



Oceanography and Climate Change

Plastic – Bane of the Oceans



Teacher's guideline

Responsible Research and Innovation www.irresistible-project.eu



Colophon



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Teacher`s guideline

In this teacher's guideline the module "Plastic – Bane of the Oceans" is presented, which was developed within the EU project IRRESISTIBLE¹. Teachers and scientists as well as experts from a museum have worked closely linked together on this, in order to support the pupils in the process of responsible handling of research and development results (RRI²). For this purpose, the pupils initially receive the necessary know-how about the plastic problem in the world's oceans in this module, a hot topic, as can be seen in the enormous media presence in the last years. Based on this basic knowledge the pupils perform their own research and investigation work on the topic. But the awareness of RRI is also raised in the module due to the pupils initiating the discussion about the responsible handling of research and development results.

The learning module follows the 6E model which means that the teaching unit is structured in six phases on the whole: In the Engage phase (contact phase) the pupils' interest about the topic "Plastic – Bane of the Oceans", is aroused by a PowerPoint presentation. This raises questions which are supposed to be answered in the course of the teaching unit. In this phase pupils also formulate the questions. The pupils receive the necessary know-how about the plastic problem in the world's oceans in the Explore and in the Explain phase. In the Elaborate phase the pupils deal with more detailed research questions around the local view of the plastic problem. In this phase the pupils perform their own experiments, read scientific publications about the topic and confront outer school learning partners (here: treatment plant employee) with questions. At the end of this phase the teaching unit is reflected relating to the six RRI aspects, which are described in more detail in the following. In order to additionally inform the public about this highly topical research field, the pupils create an exhibition which they organize themselves³. This phase is called Exchange phase. In the last phase, the Evaluate phase, pupils' knowledge about the module's contents and about responsible research and innovation will be assessed. Additionally, they reflect in this phase whether all initial questions have been answered. If there still are unanswered questions, scientists can be asked. Also there might be the possibility to visit a pupils' research lab at a local university, different research institutes or exhibitions in museums.

The module "Plastic – Bane of the Oceans", looks at the following RRI aspects: Engagement, Gender Equality, Science Education, Ethics, Open Access, Governance. These aspects are

¹ Find detailed information on the project on the internet at following address: www.irresistible-project.eu

² Find detailed information on the RRI aspects at following address: http://ec.europa.eu/research/swafs/pdf/pub_rri/KI0214595ENC.pdf#view=fit&pagemode=none

³ Find detailed information on the exhibitions organized by the pupils at the following address: <http://www.exponeer.de/index.php/de/>

integrated into the different phases and are integrated by different methodic accesses. Engagement means that all social actors – researchers, industry, policy and civil society – are involved in the research and innovation process. In this module the pupils state their opinion from different perspectives (politicians, researchers, industry, citizens) on the question whether micro plastic in cosmetic products should be forbidden. Thereby the criterion “Engagement” is viewed and can be dealt with afterwards. After that a fictive internet contribution is shown, which covers further citizen opinions. An ethical discussion shall now follow these contributions in order to look at the RRI aspect “Ethics” in more detail. It makes sense to deal with the RRI aspect “Governance” after the ethical discussion. This criterion looks at the fact that political decision-makers also have responsibility for research and innovation processes: Harmful or unethical developments such as the usage of micro plastic in cosmetic products must be prevented. There is no need to use micro plastic in cosmetic products, because alternative materials exist which also achieve a peeling effect. For that reason the Greens directed their request “Stop the release of micro plastic” dated 14.01.2015 to the German Bundestag. In this letter the German Bundestag prompts the Federal Government among other things to actively support the withdrawal of using micro plastic articles in cosmetics and cleaning agents. [18] With this example it can be understood which position policy has and how or if such demands really are implemented.

In the film “Bane of the Oceans – Plastic” current research findings on the topic are presented. It is noticeable that the scientists shown in the film are nearly all male, so that the film is suitable for basic discussion on the RRI aspect “Gender Equality”. There is a need to encourage the pupil’s interest in the MINT-area so that more boys and girls decide on scientific study paths and training occupations. The key criterion “Science Education” views this aspect. The pupils investigate in short experiments how far we are locally confronted with the plastic problem in the world’s Oceans. Based on the own research and investigation works the pupils shall state their opinion on the question whether micro plastic in cosmetic products should be forbidden. For this the pupils need the necessary basic knowledge on the topic which they receive in the Explore and the Explain phase. Research and innovation processes must be transparent and available for everyone, so that all actors can take over responsibility. Searching the internet for scientific publications – what the pupils in the Elaborate phase do – shows that not all publications are free of cost. At this point the RRI criterion “Open Access” can be dealt with.

The research cluster “Future Ocean” (Kiel, Germany) has published a series called World Ocean Review in the last years which describe the contents that this module is based on in a detailed and generally understandable way. Up to now, the series consists of four volumes and can be downloaded from the website <http://worldoceanreview.com/> as a .pdf or ordered as a printed copy free of charge. As the contents are represented in a very interesting, extensive and all-encompassing way and since important marine circumstances – in part affected by humans – are highlighted, these volumes are absolutely worth reading.

First, this publication gives a description of the status quo of the ocean, focusing on various aspects concerning man’s intervention into marine systems. The three following Science

journals further highlight the aspects of fishing, marine raw materials and sustainable treatment of the ocean in an up-to-date and more detailed fashion. In particular, the RRI-aspects Science Education, Open Access, Ethics and Governance are dealt with in a detailed manner, while the dimensions Engagement and Gender Equality are also addressed in several areas of the whole publication.

The “plastic” problem does not only apply to the ocean but also to inland waters such as lakes and rivers. In the north of Germany, a study was done testing 12 wastewater treatment plants regarding micro plastic particles in its discharge. In this study, the Alfred-Wegener-Institute of scientific marine and polar research (Kiel, Germany) found out that only an expensive final filtration step needing special filters could prevent micro plastic from being discharged. As this filtration step is only present in very few treatment plants, a considerable amount of micro plastic could be detected in most treatment plants. The results of this study were published in October 2014 in different German newspapers and science journals.

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1

Overview on the module

Overview on the module

Short description

The module “Oceanography and Climate Change” highlights the influence of mankind on the oceans. Covering more than 70% of the globe, oceans have a significant impact on the climate on earth. Due to their immense size, oceans are relatively inert systems, but being confronted with immense intakes from various domains (CO₂, plastics, pollutants,...), we have come to a level where conditions change. Illustrating some of these domains and their influence is the core idea of this module.

