitative data** refers to numerical data.
    a. First decide on a numerical scale (i.e., 1-3, 1-5, 1-10)
    b. Then assign a number for each test that represents the variation between the physical properties of the films.

Table 2. Quantification of Physical Characteristics

| Physical Properties | Number Scale | Quantification Method |
|---|---|---|
| **Color** | | |
| **Clarity** | | |
| **Fold** | | |
| **Twist** | | |
| **Stretch** | | |

3. Conduct your experiments using the methods described in Table 2 and record your quantitative data in Tables 3 & 4 below.
    a. Have each group member independently examine each film for each of the 5 properties and then average your results (you may use your phone calculator).

$$Average = \frac{Sum\ of\ All\ Values}{Total\ Number\ of\ Values}$$

Table 3. ______________________________(Name of Plasticizer)

| Film Number | Concentration of plasticizer (%) | Avg. Color | Avg. Clarity | Avg. Fold | Avg. Twist | Avg. Stretch |
|---|---|---|---|---|---|---|
| **Control** | 0 (Control) | | | | | |
| **1** | 30 | | | | | |
| **2** | 50 | | | | | |

Table 4 . ______________________________(Name of Plasticizer)

| Film Number | Concentration of plasticizer (%) | Avg. Color | Avg. Clarity | Avg. Fold | Avg. Twist | Avg. Stretch |
|---|---|---|---|---|---|---|
| **3** | 30 | | | | | |
| **4** | 50 | | | | | |

## Clean up

- Syringes should be disposed in the red “sharps” box.
- All liquids can be rinsed down the sink, rinse dishes and place on rack to dry

**Plastic Waste Data Analysis Activity- Student Copy**

**Figure 1.** Students work in groups discussing:

- Approximately, how many pounds of plastic waste the average American generates per day and per **year** (*note- map shows per day*)?
- Discuss how you and your family manage your own plastic waste
- How much of our country's plastic do you estimate gets recycled (appropriately processed and used to make a new product)?
- **Answer Mentimeter Question:**

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**Figure 2A and 2B**

- What % of the plastic generated by the packaging industry is wasted each year?
- Compare this to the % wasted for the building and construction industry, what might explain this discrepancy between these two industries?
- **Answer Mentimeter Question:**

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**Table and Figure 3**

Analyze and compare table 1 and figure 3.

- Based on your interpretations, what type of plastic do you consider to be the most problematic?
- Discuss the types of products you use that contain this type of plastic.
- **Answer Mentimeter Question:**

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**Figure 4 and Table 2.** These two representations were generated from the same data

*An area chart combines a line chart and a bar chart to show how one more groups' numerical values (volume of plastic recycled, placed in landfill, or combusted) change over the progression of a second variable, time). Each line on the area graph represents a cumulative sum; therefore, you can see each variable's contribution to the sum and how the composition of the sum changes over time.*

- Spend some time looking at Figure 4 to make sense of how the data is represented. Approximately, what percentage of plastic gets recycled in the US?
- How close was your estimate you made when examining Figure 1?
- What other observations did you make when interpreting the graph and table?
- **Answer Mentimeter Question:**

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**Figure 5**

- Based on what you've learned about plastic generation, use, and waste, discuss at least 3 factors that you think would impact the amount of plastic waste generated in a country (*population size, recycling program, "wealth" of the country- to consume plastics, plastic production industries*).
- **Answer Mentimeter Question:**

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**Figures 6**

- Discuss- what kind of data is represented in each bubble on the chart and how does this data provide more insights than Figure 5?
- Discuss- in addition to the harmful effects on our ocean and environment, plastic waste generated in the US has a significant humanitarian impact on other countries as well; particularly those that are less developed. Any ideas how?
- **Answer Mentimeter Question**
- **Watch Video**

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**Figure 7:**

This stacked bar graph shows where we export our plastic waste, specifically the countries that have poor plastic waste management infrastructure. Why do you think the US exports their plastic waste?

- How is this a global responsibility and humanitarian issue?

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# Global Plastic Waste Data Set

Figure 1: Plastic Waste Generation per Person (2010)- **Gradient map**

Figure 2A: Plastic Production by Industrial Sector (2015)- **Bar hart**

Figure 2B: Plastic Waste Generated by Industrial Sector (2015)**- Bar chart**

Figure 3: Primary Plastic Production by Polymer Type (2015) - **Bar chart**

Table 1: Types of Plastic (2015)

