



# Oceanography and Climate Change

Plastic – Bane of the Oceans



## Student material

Responsible Research and Innovation [www.irresistible-project.eu](http://www.irresistible-project.eu)





Colophon



IRRESISTIBLE is a project on teacher training, combining formal and informal learning focused on Responsible Research and Innovation. It is a coordination and support action under FP7-SCIENCE-IN-SOCIETY-2013-1, ACTOVITY 5.2.2. Young people and science: Topic SiS.2013.2.2.1-1 Raising youth awareness to Responsible Research and Innovation through Inquiry Based Science Education. The project IRRESISTIBLE is funded by the EU as FP-7 project number 612367

[www.irresistible-project.eu](http://www.irresistible-project.eu)

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Plastic  
in daily  
life -  
working  
materials

## Plastic in daily life – working materials

### Worksheets for the group work phase

#### Plastic – an ideal material

- 1) Represent graphically how the plastic production has developed in the world since 1950. Use the following data. [2][3]



Year	1950	1976	1989	2002	2009	2010	2011	2012	2013
World plastic production (in million tons)	~1.7	~47	~99	~204	~250	~270	~280	~288	~299



- 2) The production of plastic increases rapidly from year to year and replaces the conventional materials more and more. Which characteristics make plastic such an interesting material for the industry?

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- 3) Plastic products are used in nearly all areas of daily life in Europe. Consider in which of the following areas plastic is used the most / the least. Create an order in form of 1 (a lot) – 6 (little).



Packages	Construction	Automobile industry	Electronics	Agriculture industry	Other (i.e. household appliances, furniture, medical devices...)

### Plastic – what sort of material is it actually?

The first plastic was discovered in 1907 by coincidence, when the Belgian Hendrik Baekeland put a piece of phenol into a formaldehyde solution and heated this up to nearly 200°C. [4, p.6] A vicious mass developed, which hardened in the air. The German chemist Hermann Staudinger noticed 15 years later that the basic principle for the production of plastics is always the same: “Therefore the development of plastics must be imagined as chemical Lego: long chain molecules, the so-called polymers, develop from materials with smaller molecules, so-called monomers, by heat, pressure or chemical additions”. [4, p.7]

- 1) Build a paper clip model of a plastic and paste it into the worksheet. Describe the structure according to your model.

Paper clip model
Description of the structure

- 2) Inform yourself about what PCB was used for in plastic products and why this material was forbidden worldwide in 2001. [10]

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2

Plastic  
garbage  
in the  
ocean –  
working  
materials

## Plastic garbage in the ocean - working materials

## Slide show

**Task:** Watch the PowerPoint presentation and note all questions which arise while the images are shown.

[illegible]

## Mystery

**“Is the health of family Larsson on Greenland threatened, because people carelessly dispose plastic garbage into the oceans worldwide since decades?”<sup>1</sup>**

**Task:** Visualize the connection between plastic garbage in the oceans and the health of family Larsson by a flow chart and answer the question.

### Procedure for answering on the task:

1. Read the information cards of your stack of cards.
2. Share the content of your information cards. Be aware of presenting all cards!
3. Sort the information cards. Proceed as follows:
  - a.) Consider which cards are not relevant for answering the question. Sort these out.
  - b.) Put the other information cards into a sensible order and number the cards.
4. Present the idea briefly to your teacher and ask questions if necessary.
5. Get yourself a DIN A3 poster from the desk and create a flow chart according to the given scheme, which demonstrates how the plastic garbage that is carelessly thrown into the ocean relates to the health of family Larsson.
6. Give your opinion on the statement: “Is the health of family Larsson actually threatened, because people dispose plastic garbage into the oceans worldwide since decades?”