The submodule “Plastic – Bane of the Oceans” explores the influence of plastics on the ocean such as the different ways of contamination, the behavior of plastics in the ocean (e.g. aggregation in huge garbage patches), the adsorption of pollutants on micro plastic particles, as well as their intrusion in the food chain. The submodule has a global as well as local level and includes experimental and group work.

Framework

CoL members: Christine Bethke, Katja Weber, Katrin Knickmeier, Klaus Ruppertsberg, Lorenz Kampschulte, Ilka Parchmann

Module focused on: 9th grade natural sciences / chemistry course (15+ years); optional using an interdisciplinary approach, e.g. including chemistry, biology, economics/politics and geography

Duration of the module: 13 hours (à 45 min.) + ~ 10 hours for building the exhibition

Starting level: It is required that students have a basic knowledge on the topic of plastics, e.g. structure of plastics, production methods, material properties, use in everyday life.

Learning goals and learning outcomes of the module

Main goal: Students gain basic knowledge on this complex, global problem, to take an active role in socially relevant discussions like „Should the use of micro plastics in cosmetics be prohibited?“. After having worked with this module, students should be able to identify important aspects of responsible research and innovation and to transfer these to other topics.

Learning outcomes (content)

At the end of the module, students will be able to:

- Describe where the millions of tons of plastic waste that are brought into the sea each year originate from.

- Explain what happens to the plastic waste in the oceans.
- Describe the ways in which macro and micro plastic threatens marine life.
- Explain whether human health is endangered by the plastic waste in the oceans.
- Based on their own research make a statement to which extent we are affected locally by the plastic problem in the world's oceans.

Learning outcomes (RRI)

At the end of the module, students will be able to:

- Take responsibility and to reconsider their own options for action and if necessary to change them, based on the knowledge gained in the module. In addition, they should be able to actively participate in socially relevant issues ("Science Education").
- Understand why it is important to involve all relevant stakeholders for research and development processes ("Engagement").
- Give arguments why the public access of research results is important ("Open Access").
- Take part in ethical discussions about the plastic problem in the world's oceans and to develop their own opinion on this subject ("Ethics").
- Recognize the gender imbalance in most research fields and learn what is done in Germany to attract more women to research and innovation ("Gender Equality").
- Recognize the complex role of politics and regulations between promoting research and securing public safety ("Governance").

Learning activities

The use of the 6E model to structure the module:

Engage: The module starts with a PowerPoint slideshow, showing flora and fauna of the ocean in fascinating pictures. Gradually the presentation shifts from great pictures to touching photographs showing the impact of plastic on the ocean and its inhabitants.

Explore: Mystery: "Why is the health of the Larsson family in Greenland possibly in danger because they don't want to give up their traditional diet?" Students get 16 fact cards with different statements. In groups of 4 they analyze the statements and try to create a path to solve the question. This exercise should give an idea of the complex relations playing together in the ocean.

Explain: As a result of the mystery students describe a possible way how the Larsson's family is connected to the global problem of plastic waste in the ocean. This usually induces a lot of new questions to be answered in the "Elaborate" phase.

Elaborate: Pupils deal with further research questions about the local observation of the plastic problem. In this phase pupils perform their own experiments, read scientific publications on the subject and confront extracurricular learning partners with questions. In the second part of

the Elaborate phase the aspects of RRI are discussed in class, looking back and highlighting them in the module performed so far.

Exchange: An exhibition is developed to exchange the gained knowledge with peer students and/or parents.

Evaluate: At this stage the expertise of the students is checked with a test. This includes questions about both the global and the local view of the problem.

Addressing RRI:

When performing the module, different RRI aspects show up, but are not highlighted as such. At the end of the Elaborate phase a reflecting unit is embedded, looking back and collecting all those pieces of RRI:

Engagement: Integration of researchers, society (Larsson family) and politics view into the module.

Gender Equality: Almost all material presented is only featuring male researchers.

Science Education: The module present ocean research as a highly interdisciplinary field of science, including both global and local components. Experiments train scientific views and skills.

Ethics: The discussion on the Larsson's family dilemma is sparked by a more general discussion in a fictive internet forum that continues in class heading over to the role of plasticizers in particular.

Open Access: The role of openly available information is touched at several points. During the reflecting unit it is discussed in the framework of media literacy.

Governance: One of the groups in the Elaborate phase focuses on the given political framework for plastic (waste). In the discussion on plasticizers the problems of regulating not fully understood systems shows up.

Assessment


The achievement of the learning goals is assessed at several points in the module

- Reflection on RRI at the end of the Elaborate phase
- Exhibition outcome
- Written exam at the end
- RRI questionnaire

Planning the course

If this module is used in lower grades (i.e. students have not yet learned some chemical background on plastics), the introductory unit “Plastic in daily life” should be taught in advance of the module. This unit explains the basic structure, properties, and use cases of plastics, which are relevant for understanding the more complex processes in the ocean (duration ~1-2 lessons).

The lesson plan of the actual module “Plastic – Bane of the Oceans” is listed in the following table:



Phase	lesson (45 min)	comment
Engage-Phase	1	Resources: PowerPoint presentation, worksheets
Explore-Phase	3	Resources: Mystery cards, film (“Bane of the Oceans – plastic”, Max Mönch, Friedemann Hottenbacher) RRI criteria which are present in this phase but not yet addressed: Science Education, Gender Equality
Explain-Phase	2	Resources: worksheets RRI criteria: Science Education
Elaborate-Phase	6	Resources: material for experiments, computers with internet access, overhead projector and transparencies RRI criteria: Science Education, Ethics, Governance, Open Access, Engagemenet (the RRI criteria that were already present in the Explain phase are now addressed)
Exchange-Phase	Preparation of exhibition and building day (ca. 10h)	In the exhibition the RRI aspects are addressed and deepened.
Evaluate-Phase	1	Assessment of the content and RRI knowledge with a written exam.

In addition there is a sum-up guide for pupils as well as for teachers which gives a rough overview of the whole unit.

At the end of each topic area, pupils should write down questions that have remained unanswered or further questions that evolved after the unit. Such questions can be noted on the teachers’ sheet and can be used for the preparation of the next lesson. At the same time, each lesson can be reflected based on the questions formulated by the students. At home, pupils should write down a reflective summary about things that they had learned. The homework could be discussed at the beginning of the following lesson or could be collected for evaluation and / or feedback purposes.