Figure 4: Plastic Waste Management- **Area chart**

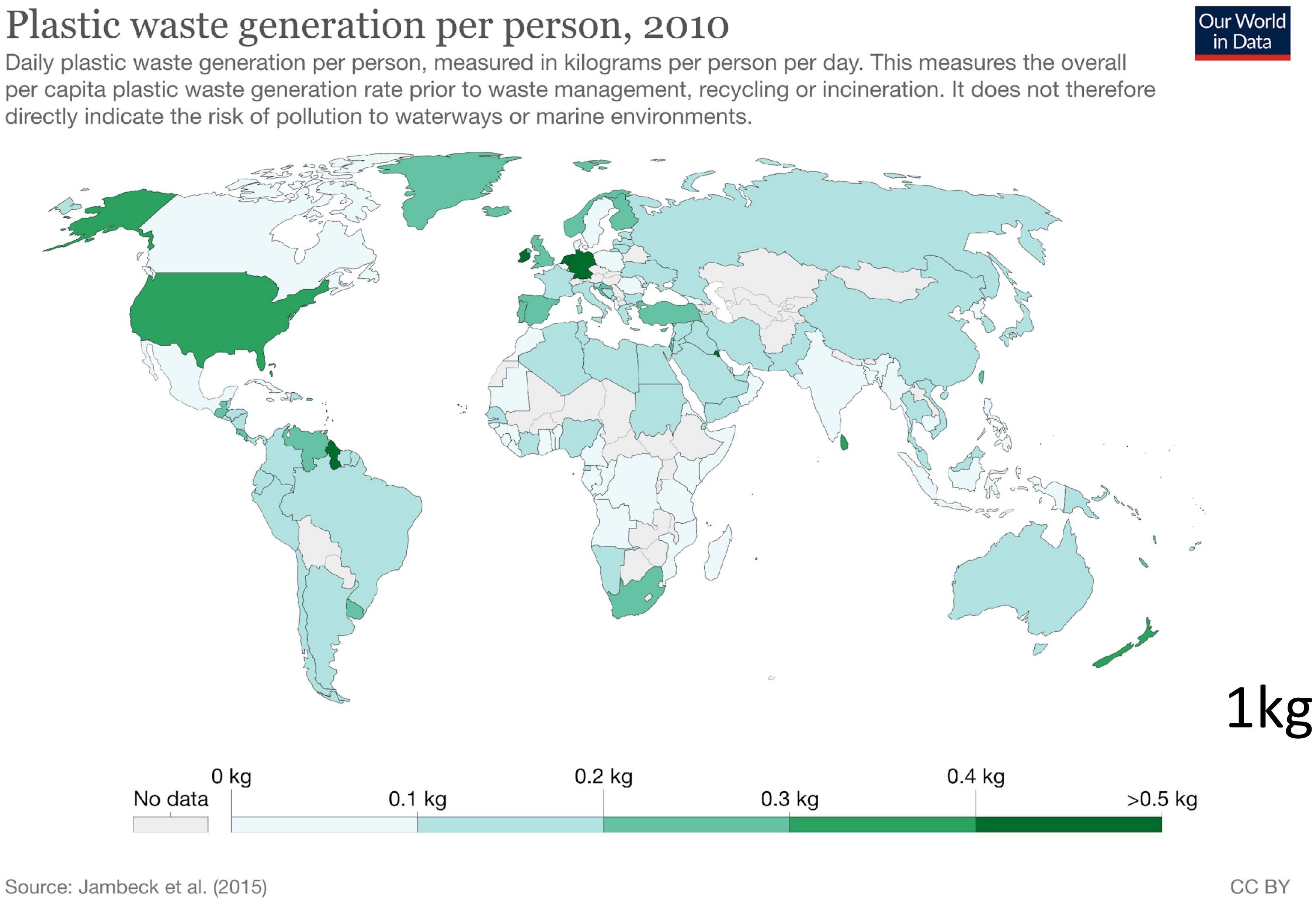
Table 2: Plastic Waste Management Pathway

Figure 5: Plastic Waste Generated by Country (2010)- **Gradient map**

Figure 6: Per Capita Plastic Waste Versus GDP per Capita (2010) – **Bubble chart**

Figure 7: US Plastic Waste Export To Countries With Poorly Managed Waste (2019)- **Stacked bar chart**

# Figure 1. Gradient Map




1kg = 2.2 lbs.