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<sup>1</sup> The PCB problem on Greenland is dealt with based on the fictive family Larsson from Greenland. You will find information on this in the following video contribution: <https://vimeo.com/55622467> [5]

## Card 1

In **1950** 1.7 million tons of plastic were produced worldwide. In the following years the global plastic production increased rapidly. [2][3]

Year	World plastic production (in million tons)
1950	~1.7
1976	~47
1989	~99
2002	~204
2009	~250
2010	~270
2011	~280
2012	~288
2013	~299

Listed below are the countries which had which share on the global plastic production in 2013: [2]

China (24.8%), EU + Switzerland + Norway (20%), NAFTA (19.4%), Rest of Asia (16.4%), Middle East + Africa (7.3%), Latin America (4.8%), Japan (4.4%), CIS (2.9%)

## Card 2

The most sorts of plastic have a lower density than seawater and they float, for that reason the garbage is carried across far distances along with the surface currents and by wind. [8, p.22] The plastic garbage can be on the way for years, until it finally reaches one of the five so-called Garbage Patches. The whole plastic garbage that ended up in the oceans gathers in these extensive ocean regions, so that an enormous amount of garbage in different sizes and types gather here. Due to temperature and salt content differences of the ocean water and by winds and the earth's rotation, enormous amounts of water – and therefore also the plastic garbage – circle continuously in these ocean regions in whirls that are several kilometers wide. [8, p.22][7]

## Card 3

A great number of different waste products drift on the oceans. The quantities are significant. In 1997 the National Academy of Sciences in the USA already estimated the yearly input of garbage to be 6.4 million tons. [7] A large part of it is plastic garbage. But the actual amount of garbage existing in the oceans is difficult to estimate up to now, because the plastic garbage spreads widely very fast due to the global ocean currents. A further problem which makes the recording of the actual pollution of the oceans difficult is the fact that a great number of the plastic garbage sinks to the ocean ground sooner or later. [9, p.40] Whatever happens to the plastic garbage that is in the deep seas because of the larger density than sea water is unexplored up to now.

## Card 4

A large part of the plastic garbage is brought into the oceans by land. It is estimated that approx. 80% of the plastic garbage in the oceans are due to land-based sources. [8, p.21] A large amount of the accruing garbage ends up in the ocean because of missing disposal possibilities in many countries, hereby both local people and tourists play a key role. [8, p.21] Immense inputs of any kind of garbage are due to disasters such as i.e. the Tsunami in Japan in 2011. [8, p.22] But plastic garbage is also brought in straight on the water. Accruing disposal fees in many ports often lead to illegal, but free of charge dumping by the crew at sea. [9, p.39] Even though this is forbidden worldwide since the MARPOL Agreement in 1988, a total containment has still not succeeded up to now because of lack of control and the large amount of passing ships. [8, p.22]. "It is estimated that the largest part of the plastic garbage that is released in the ocean relates to fishing (Andrady 2011)." [8, p.22] Numerous nets and ropes made of plastic can be found in the oceans, which are either purposely disposed or went lost by mistake. These "ghost nets" can become a large risk for the animals in the ocean. A further source for the import of plastic garbage into the oceans are containers which accidentally fall off container ships during storms due to inadequate securing, and release the container content during the impact. [8, p.22] In this way 18.000 Nike sneakers ended up in the world's oceans in 1999. [9, p.40]

## Card 5

When Charles Moore and his team sailed from Hawaii to Long Beach on their way home from a regatta in 1997, they discovered the "Great Pacific Garbage Patch" in the North Pacific. [9, p.39] Over an area of 700.000 to 15.000.000 km<sup>2</sup> approx. three million tons of plastic garbage rotates in the ocean region. [6, p.41] It is difficult to measure how much garbage really exists in this area, because it spreads within the whole water column [14, p.28] Apart from the large and visible macro plastic, also a great number of small micro plastic particles hardly visible to the naked eye were found by careful investigations. Therefore these five Garbage Patches are not a "Garbage carpet" which covers the ocean, but rather a "Garbage soup" consisting of large and small parts. [8, p.22]

## Card 6

A great number of pollutants exist in the ocean such as PCB which was, among others, used as softener in plastics of many daily products until 2001. [10] PCB is difficult to degrade so that these materials are in the environment for a long time, therefore also in the ocean. [11] Nevertheless, the concentration on released PCB in the water is very low, because these materials are nearly always bound to the micro plastic particles. [11] If a PCB polluted micro plastic is ingested by ocean organisms, it enriches in the food chain which is called bioaccumulation. [11] Animals at the top of the food chain such as seals are therefore especially strongly loaded with pollutants, because they eat higher polluted food than animals at the bottom of the food chain. [11][12]