2

Plastic
in daily
life

Plastic in daily life

Professional background

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 viscous 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] There are plastics which are only made up of one sort of monomers. One example for this is polystyrene, which is only made up of styrene monomers. Many other plastics are made up of two different sorts of monomers such as nylon. [4, p.7] Plasticizers are added to many plastics, making the plastics easy to shape and flexible. Without these the plastics are brittle and break easily. [22] A large number of various plasticizers exist on the market. Some of them are considered critical nowadays, as more and more studies noticed negative effects for humans and animals. In the past polychlorinated biphenyls (short: PCB) were used as plasticizers. Because of their harmful effect on the metabolism of organisms, the substance PCB was forbidden worldwide [11]. The plasticizers (additives) are not firmly

connected to the plastic and can therefore be released from the plastic under certain conditions. [5, p.5]

Note: An experiment to produce Nylon fibers can be integrated in this context. In [23] you can find the experiment description. Due to the risk potential of the used chemicals this experiment is only possible in the form of a teacher experiment. Carrying out such an experiment at this point makes sense to give pupils a rough impression, how and what from several of the well-known everyday subjects are made, which will play a big role in the next lessons.

Comments about the lessons

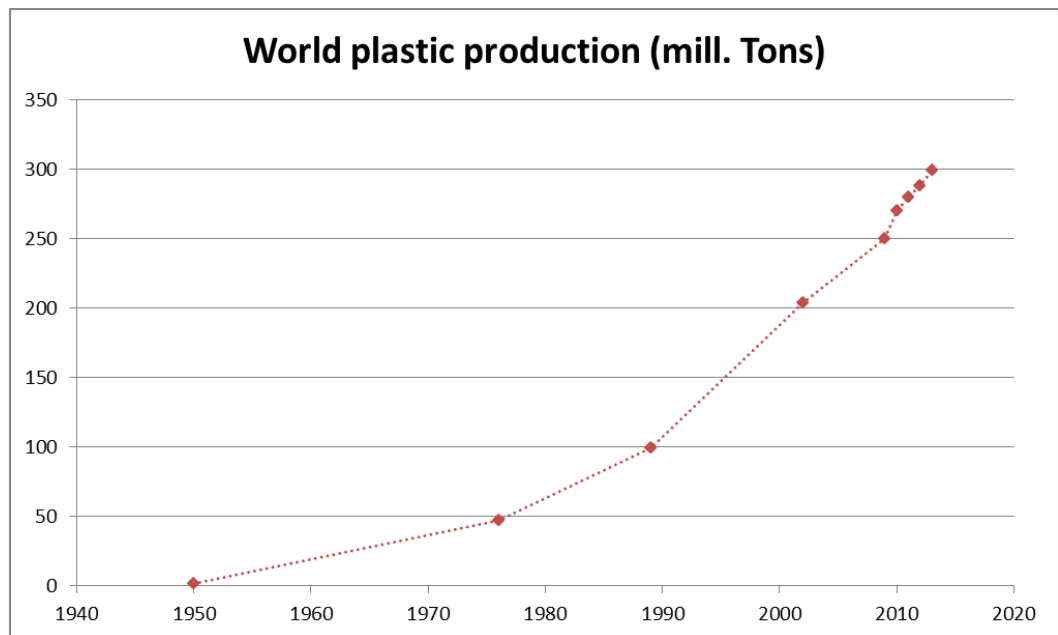
First the pupils work on the worksheets about the topic “Plastic in daily life” on their own and then exchange views on the results with the neighbor. They do not work with structural formula and reaction mechanisms at this point, because this teaching unit was performed in a middle school class (9. grade, 14-15 years old).

Plastic in daily life – working materials

Worksheets for the group work phase (solutions)

Plastic – an ideal material

- 1) Represent graphically how the plastic production has developed in the world since 1950. Use the following data. [6][8]

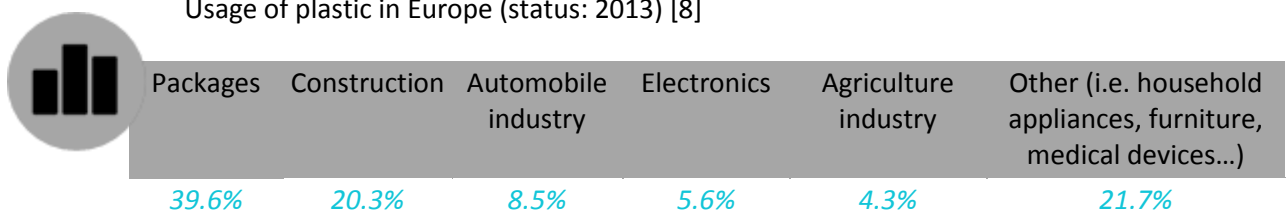


- 2) The production of plastic increases rapidly from year to year and replaces the conventional materials more and more. Reflect which characteristics make plastic such an interesting material for the industry.

Plastics are „light, cheap, stable, thermally and electrically insulating, shapeable, and useable for many purposes [...]“. [7, p.27] But the many positive characteristics also have a downside at the same time: Longevity: Plastics decompose very slowly in the environment. Cost-effective production: A large part of the plastic is only produced for single use. Light: Drifting into distant regions by wind and water. [7, p.28]

- 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) to 6 (little).

Usage of plastic in Europe (status: 2013) [8]



Plastic – what sort of material is it actually?

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

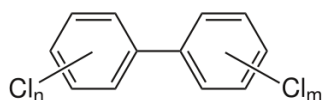
Paper clip model



Description of the structure

Plastics consist of many small molecules (here: paper clip), which are linked together to form long chains. These are called polymers.

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



Structural formula of PCB [21]

Polychlorinated biphenyls (in short: PCB) were used in numerous daily life products until 2001 like in plastics as plasticizers. [11] After that the material was forbidden worldwide, because it was proved in numerous scientific studies that this toxicity is harmful to humans and animals.

Investigations 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. [9, S.5][11] If the PCB concentration in the body is high, chloracne, skin thicknesses, increased pigmentation or respiratory diseases can be the result. [9, p.5] A higher PCB level can also lead to immune and reproductive disorders and to liver dysfunctions. [9, p.5] “A cancer-causing effect was indicated in an animal experiment, but could so far neither be reliably proven in humans nor disproved.” [9, p.5]

3

Plastic
garbage
in the
ocean

Plastic garbage in the ocean

Professional background

More than 6 million tons of plastic garbage per year ends up in the oceans through various sources. [16] There are many sorts of plastic which have different characteristics such as different densities. Plastic types with a higher density than seawater sink into the deep sea. It is assumed that a large part of the plastic garbage in the oceans sinks into the deep sea sooner or later. [2, p.40] If plastic has a lower density than seawater, it floats on water and can be spread worldwide by ocean currents. Finally the plastic garbage in the oceans gathers in specific places of the oceans which are called Garbage Patches. All together there are five of these garbage gatherings in the ocean: in the North and South Atlantic, in the North and South Pacific and in the Indian Ocean. [10]