## Figure 2A. Bar chart

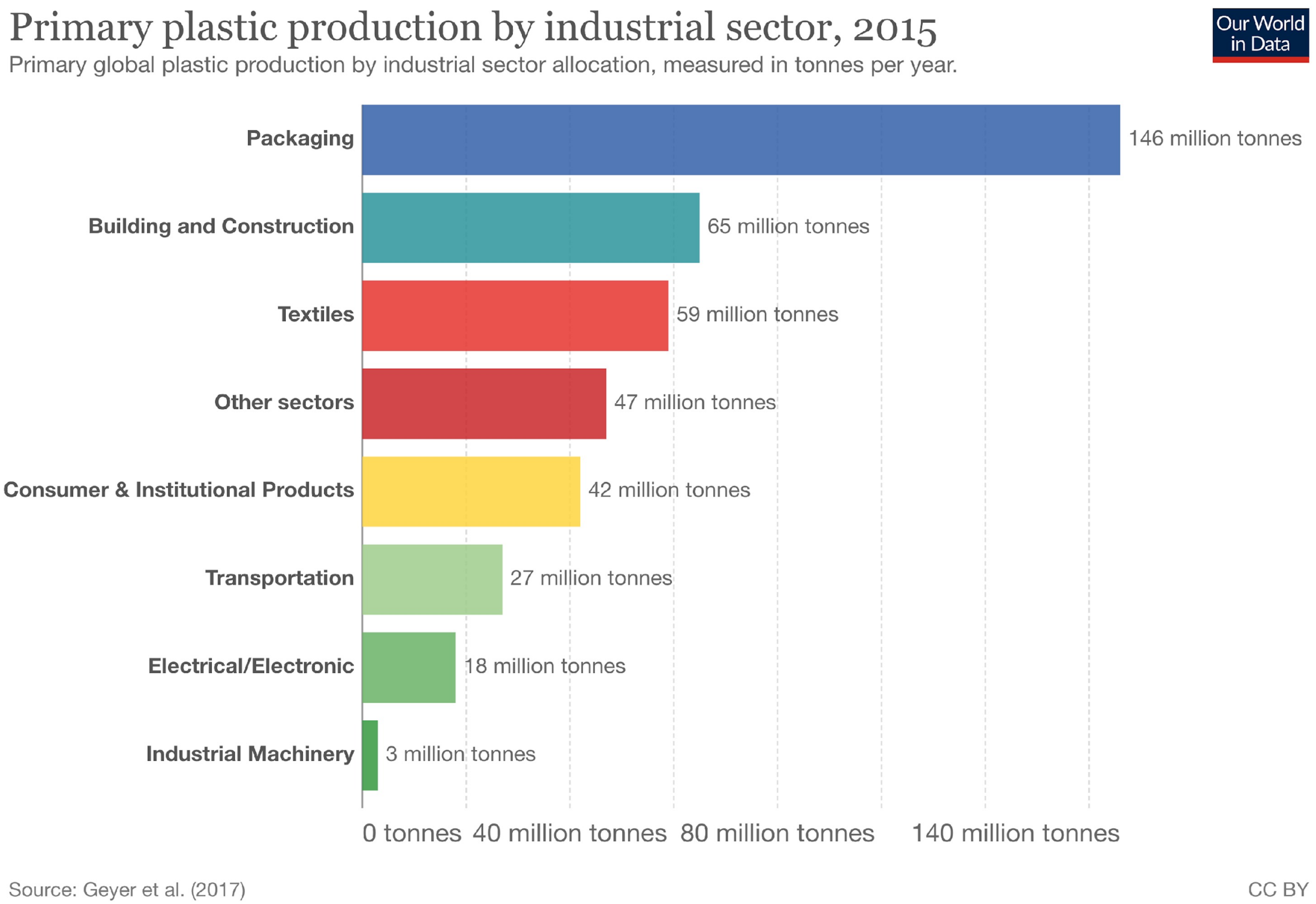


**Figure 2B. Bar chart**

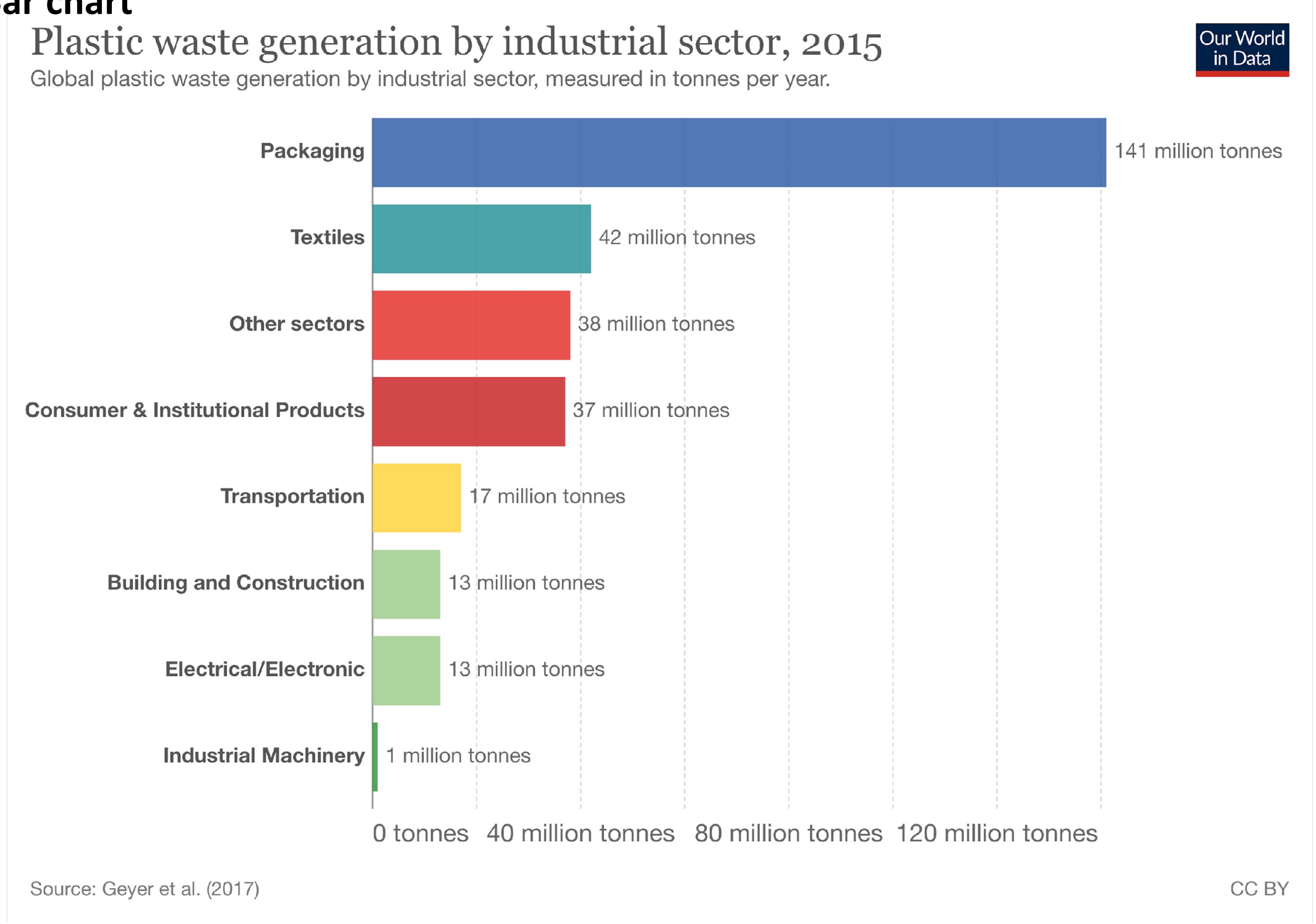


Table 1.

| Plastic # | Types of Plastics | Common Uses | Recycling Rate | Recycled Into | Decomposition Time (Perfect Conditions) |
|---|---|---|---|---|---|
| 1 | Polyethylene terephthalates (PET) | Soft drink, water bottles, clothing, carpet | 29% | Polar fleece clothes, backpacks and carpets. | >450 years |
| 2 | High Density polyethylene (HDPE) | Plastic bags, shampoo bottles, milk bottles, packaging | 30% | Non-food bottles like cleaning solution, motor oil | 100 years |
| 3 | Polyvinyl chloride (PVC) | Makeup containers, plumbing pipes, vinyl flooring, shower curtains, credit cards | Considered not recyclable <1% | NA | >450 years |
| 4 | Low-density polyethylene (LDPE) | Grocery bags, garbage bags, sandwich bags, squeezable condiment bottles, water bottle caps, kids toys | Not accepted by most recycling centers. 6% | Floor tiles, shipping envelopes, outdoor furniture | 500-1000 years |
| 5 | Polypropylene (PP) | Yogurt containers, margarine containers, syrup bottles, disposable cups, diapers, packaging material | 1-3% | Plastic lumbers, park bunches, auto parts | 20-30 years |