## Card 7

Plastic particles that are smaller than 5 mm are called micro plastic. [8, p.23] All larger plastic parts in the environment are called macro plastic. The micro plastic that develops during the degradation of macro plastic is called secondary micro plastic. [8, p.23] Apart from this also primary micro plastic exists in the ocean. This is added to i.e. cosmetic products in order to achieve a peeling effect. [8, p.23] Such additives are found in shower gels, toothpaste, washing gels, etc.. Treatment plants can only partly or not at all hold back these tiny particles, so that they end up in the oceans along with the clarified water. [8, p.23] Micro plastic particles do not only end up in the oceans after using cosmetic products, but also through washing of certain synthetic pieces of clothing like fleece sweaters. [8, p.23]

## Card 8

New studies have shown that micro plastic appears as a so-called pollutant absorber which means that it attracts pollutants from the environment which are enriched on the surface. [8, p.24].

Simplified, the principle can be compared with a magnet that attracts iron filings. This is due to the hydrophobic properties of the plastic and the pollutants. Hydrophobic materials are strongly water resistant, so they do not mix with water. Plastic can enrich pollutants with the factor of 1:1 million compared to seawater, depending on the type of plastic and which pollutant is viewed. [8, p.24]

According to this, the micro plastic particles are small toxin transporters that give back a part of the pollutants when they end up in the gastrointestinal tract of animals and then store them in the fat tissue or in the organs of the living beings (i.e. liver). [8, p.24] There they can cause significant damages in the organism.

## Card 9

Studies have shown that PCB can be detected in human tissue (i.e. muscle or hepatic tissue) and that this material has numerous negative impacts on human health. [11, p.5] If the PCB concentration in the body is high, i.e. chloracne, skin thicknesses, increased pigmentation and respiratory diseases can be the result. [11, p.5] A high PCB level can also lead to immune and reproductive disorders and to liver dysfunctions. [11, p.5] "A cancer-causing effect was indicated in an animal experiment, but could so far neither be reliably proven in humans nor disproved." [11, p.5] As PCB affects human and animal health, the material was forbidden worldwide in 2001.

## Card 10

Plastic is gradually reduced to small pieces in the ocean by various environment impacts. If macro plastic parts (i.e. plastic bottles or plastic bags) end up in the oceans, the softeners are released from the plastic because these are not firmly bound to the plastic. Due to this the plastic becomes brittle and very rough under the influence of UV light, so that it can easily break. [8, p.22] During transport by the ocean currents this brittle macro plastic is reduced to small pieces by the mechanical forces of the waves and rubbing on other flotsam or on rocky coasts. [8, p.23] Finally, secondary micro plastic develops due to continuing fragmentation processes (grinding processes). A biological degradation by bacteria hardly takes place. [8, p.23]

## Card 11

Mr. Larsson from Greenland commented in an interview as follows: “My grandfather was a skillful hunter. For that reason we ate a lot of seal meat during my childhood. We also like to eat the fat part of the seals – called blubber – because it is a real delicacy. We eat everything of animals – including the liver. Hunting is a part of our daily life. We do not want to do without our traditional food.” [5]

## Card 12

The Arctic is one of the cleanest places in the world. Large industries do not exist, the fish industry is the main industry on Greenland. Even though the ocean around Greenland as well as the mainland hardly shows signs of pollution, the Greenlanders show a very high concentration of the environment toxin PCB in the body. Scientists have also investigated the PCB concentration of marine organisms near Greenland and noticed that whales and seals have enriched a large part of the environment toxin, especially in the fat layer (blubber). Even though PCB is forbidden since decades, humans and animals are still contaminated with this toxin today. [5]

## Card 13

In the past 100 years the world population has quadrupled. The amount of produced garbage has tenfold increased connected to this growth. [8, p.21] Today we produce about 1.3 billions of garbage per year. [8, p.21] Apart from the amount of garbage, the garbage composition has also changed in this time period. While garbage consisted of rapidly degradable plants and animal remains in the past, plastic products dominate the waste today. [8, p.20]

## Card 14

The current research results are a mystery to the scientists: A great number of scientific studies showed that human and animal health is affected by the environment toxin PCB in many ways. [11] Even though family Larsson on Greenland shows a high PCB concentration in the body, no diseases have occurred up to now which could be connected to this toxin. How can this be? This discovery runs counter to all research results worldwide. Scientists have an assumption: It may be that seal meat contains a substance that removes the negative effects of PCB. That would mean that even though the Greenlanders are poisoned through the meat, this also protects humans at the same time. But initially this is only an assumption. Scientists are intensively working on solving the mystery of Greenland. [5]