The macro plastic parts drifting in the ocean such as plastic bottles change by influence of certain environment factors. For example UV light makes the plastic brittle. [3, p.22] The plastic gets even more brittle by releasing the softeners. Mechanical forces such as breaking of the waves make the brittle macro plastic fall into very small macro plastic parts. If these plastic particles reach a size of less than 5mm, they are called secondary micro plastics. [3, p.23] Apart from the micro plastic that developed by process of disintegration, you can also find

primary micro plastic, that means, micro plastic that is added to cosmetic products, for example in order to achieve a peeling effect. [3, p.23] By using the products the micro plastic ends up in the treatment plants along with waste water and can be only partial removed from the water. The clarified water is led into the oceans by rivers. Another source for micro plastic is pieces of clothing made of synthetic fibers. These set micro fibers free during the washing process, which can end up in the oceans the same way as micro plastic from cosmetic products. "It is estimated that 900 million micro plastic particles per year end up in the North Sea through, for example the treatment plant in Wilhelmshaven (Liebezeit 2012)." [3, p.23]

There are a great number of pollutants in the ocean such as PCB. PCB was added to many daily life products, also to plastics as softener. [11] Now if these macro plastic parts end up in the ocean, the softeners are released from the plastic because as an additive, they are not firmly bound to the molecular structure. Because of the numerous negative impacts of PCB on humans and animals the application of this substance was forbidden worldwide in 2001. [11] Nevertheless, this persistent toxin can still be found in the environment today. Because of their hydrophobic properties, some existing pollutants in the ocean like PCB are attracted by micro plastic particles which are also hydrophobic. [7, p.31] As the micro plastic particles have a very large surface compared to their volume, they enrich a great number of pollutants and therefore become dangerous poison transporters and a risk for animals and humans. Living beings

ingest the micro plastic particles which are enriched with pollutants. In the gastrointestinal tract of the living beings the pollutants can be released from the surface and enrich in the fat tissue of the living beings due to their hydrophobic properties. [3, p.24] Living beings at the top of the food chain like seals or whales show a quite high pollutant concentration. [12] This also explains the fact that traditional living Inuits show a high PCB concentration in their body, because they eat a lot of seal and whale meat. It is amazing that despite a high PCB concentration, the scientists could not find any diseases in the test persons that could be associated with the pollutant PCB. [13] This runs counter to the scientific knowledge, because it could be shown in numerous studies that PCB harms human health in a number of ways. [9] Scientists assume that Inuits ingest a substance at the same time as the seal meat, which removes the negative effects of PCB. [13] But this is only a presumption and must still be scientifically tested.

Engage phase

The Engage phase provides the introduction into the topic “Plastic in the Oceans” and offers a first pictured overview. It should spark pupil’s interest and motivation and stimulate to raise questions. The implementation is realized with a 5-minute PowerPoint presentation.



Duration: 1 school lesson (45 min.)



Required material: PowerPoint presentation

PowerPoint presentation (slide show)

This initially shows the intact habitat of marine animals which is increasingly polluted with plastic garbage. The presentation ends with different dead animals and the question whether humans are also threatened by plastic garbage in the oceans. The pupils formulate questions on the images. During the teaching unit all questions shall be answered. If questions remain unanswered, scientists will be contacted.

Comments on the process of the lesson

The teacher shows the presentation once without saying anything (silent impulse) and gives the following work task to the pupils before playing the second time:

- a) Watch the PowerPoint presentation and note all questions which arise while the images are shown.
- b) Interact with your neighbor about the questions. Create overarching categories, which you can assign your questions to.

In order to consider the previous knowledge of the pupils the questions are picked up in the class discussion.

First experiences from teaching practice

The pupils were very interested in the topic. Among other things, that is because some pupils have already seen polluted beaches and waters on holiday. Therefore they developed a large number of different questions based on the presentation such as:

- *How heavily is the Baltic Sea polluted with plastic?*
- *How many animal types are threatened by the garbage?*
- *In which region is it extremely bad?*
- *How much plastic is produced every day?*
- *How does so much garbage end up in the oceans?*
- *What are those small plastic beads? Where are they enclosed?*
- *Does the plastic in the ocean also harm humans?*
- *Do organizations exist which remove the garbage? ...*

Due to the enormous media presence the pupils bring previous knowledge about the topic with them; but they notice that this is not enough in order to answer the questions of the classmates. By reaching the students limits actively with topics they are interested in, their motivation to increase their knowledge is getting stronger.

Explore-phase

In this phase the pupils receive the necessary basic knowledge on the complex dimension of the plastic problem in the world's oceans by solving the Mystery⁴ "Is the health of family Larsson on Greenland threatened, because people dispose plastic garbage into the oceans since decades?" in group work. The know-how acquired during the first phase is consolidated by the film "Bane of the Oceans – Plastic" and increased by new aspects. Additionally the pupils can observe that the scientists shown in the film are nearly all male, so that the RRI dimension "Gender Equality" can be dealt with at this point. As scientists from all over the world are shown, the global aspect of the problem becomes clear.



Duration: 3 school lessons (45 minutes each)



Required material: Mystery, film (*Bane of the Oceans – Plastic*, Max Mönch, Friedemann Hottenbacher)

Mystery method



- 1) The Mystery question "Is the health of family Larsson on Greenland threatened, because people dispose plastic garbage into the oceans since decades?" is presented on the board. The pupils express presumptions about the connection between plastic garbage in the ocean and the health of family Larsson on Greenland.
- 2) After that groups of three are formed. Each group receives an envelope with the Mystery cards and the work tasks.
- 3) Each pupil receives 5 text cards, works out the contents due to these and presents them to the group members in a short presentation.
- 4) The pupils decide together which cards are useful and important for solving the Mystery.
- 5) Based on the contents of the cards the pupils create a flow chart which gives an overview about all processes in the oceans. In case the pupils do not know what a flow chart is, this must briefly be explained on the board.
- 6) The pupils view the Mysteries of the other groups (window shopping) and complete missing information with a pencil.
- 7) One group finally presents the completed solutions.