**Figure 3. Bar chart**

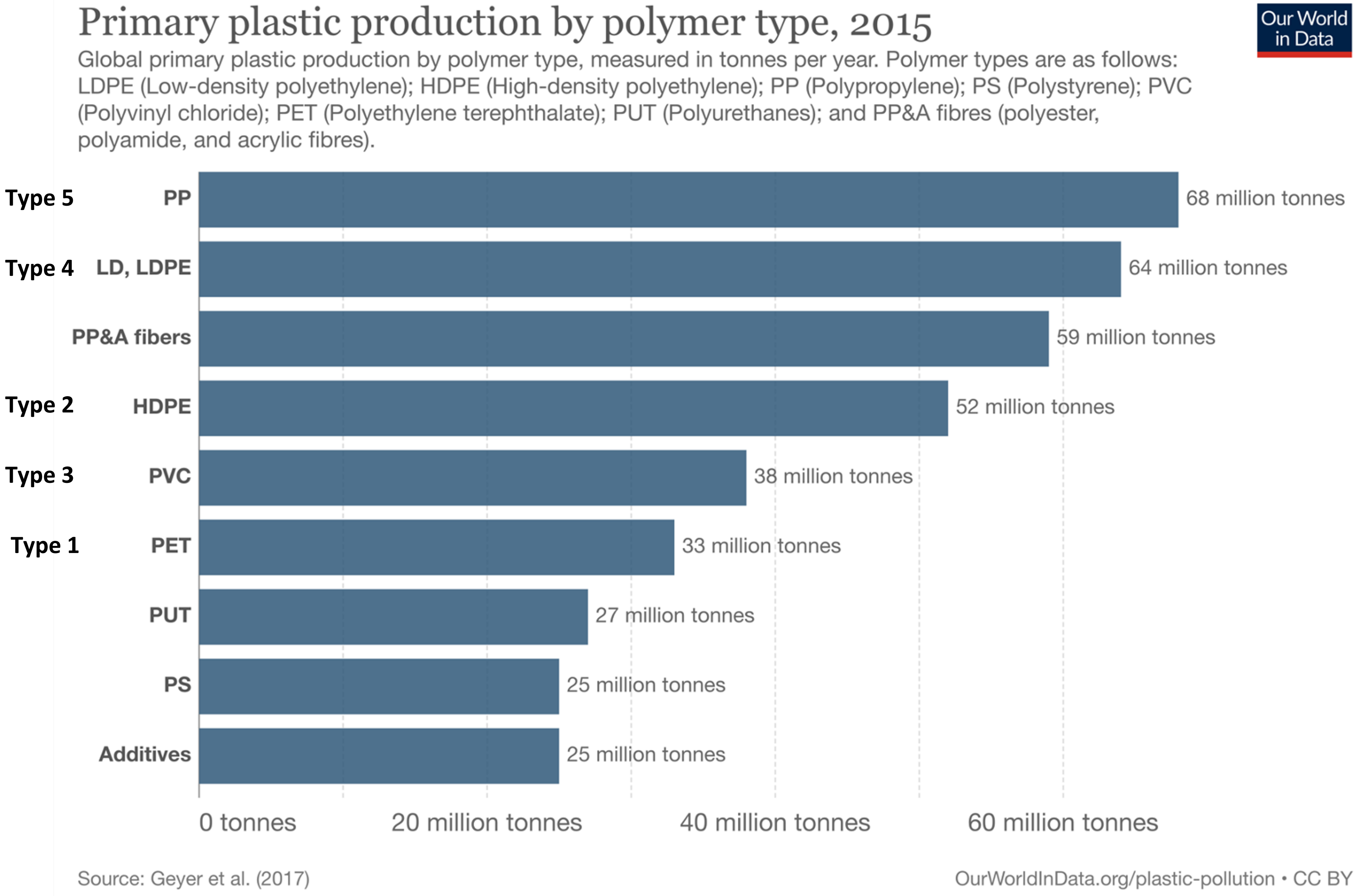


**Figure 4 . Stacked Area Chart (US Data)**

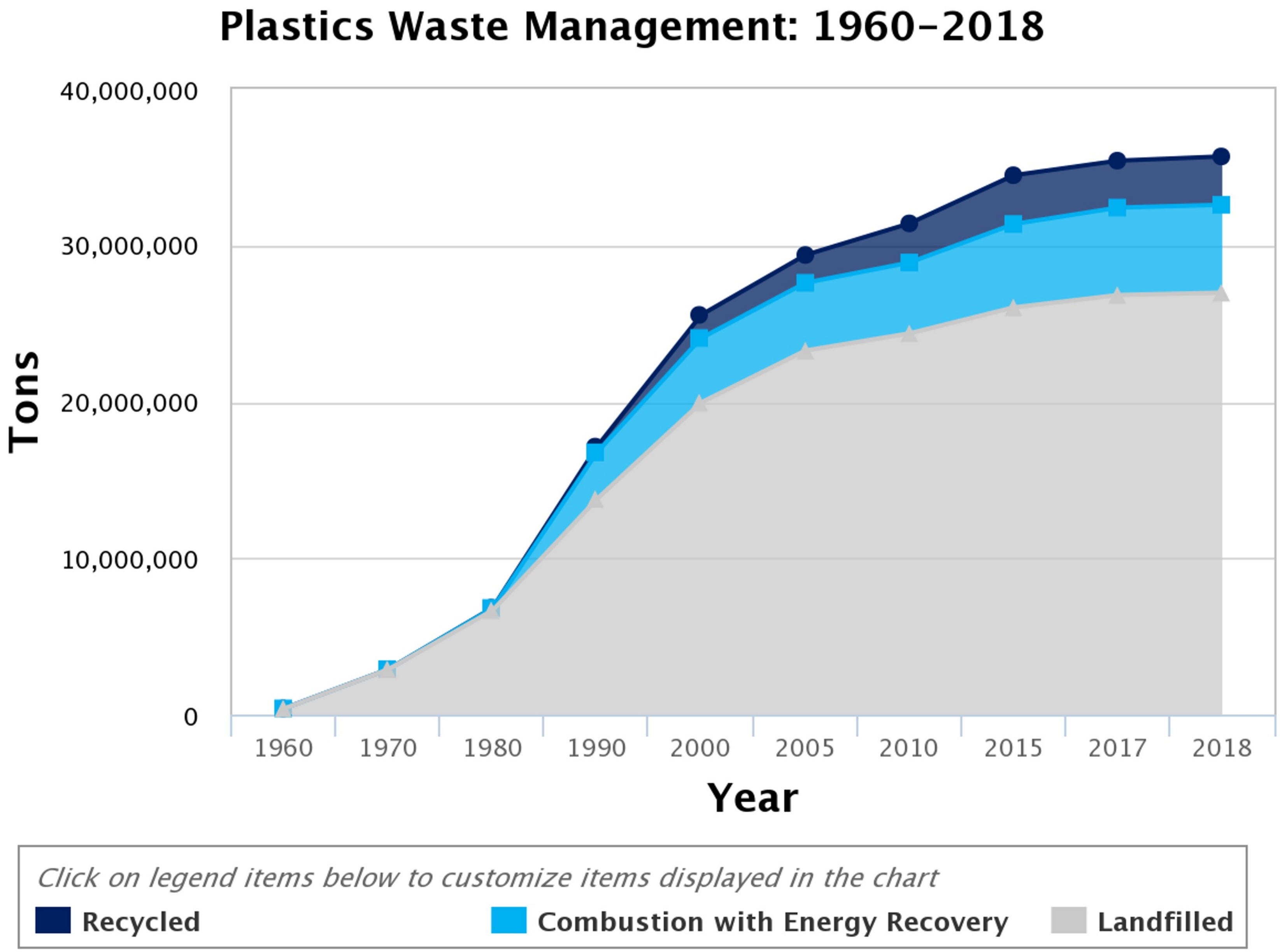


**Table 2**

# Plastics Table and Graph

The data below are from 1960 to 2018, relating to the total number of tons of plastics generated, recycled, composted, combusted with energy recovery and landfilled.

**1960-2018 Data on Plastics in MSW by Weight (in thousands of U.S. tons)**

| Management Pathway | 1960 | 1970 | 1980 | 1990 | 2000 | 2005 | 2010 | 2015 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Generation** | 390 | 2,900 | 6,830 | 17,130 | 25,550 | 29,380 | 31,400 | 34,480 | 35,410 | 35,680 |
| **Recycled** | - | - | 20 | 370 | 1,480 | 1,780 | 2,500 | 3,120 | 3,000 | 3,090 |
| **Composted** | - | - | - | - | - | - | - | - | - | - |
| **Combustion with Energy Recovery** | - | - | 140 | 2,980 | 4,120 | 4,330 | 4,530 | 5,330 | 5,590 | 5,620 |
| **Landfilled** | 390 | 2,900 | 6,670 | 13,780 | 19,950 | 23,270 | 24,370 | 26,030 | 26,820 | 26,970 |