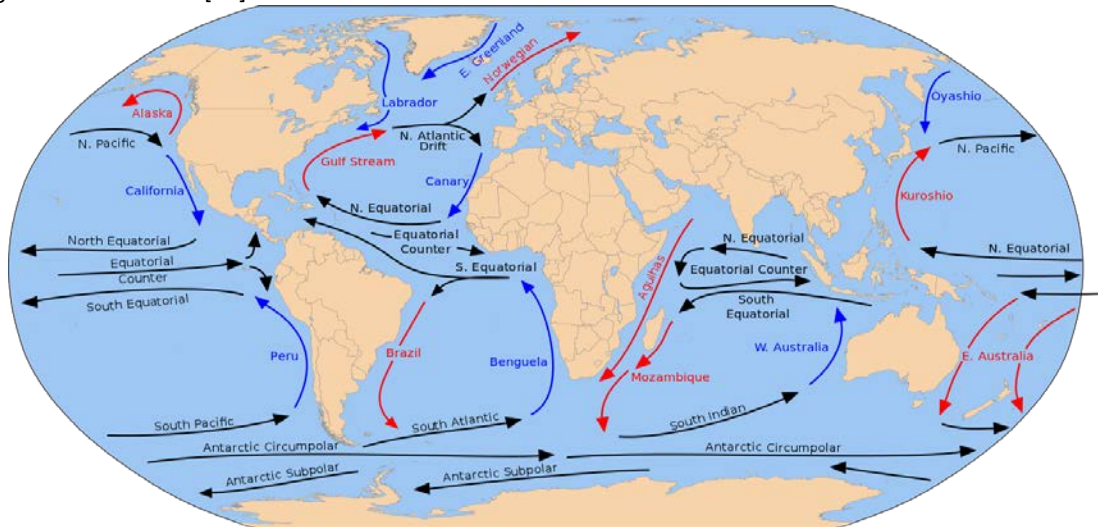
## Card 15

It is estimated that 1 million sea birds and 100.000 marine mammals die per year due to the plastic garbage in the ocean. [8, p.24] Many animals mix up plastic with their natural prey and swallow it. One example for this is a whale that was found dead on the Spanish coast in 2012. Scientists recognized that the animal with a weight of 4.5 tons had swallowed 17 kg plastic garbage and as a result the intestine was completely clogged. [13] Birds also often mix up plastic with the natural prey. Investigations have shown that 95 % of the Fulmars from the southern North Sea contained 35 plastic particles in the stomach. [14, p.29] The plastic parts in the stomach cause pseudo saturation. [8, p.23] Due to this the animals do not ingest food anymore and starve. But this is not the only risk caused by the plastic garbage in the ocean. A further deadly risk is that the animals can get entangled in nets or ropes under water and suffocate. [8, p.24]