⁴ Idea for die Mystery Method by Jochen Kempe and Carsten Bornemann



Film (Bane of the Oceans - Plastic)

Before the film is shown the pupils receive the following observation tasks:

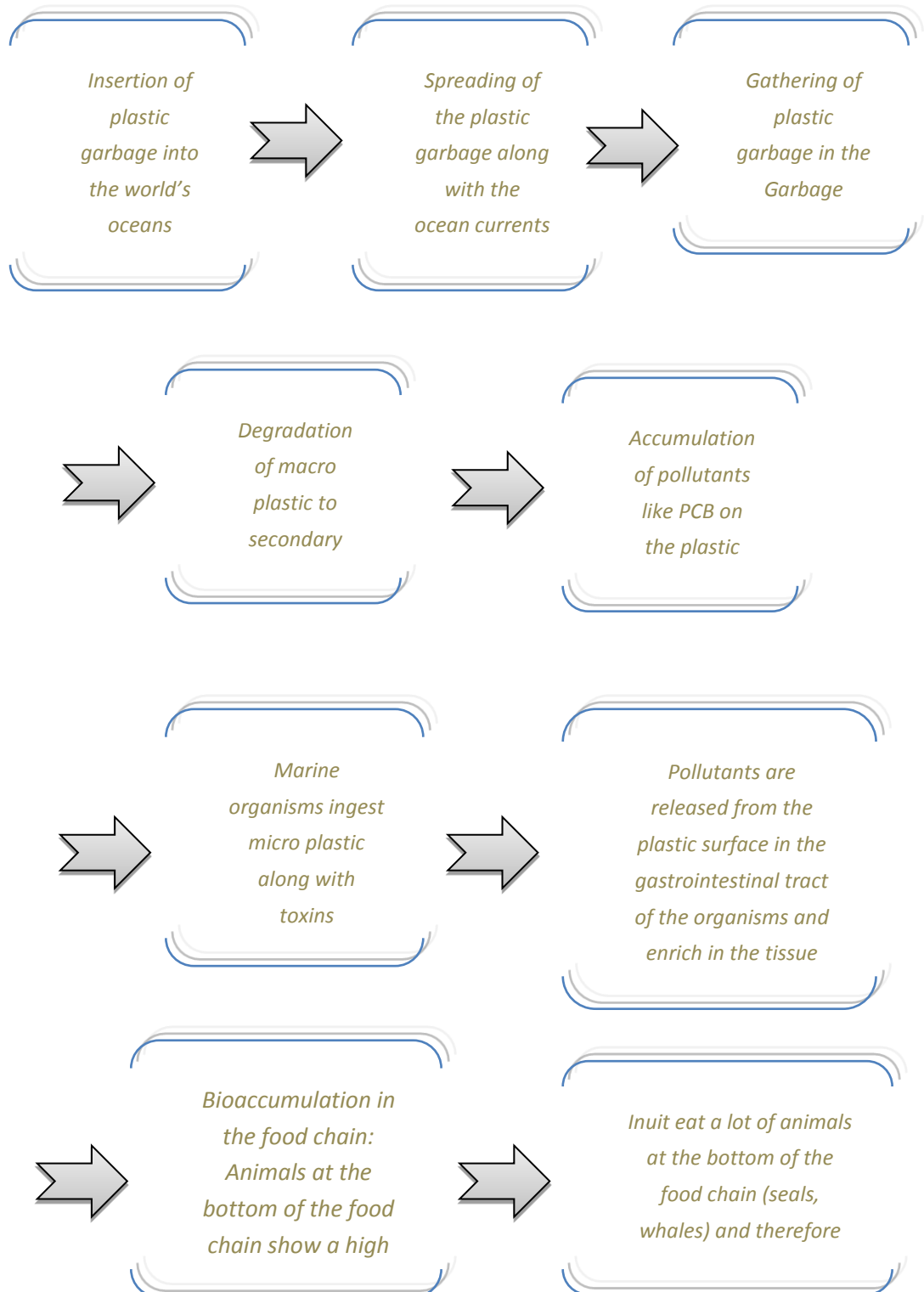
- 1) Produce a table in which you list how many male and female scientists are shown. (The meaning of this task should be briefly discussed).
- 2) Note at least two further aspects about the plastic problem in the world's oceans which you consider to be interesting.

First experiences from the teaching practice

Most of the pupils do not yet know about the Mystery method, because this method is quite new in scientific lessons. The motivation to deal with the complex problem by this method was very high in all groups. The task is quite demanding because the pupils must initially sort out unimportant information cards and then work out the central contents from the remaining. It was shown that the mutual survey of the Mysteries is meaningful, because the pupils complete missing connections and can therefore achieve a widespread and extensive image on this topic. It was important to the pupils to watch the film after the Mystery, because thereby some aspects were further consolidated, like the accumulation of toxins on micro plastic and the inclusion in the food chain. As the film is quite long it is recommended not to show all film contents. The teachers should choose the suitable episodes beforehand.

Mystery solution

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



Conclusion: The health of family Larsson does not seem to be threatened despite a high PCB concentration. (See professional background). [13]

Explain phase

In this phase in order to secure the know-how of the Explore phase the pupils solve the tasks about the plastic problem in the world's oceans after the film with the help of worksheets.



Duration: 2 school lessons (45 minutes each)



Required material: worksheets

Group work: macro / micro plastic – security of the professional contents

- 1) The pupils form groups of four and receive the worksheets. First the tasks are solved alone, then initially with the partner and then they are discussed with the group (Think-Pair-Share method).
- 2) Each group receives a concrete task during the processing phase for which they are responsible during the presentation at the end of the processing.

First experiences from the teaching practice

The group work at the end is important in order to ensure the contents of the Mystery and of the film. Attention should be paid to the strict compliance of the Think-Pair-Share method, so that all pupils are motivated to think.