## Figure 5. Gradient Map

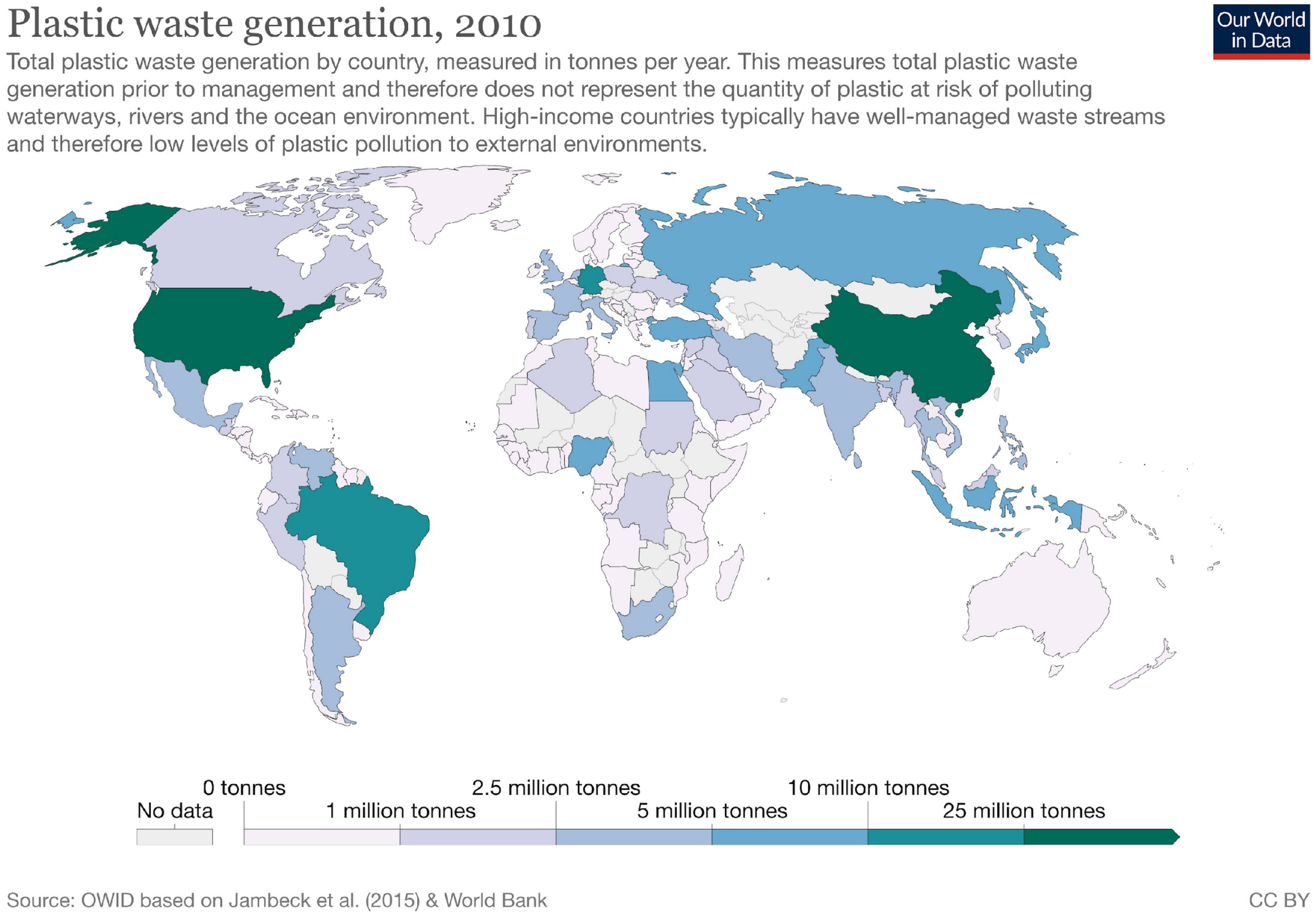