## Card 16

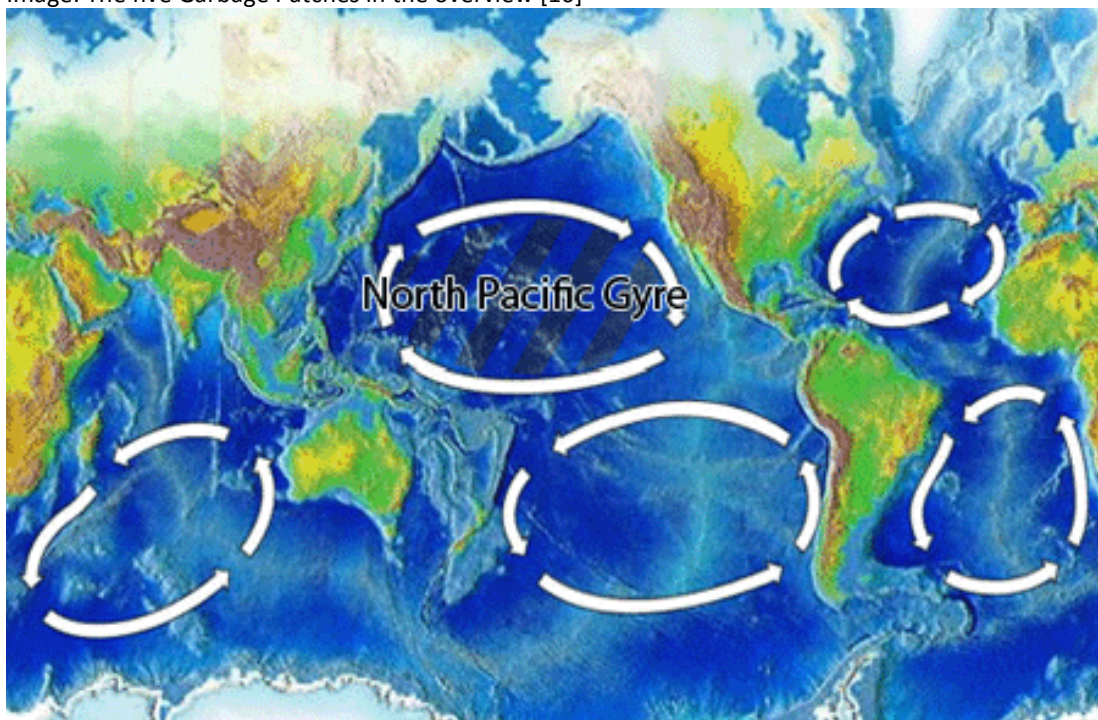
Image: Ocean currents [15]



Source: <http://upload.wikimedia.org/wikipedia/commons/thumb/7/74/Corrientes-oceanicas.svg/1280px-Corrientes-oceanicas.svg.png>  
 (Call-up: 16.06.2015, original image made by Dr. Michael Pidwirny)

## Card 17

Image: The five Garbage Patches in the overview [16]



Source: [http://upload.wikimedia.org/wikipedia/commons/6/64/North\\_Pacific\\_Gyre\\_World\\_Map.png](http://upload.wikimedia.org/wikipedia/commons/6/64/North_Pacific_Gyre_World_Map.png) (Call-up: 15.01.2015, Author: Fangz)



## Group work: macro / micro plastic

### Work task for the group:

1. Work on the following tasks about the plastic problem in the world's oceans on your own first and then discuss them with the group members.
2. Prepare yourself in a way that you are able to present your part at the end of the teaching unit.

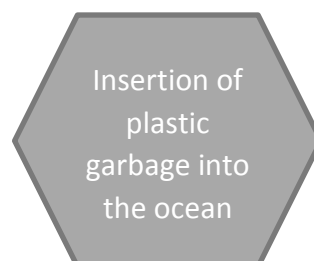
Macro- as well as micro plastic exists in the ocean. Find a suitable definition for these two terms:

Macro plastic: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Micro plastic: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## How does plastic garbage end up in the ocean?

Create a chart identifying where the million tons of plastic come from that exist in the world's seas.



## What happens to the plastic garbage in the ocean?

Plastic garbage with a lower density than seawater can be spread worldwide by the flow systems. [8, p.22] The last stations of the plastic garbage are the so-called Garbage Patches.



- a) Indicate which of the following sorts of plastics swim, float or sink. The density of seawater is about  $1.025 \text{ g/cm}^3$ , at  $25^\circ\text{C}$ . [18]

Plastic	Density in $\text{g/cm}^3$	Performance in seawater
PC	1.20	
PE	0.95	
PP	0.91	
PVC	1.36	

- b) Explain what is understood by „Garbage Patch“.

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- c) There are five Garbage Patches: in the North and South Atlantic, in the North and South Pacific and in the Indian Ocean. Mark the locations of the five oceanic Garbage Patches in the following image with a blue circle and give the direction of their circulation. [17]



**The garbage in the ocean will be degraded – it is only a question of time**

- 1) Sort the following products by your assumed degradation rate from the fastest (1) to the slowest (6) and also make a suggestion on the duration of the degradation in months or years. Enter your assumptions in the following table!

Paper towels, fishing lines, aluminum cans, plastic bags, newspapers, plywood

- 2) Enter the actual degradation rates. [7]



Degradation rate of garbage in the order: fast (1) to slow (6)	Assumed degradation rate in weeks/years	Actual degradation rate in weeks/years
1.		
2.		
3.		
4.		
5.		
6.		