Solution on the worksheets

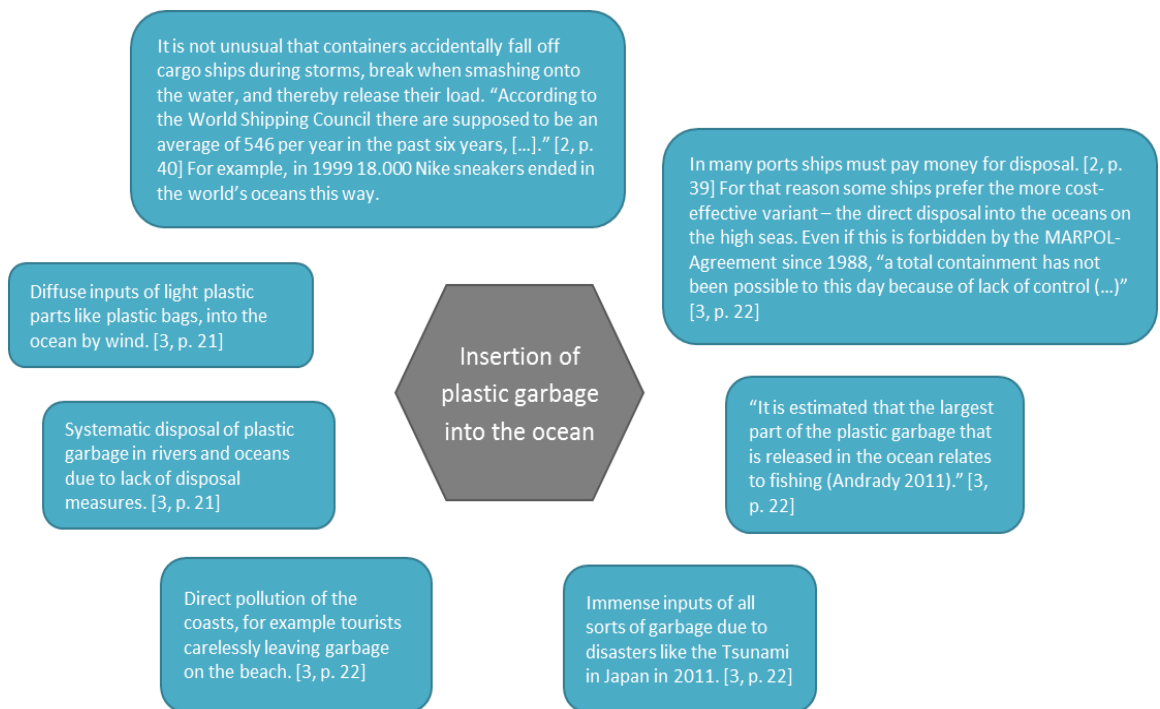
Macro as well as micro plastic exists in the ocean. Find a suitable definition for these two terms:

All plastic parts that are larger than 5 mm are called macro plastic. All smaller parts are called micro plastic. [3, p.23]

How does plastic garbage end up in the ocean?

Create a chart showing where the million tons of plastic that exist in the world's oceans come from. [3, p.21/22][2, p.40]

It is estimated that 80% of the plastic garbage in the ocean ends up in the oceans by land-based sources and only 20% of the plastic garbage is directly discharged at sea. [3, p.21]



What happens to the plastic garbage in the ocean?

Plastic garbage with a lower density than the seawater can be spread worldwide by the flow systems. [3, 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 in seawater. The density of seawater is about 1.025 g/cm^3 , at 25°C . [14]



Plastic	Density in g/cm^3	Performance in seawater
PC	1.20	<i>sinks into the deep seas</i>
PE	0.95	<i>swims</i>
PP	0.91	<i>swims</i>
PVC	1.36	<i>sinks into the deep seas</i>

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

Garbage Patches are garbage gatherings in the ocean which developed in the centers of the large ring streams. You should not imagine these Garbage Patches as a consistent "garbage carpet", but rather as a "garbage soup" consisting of macro and micro plastic particles. [3, p.22]

- 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. [15, blue circles added]



The garbage in the ocean will be degraded – it is only a question of time [1]



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. Paper towels		2-4 weeks
2. Newspapers		6 weeks
3. Plywood		1-3 years
4. Plastic bags		1-20 years
5. Aluminium cans		200 years
6. Fishing lines		600 years

Note: This context can be visualized very nice and impressive on a big poster (see p.33). This can be put up in the class room and later on become a part of the exhibition.

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.

If macro plastic parts (i.e. plastic bottles or plastic bags) end up in the oceans, the softeners are released from the plastic because as additives they are not firmly bound to the plastic. Due to that and because of the impact of UV light, the plastics become brittle and break easily. [3, p.22]

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

During transport by the ocean currents this brittle macro plastic is split into more and more small macro plastic particles and finally into micro plastic particles by the mechanical forces of the waves and rubbing on other flotsam. [3, p.23]

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

Apart from micro plastic (=secondary micro plastic) which has developed by degradation processes, also primary micro plastic, therefore micro plastic that is added, for example, to cosmetic products in order to achieve a peeling effect, is found. [3, p.23] By using the products the micro plastic ends up in the treatment plants along with waste water and cannot be totally removed from the water. The clarified water is led into the oceans through rivers. The central difference is that primary micro plastic is purposely synthesized in such a small size, while secondary micro plastic develops as a result to the fragmentation processes (=degradation processes).

Impacts of macro and micro plastic on marine living beings

Name at least three risks for the marine organisms which come from the macro plastic in the oceans: [3, p.23-25]

- a) *Pseudo saturation: The living beings starve despite of a full stomach*
- b) *Constipation of the gastrointestinal tract*
- c) *Entangling in i.e. "ghost nets": The living beings suffocate under water*

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:

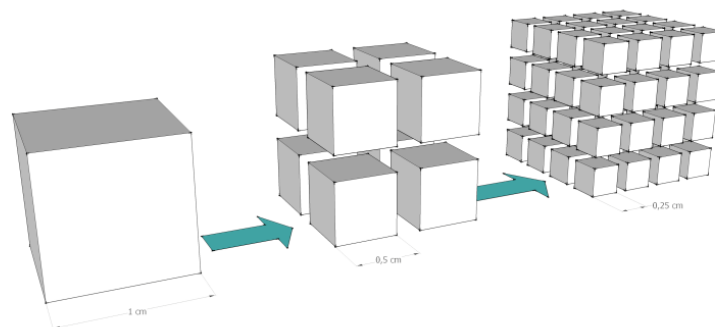


The hydrophobic micro plastic particles attract hydrophobic pollutants which are accumulated on the surface. These are ingested by living beings along with the natural food. The hydrophobic pollutants are released from the plastic surface in the gastrointestinal tract and enrich in the living beings, where they can possibly develop their toxic effect. [3, p.23-24]

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

Both materials are hydrophobic.

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.



If a macro plastic product is shredded into numerous micro plastic particles the whole surface of the micro plastic particles is significantly larger than that of the macro plastic particle. This can be seen in the image: The large cube (=macro plastic) has a total surface of 6 cm^2 (with an edge length of 1 cm). If this cube is shredded into eight small cubes (=micro plastic) the total surface is already 12 cm^2 (with an edge length of 0.5 cm). If these are shredded again (=very small micro plastic) the total surface of the 64 cubes is already 24 cm^2 . That way more pollutants can be accumulated on the surface in total. In addition, the tiny particles can be ingested by minute organisms and therefore already end up in the basis of the food chain.

Note: The increase of surface area can be introduced to the pupils through a little demonstration. For this, a loaf of bread could be brushed on one side with chocolate cream, marmalade or the like. Then, a second loaf – identical in size – could be cut into slices and each slice could again be brushed on one side with chocolate cream. Based on the brushed area, pupils can better see and understand the increase of surface area of micro plastic as compared to macro plastic. This demonstration can be used for introductory purposes as well as for explaining and retaining purposes.