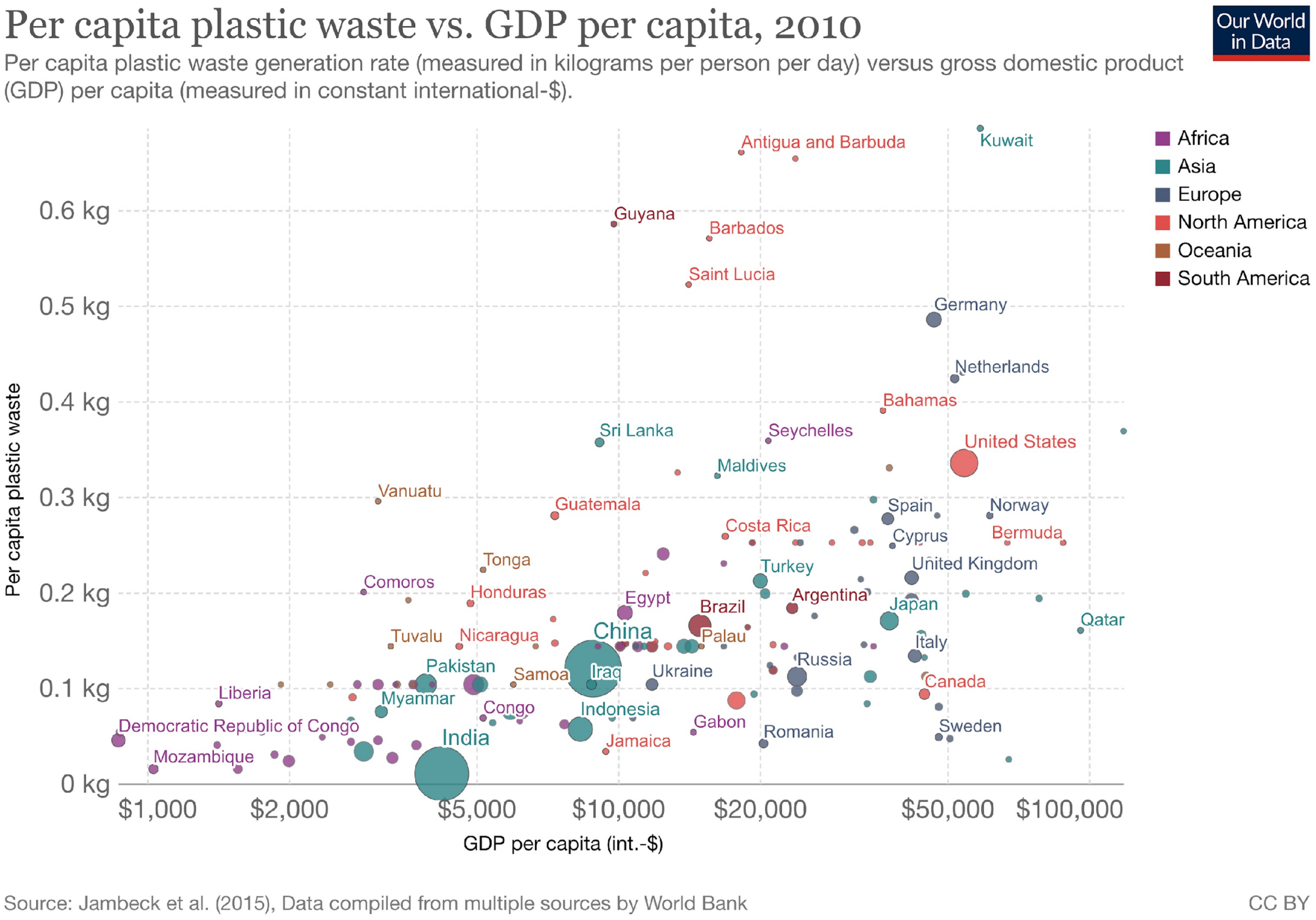
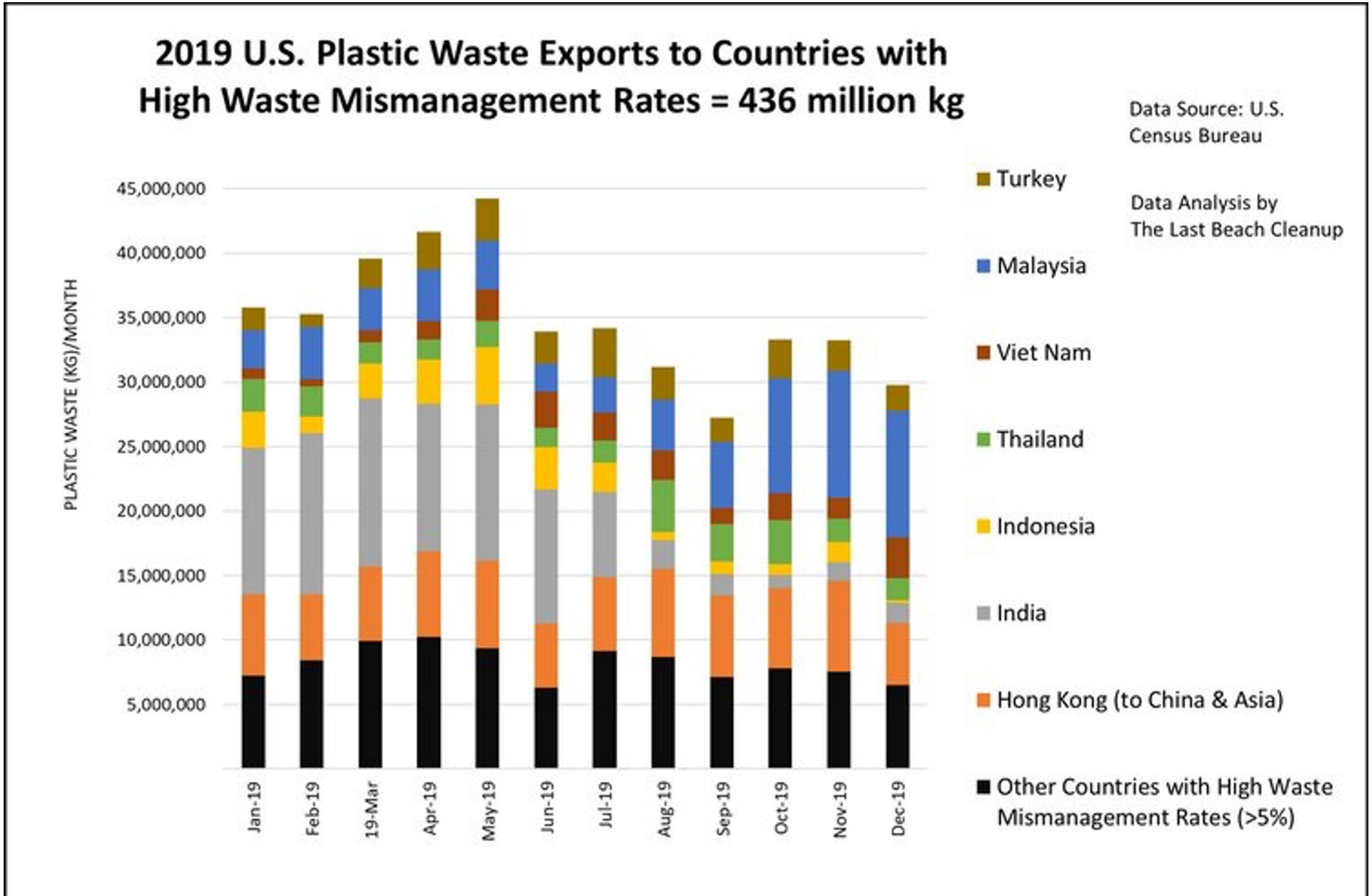