**From macro plastic to secondary micro plastic**

Macro plastic becomes brittle and fragile when it floats on water for a long time. Explain this phenomenon.

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Secondary micro plastic develops due to the degradation of the brittle macro plastic. Name two processes that lead to degradation of macro plastic.

a) \_\_\_\_\_ b) \_\_\_\_\_

The micro plastic in the ocean is divided into primary and secondary micro plastic. Explain the difference.

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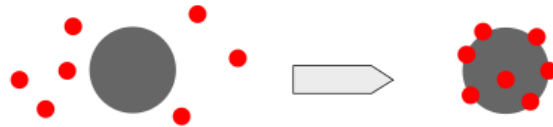
## Impacts of macro and micro plastic on marine living beings

Name at least three risks for the marine organisms that come from the macro plastic in the oceans:

- a) \_\_\_\_\_
- b) \_\_\_\_\_
- c) \_\_\_\_\_

Even though micro plastic particles are very small, a great risk comes from them for the marine organisms. Explain this statement by including the following sketches A, B and C in your explanation.

A:



B:



C:




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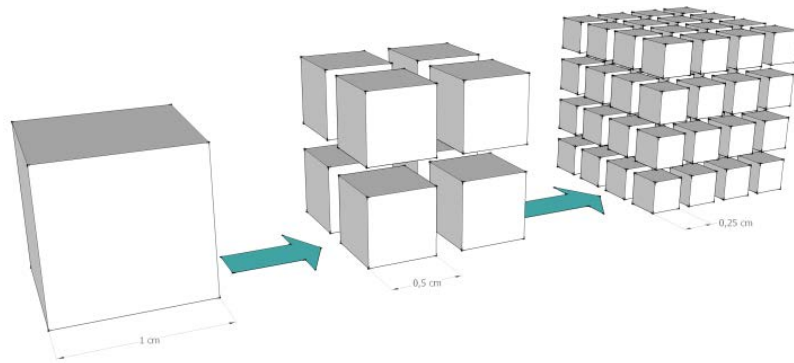
Explain why the plastic particles and the pollutants floating on the water attract each other like a magnet attracts iron filings.

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Scientists assume that a greater risk comes from micro plastic than from macro plastic. Consider for which reasons this assumption could be correct. Include the following image as doing so.




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Seals show a clearly higher pollution in the tissue than i.e. fishes. Find an explanation for this. [12]

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### Plastic garbage in the oceans – also a risk for humans?

Can the plastic garbage in the world's oceans also become a risk for humans?

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## Group work: Plastic in local context

### Group 1: Product testing: In which cosmetic products does micro plastic exist?

A great number of companies have stated to use peeling agents of natural origin from now on instead of micro plastic, because more and more studies show that micro plastic has negative impacts on living beings and the environment. One of these companies is the Rossmann GmbH whose aim it is to optimize all concerned cosmetic products until the end of 2014. "Only peeling agents of natural origin will be used in new products. That includes nine products (the brands Rival de Loop, Isana, and Synergen) in a total which still contain polyethylene." [19]

Source:

[http://www.bund.net/themen\\_und\\_projekte/meeresschutz/muellkampagne/mikroplastik/erfolg/](http://www.bund.net/themen_und_projekte/meeresschutz/muellkampagne/mikroplastik/erfolg/)  
(Call-up: 13.4.2015)

#### Work task:

- [1] Go to a Rossmann store in your area and choose different products in which you think micro plastic is contained.
- [2] Consider, how you can check experimentally with a tea filter and water whether the products were really optimized. Before carrying out the experiments, discuss your ideas with your teacher.
- [3] Look at the label and search for the content „polyethylene“. Those are small micro plastic beads. Compare your test results with the label.
- [4] Prepare yourself in a way that you can present the results to your classmates.

### Group 2: Micro plastic in cosmetic products: What does policy do?

The Alliance 90/The Greens want to prevent the release of micro plastic particles by cosmetic products and contacted the Federal Government on the 14.01.2015. [1]

#### Work task:

- [1] Search the internet about what the Greens require in their application (18/3734) and how they justify their requirements.
- [2] Prepare yourself in a way that you can present the results to your classmates.