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

Seals are at the bottom of the food chain. Pollutants enrich in the food chain, which is called bioaccumulation as a specialist term. [9, p.4] Animals at the bottom of the food chain eat living beings which already show a high pollution concentration in the body themselves. [9, p.4]

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?

As the case of the fictive family Larsson from Greenland shows, humans also ingest the pollutants along with food, because these enrich in the tissue of the living beings. The results for humans are already well researched for PCB, whereby the usage of this chemical was forbidden worldwide. But there are many other substances that are threatening the human organism. The scientists are intensively investigating on researching the results for humans relating to new pollutants such as bisphenol A.

Elaborate phase

The pupils have learned about the complex dimension of the global problem through the Mystery and the following film. In the following lessons the plastic problem is viewed locally. Thereby the pupils work in groups on different aspects of the topic “Micro plastic in cosmetic products” The topics are presented by a transparency. For this first part four lessons are planned in total. At the end of the Elaborate phase the module is reflected referring to the RRI criteria. This part of the Elaborate phase includes two lessons.



Duration: 6 lessons (45 minutes each)



Required material: Experiment materials, laptop with internet access

Part 1: Group work (local view of the plastic problem)



- 1) The pupils choose the topic according to personal interest. There should always be four persons per group.
- 2) The pupils have 3 lessons for working out the tasks and preparing a 5-minute presentation.
- 3) The pupils present their results in the fourth lesson. The individual groups prepare three questions for each lecture which are answered by each pupil after the lecture, and discussed in the plenum afterwards. This is the handout for the lecture.



Group	Topic
1	Product testing: In which cosmetic products does micro plastic exist?
2	Micro plastic in cosmetic products: What does policy do?
3	Micro plastic in waste water: Too small for the filter systems of the Kiel-based treatment plant?
4	Summer, sun, beach and plastic: How heavily is the sand on Kiel-based beaches polluted by micro plastic?
5	Summer, sun, beach and plastic: How heavily is the water on Kiel-based fjords polluted by micro plastic?
6	Micro plastic – risk for local marine organisms?

Note: A local drugstore (Rossmann) and an application to the Federal Government were chosen for the local view of the problem. Relevant sources for the local view of the problem in other countries were supposed to be found.

The scientific workouts are in German, as these refer to the local waters (North and Baltic Sea). In order to see which contents from the scientific workouts were relevant for our pupils, you will find a short summary of the contents in the following.

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

Isolation of micro plastic from cosmetic articles [17]

Microscopic objects are not visible to the „naked eye“, only with a microscope, a binocular or a magnifier. Therefore a polyethylene bead, sized 50 μm , which is caught by a coffee filter, is micro plastic while visible polyacrylic fluffs are macro plastic.

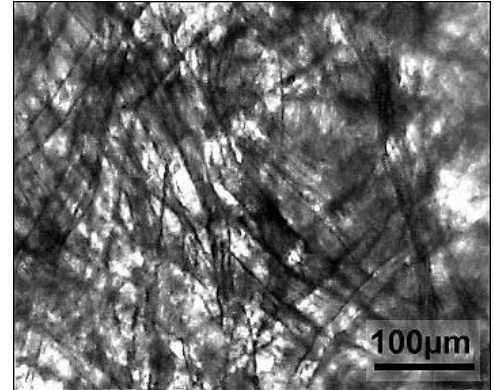
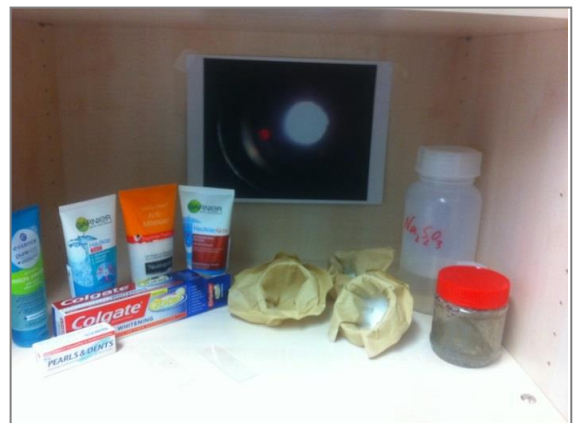
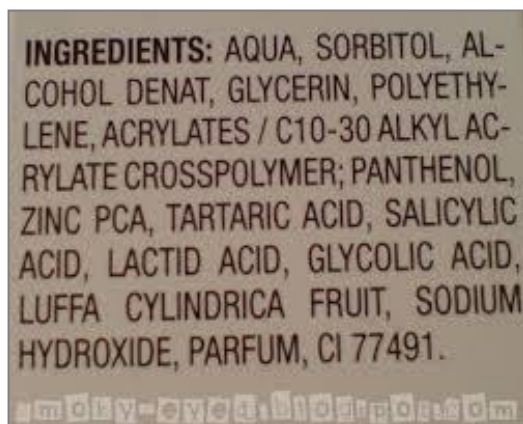


Photo: from: <http://de.wikipedia.org/wiki/Filter> of 24.11.2014

When investigating if products contain micro plastic, for the pupils experiment at least to products (peeling, toothpaste, shower gel, ...) should be selected, one containing micro plastic, the other not.

To carry out, a pea-sized portion of the explorative product should be mixed with 50 ml water and subsequently be filtered with a tea filter⁵ (pore size: 10-60 μm). At the same time it should be explored, if there are references to plastic ingredients (e.g. Polyethylene) in the description on the packaging. Afterwards the analysis of the label should be matched with the outcome of the experiment.



Photos: Klaus Ruppertsberg

If the product contains micro plastic, a sandy film will remain in the filter. These are the micro plastic particles, which can't diffuse through the pores of the tea filter. If there isn't any micro plastic in the product, the solution should pass thru the filter without any residue.

⁵ A coffee filter can be used alternatively.