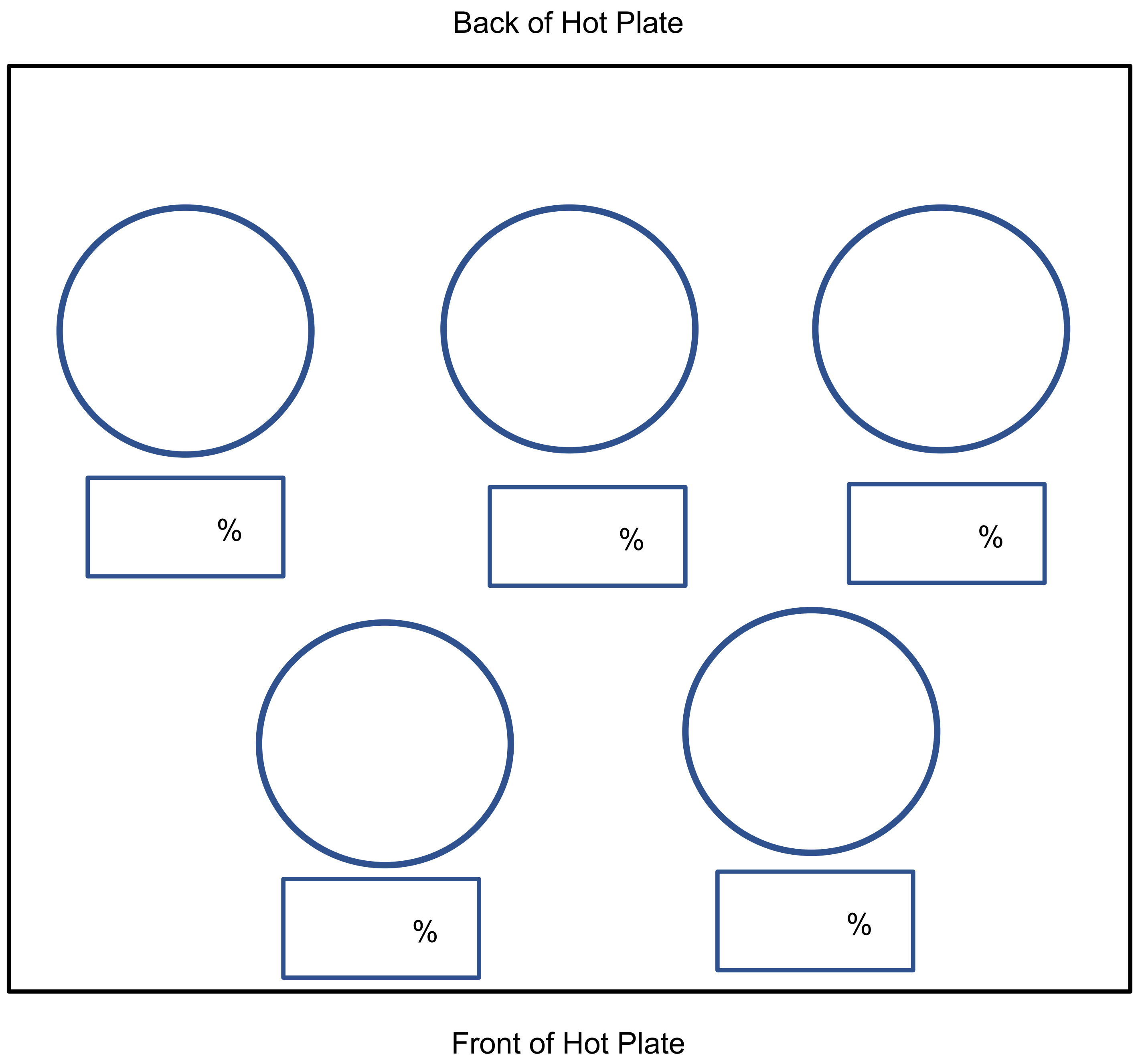
**Figure 6. Bubble Chart**



## Figure 7: Stacked bar chart




https://www.plasticpollutioncoalition.org/blog/2020/4/6/why-is-the-us-still-offshoring-post-consumer-plastic-waste-around-the-world



Back of Hot Plate
%
%
%
%
%
Front of Hot Plate

**Plastic Waste Data Analysis Activity**

**Figure 1.** Students work in groups discussing:

- Approximately, how many pounds of plastic waste the average American generates per day and per **year** (*note- map shows per day*)?
- Discuss how you and your family manage your own plastic waste
- How much of our country's plastic do you estimate gets recycled (appropriately processed and used to make a new product)?

**Mentimeter (bar graph):**
*How many pounds of plastic waste does the average American generate each year?25-75 lbs, 200-300 lbs, 500-700 lbs*

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**Figure 2A and 2B**

- What % of the plastic generated by the packaging industry is wasted each year?
- Compare this to the % wasted for the building and construction industry, what might explain this discrepancy between these two industries?

**Mentimeter (ranking question):** *Between the packaging industry, the consumer products, the transportation industry and building/construction industry, rank the order the % of generated plastic that is wasted each year from highest to lowest? (packaging, consumer products, transportation, building).*

**Open discussion**: *If you compare the packaging and construction industries, what might explain this discrepancy?*

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**Table and Figure 3**

Analyze and compare table 1 and figure 3.

- Based on your interpretations, what type of plastic do you consider to be the most problematic?
- Discuss the types of products you use that contain this type of plastic.

**Mentimeter (bar graph)** *Which type of plastic do you consider to be the most harmful to the environment? (Type 1, 2, 3, 4, 5). Not one right answer. Expect 3, 4 or 5 for different reasons. Students should consider, how much is made, how much can be recycled, and how long it takes to decompose.*

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**Figure 4 and Table 2.** These two representations were generated from the same data

*An area chart combines a line chart and a bar chart to show how one more groups' numerical values (volume of plastic recycled, placed in landfill, or combusted) change over the progression of a second variable, time). Each line on the area graph represents a cumulative sum; therefore, you can see each variable's contribution to the sum and how the composition of the sum changes over time.*

- Spend some time looking at Figure 4 to make sense of how the data is represented. Approximately, what percentage of plastic gets recycled in the US?
- How close was your estimate you made when examining Figure 1?
- What other observations did you make when interpreting the graph and table?

**Mentimeter**:
*Approximately, what percent of plastic waste gets recycled (processed and used to make a new product)?*

*A. 9; B. 20; C.50*

*What other observations did you make when interpreting this graph and table? (open answer)*
*What form of data do you think was most impactful?*

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**Figure 5**
Based on what you've learned about plastic generation, use, and waste, discuss at least 3 factors that you think would impact the amount of plastic waste generated in a country (*population size, recycling program, "wealth" of the country- to consume plastics, plastic production industries*).
**Mentimeter (word cloud):** *List 2 factors you think impact how much plastic waste a country generates*

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**Figures 6**

- Discuss- what kind of data is represented in each bubble on the chart and how does this data provide more insights than figure 5?

**Mentimeter (multiple choice):** *What type of pattern do you see on figure 6?*
*A. A positive correlation between GDP per capita and plastic waste generated*
*B. A negative correlation between GDP capita and plastic waste generated*
*C. No correlation between GDP per capita and plastic waste generated*

***Open Discussion****: What is one possible explanation for this pattern?*

**Mentimeter (open or word cloud):** *What are some of the consequences of the plastic waste problem that you are aware of?*

In addition to the harmful effects on our ocean and environment, plastic waste generated in the US has a significant humanitarian impact on other countries as well; particular those that are less developed. Any ideas how?

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**Watch:**
This video talks about another consequence that many people in the US are not aware of
Watch video: "Not Disposable: Waste Pickers"
**https://www.youtube.com/watch?v=ULAbMUzAVek**

**Figure 7**: This stacked bar graph shows where we export our plastic waste, specifically the countries that have poor plastic waste management infrastructure. Why do you think the US exports their plastic waste?

- How is this a global responsibility and humanitarian issue?