**Group 3: Micro plastic in waste water: Too small for the filter systems of the Kiel-based treatment plant?**

**Work task:**

- [1] Research on the internet, whether the treatment plants are generally able to remove micro plastic from the waste water.
- [2] Prepare an interview in order to receive more detailed information about the Kiel-based treatment plant. Ask your teacher if he/she can send your questions to a treatment plant employee.
- [3] Prepare yourself in a way that you can present the results to your classmates.

**Group 4: Summer, sun, beach and plastic: How heavily is the sand on Kiel-based beaches polluted by micro plastic?**

**Work task:**

- [1] Search for „Google Scholar“ in Google. With this searching platform you will find scientific articles on different topics.
- [2] Search for the following article: Macro and micro garbage in the Lower Saxony Wadden Sea, by Gerd Liebezeit. [6] Read the material and method part and find out how the scientists have separated micro plastic particles and sand. Talk to your teacher about how to perform the test at school.
- [3] Check experimentally whether the sand of the Kiel-based beaches is polluted with micro plastic.
  - a) Perform the test initially with the sand sample A (contains a lot of micro plastic).
  - b) Perform the test with sand from different Kiel-based beaches.
- [4] Prepare yourself in a way that you can present the results to your classmates. Additionally, describe your procedure during the search on the internet.

**Group 5: Summer, sun, beach and plastic: How heavily is the water on Kiel-based fjords polluted by micro plastic?**

**Work task:**

[1] Search for „Google Scholar“ in Google. With this searching platform you will find scientific articles on different topics.

[2] Search for the following article: Macro and micro garbage in the Lower Saxony Wadden Sea, by Gerd Liebezeit. [6] Read the material and method part and find out how the scientists have isolated micro plastic particles and water samples. Talk to your teacher about how to perform the test at school.

[3] Check experimentally whether the water of the Kiel-based fjords is polluted with micro plastic.

- a) Perform the test initially with the water sample A (contains a lot of micro plastic).
- b) Perform the test with water samples from different areas of the Kiel-based fjords.

[4] Prepare yourself in a way that you can present the results to your classmates. Additionally, describe your procedure during the search on the internet.

**Group 6: Micro plastic – a risk for marine organisms?**

**Work task:**

[1] Search for “Google Scholar” in Google. With this searching platform you will find scientific articles on different topics.

[2] Search for the following article: Micro plastic – an invisible troublemaker, by Prof. Dr. Patricia Holm [6] Which problem occurs by reading the article? Ask your teacher for help.

[3] Prepare yourself in a way that you can present the results to your classmates. Describe the problems that occurred in order to read the article.



## Responsible Research and Innovation

### Shall micro plastic in cosmetic products be forbidden?

**Role: Politician (Representative of The Alliance 90/The Greens)**

**Work task:**

- ❖ Try to understand the given role and consider how the respective person would argue.
- ❖ Note your considerations on the role card.

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### Shall micro plastic in cosmetic products be forbidden?

**Plastic industry (industry boss/in a plastics industry)**

**Work task:**

- ❖ Try to understand the given role and consider how the respective person would argue.
- ❖ Note your considerations on the role card.

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### Shall micro plastic in cosmetic products be forbidden?

**Chemical industry (industry boss/in a chemical industry which alternatively produces peeling additives)**

**Work task:**

- ❖ Try to understand the given role and consider how the respective person would argue.
- ❖ Note your considerations on the role card.

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### Shall micro plastic in cosmetic products be forbidden?

**Role: Researcher (biologist who dissects dead birds and examines for plastic since years)**

**Work task:**

- ❖ Try to understand the given role and consider how the respective person would argue.
- ❖ Note your considerations on the role card.

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### Shall micro plastic in cosmetic products be forbidden?

**Role: Researcher (chemist who deals with the pollutants in the ocean)**

**Work task:**

- ❖ Try to understand the given role and consider how the respective person would argue.
- ❖ Note your considerations on the role card.

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### Shall micro plastic in cosmetic products be forbidden?

**Role: Researcher (Water analyst of a treatment plant)**

**Work task:**

- ❖ Try to understand the given role and consider how the respective person would argue.
- ❖ Note your considerations on the role card.

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### Shall micro plastic in cosmetic products be forbidden?

**Role: Citizen (own opinion)**

**Work task:**

- ❖ Try to understand the given role and consider how the respective person would argue.
- ❖ Note your considerations on the role card.

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# Sources

# Sources

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