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

Application: Stop the release of micro plastic (printed matter 18/3734)

Short summary of the article; the complete article can be found in the notes. [18]

The parliamentarians Peter Meiwald, Nicole Maisch, Dr. Valerie Wilms, Annalena Baerbock, Bärbel Höhn, Sylvia Kotting-Uhl, Oliver Krischer, Christian Kühn (Tübingen), Steffi Lemke, Dr. Julia Verlin den, Harald Ebner, Matthias Gastel, Stephan Kühn (Dresden), Friedrich Ostendorff, Markus Tressel, and the Alliance 90/The Greens parliamentary group, directed their application „Stop the release of micro plastic“ dated 14.01.2015 to the German Bundestag. The German cosmetic industry brings about 500t polyethylene micro plastic to the market per year. Apart from this, micro plastic particles such as polypropylene are also used in the cosmetic industry. The micro plastic particles are used in cosmetic- and personal care products, i.e. in order to achieve a peeling effect. After usage these end up in the treatment plants along with waste water and cannot be completely removed from waste water. The tiny plastic particles end up in the aquatic ecosystems along with the clarified water. Micro plastic does not only exist in clarified water, but also in sewage sludge, which is i.e. used to fertilize agricultural areas. That way the micro plastic also ends up in the environment. Current research results prove that a great risk comes from micro plastic; i.e. living beings die because they mix up micro plastic with their food and therefore have no feeling of hunger. Even though these risks are known, there are still many products on the market that contain micro plastic. Discussions by the Federal Government with the concerned branches have only brought few improvements up to now. Campaigns of different none-governmental organizations have convinced some producers to do without adding micro plastic. Nevertheless, many products still contain micro plastic particles. The impacts on human health are very little researched up to now. The German Bundestag prompts the Federal Government that the disposal of micro plastic particles from cosmetic products should be secured and a release into the environment should be totally prevented. In addition, the Federal Government should actively support the withdrawal of using micro plastic particles in cosmetics and cleaning agents, and inform public and Bundestag about the current status of negotiations with the economy on a regular basis. As a final point the parliamentarians of the Greens require that the Federal Government intensifies research activities around the micro plastic problem, in order to receive more data about how much micro plastic is contained in the environment and which impacts micro plastic has on the environment and human health. The area of sewage technology research must also be intensified.

[Article has been shortened]

Source: <http://dipbt.bundestag.de/doc/btd/18/037/1803734.pdf> (Call-up: 05.06.2015)

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

Conventional treatment plants are not able to fully remove micro plastic particles from waste water. However, with special filter systems it is technically possible but expensive. So to our understanding today not many treatment plants are equipped with these special filter systems. A short article summarizing the study performed by the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research in 12 treatment plants in Northern Germany can be found in [19].

Group 4/5: Summer, sun, beach, and plastic: How heavily is the sand on Kiel-based beaches polluted by micro plastic?

Gerd Liebezeit: Macro- and micro garbage in the Lower Saxony Wadden Sea [20]

Short summary of the article; the complete article can be found in the notes.

Investigations in the Lower Saxony Wadden Sea have shown that it is polluted by macro- as well as micro plastic. The latter could be found on beaches as well as in the water, and in sediment samples. The macro garbage was counted and documented in the investigation area for four years. Only garbage pieces that were larger than 20 cm were recorded in the counts.

1) Investigation of beach- and sediment samples for micro plastic

The scientists proceeded as follows in order to check whether the beach- and sediment samples contained micro plastic:

- a) Drying of the samples followed by slurry in a zinc chloride solution (density 1,52 g/cm³)
- b) As plastic has a lower density than sand, the plastic particles in the zinc chloride solution swam on the surface.
- c) Separation of the plastic-sand-mixture with a 0.2 µm sized polycarbonate filter
- d) The filter residue was rinsed with distilled water and dried at room temperature.

2) Investigation of water samples for micro plastic

The scientists proceeded as follows in order to check if the water samples contained micro plastic:

- a) Water sampling scooped by hand
- b) Filtering of 100 ml samples in 0.2 µm sized polycarbonate- or 0.45 µm sized cellulose nitrate filters
- c) The filter residue was rinsed with distilled water
- d) Investigation of the filtered material with a binocular

[Article has been shortened]

Source: Liebezeit, Gerd: Macro- and micro garbage in the Lower Saxony Wadden Sea, IN: WATER und GARBAGE 6/2011, p.41

Instruction manual: Isolation of micro plastic from sediment samples [17]

Give some dry sand into a saturated sucrose solution. Due to the high density (approx. 1.3 g/ml), heavier plastic pieces now refloat. Pipette them off and put them on a slide without a cover glass. Microscopically examine with the red objective (lowest magnification). You will find micro plastic in some sand samples straight at the first try:

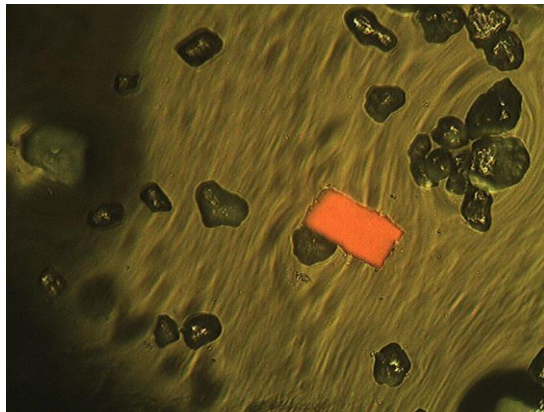


Photo: Klaus Ruppertsberg

Note: If the school isn't situated close to marine water, samples can also be taken from a river or a big lake. It is rather easy to find micro plastic in such bodies of water that run through waste water treatment plants as most of those plants, at least in Germany, don't have superfine filters for absorbing micro plastic particles yet.

Note: If it is not possible to take a sample from a local body of water, the following experiment can be conducted: Wash a garment of fleece by hand in clear water. Through this, superfine fibers come off the fabric which is classified as micro plastic too. Filter the wash water with a coffee or tea filter and analyze the residue using a binocular. Discuss the daily use of fleece textiles with regard to the wastewater treatment plants' limited possibilities of filtration and the resulting influence on waters and the ocean. This experiment can also be used to complement the investigation of marine samples.

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

Patricia Holm, Gerhard Schulz, Kiriaki Athanasopulu: Micro plastic – an invisible troublemaker [7]

Short summary of the article; the complete article can be found in the notes. [7, p. 31]

Among other things the impacts of micro plastic on the aquatic living beings are described in the article. It is known that numerous marine living beings such as plankton-eating animals, turtles, or marine mammals, ingest micro plastic and thereby can be harmed in different ways. For example, if the micro plastic has sharp edges, the sensitive mucus membranes of the gastrointestinal tract can be harmed. The living beings cannot digest the ingested micro plastic so that this enriches in the gastrointestinal tract. As a result, the animals can starve despite of a full stomach, because they are no longer able to ingest enough food. A further risk comes from the toxins, which are accumulated on the surface of micro plastic. These detach in the gastrointestinal tract of the living beings and are ingested in the tissue where they can unfold their toxic impact.

[Article has been shortened]

Source: Holm, Patricia, Schulz, Gerhard, Athanasopulu, Kiriaki: Micro plastic – an invisible troublemaker. IN: Focus on micro plastic, DOI: 10.1002/ biuz.201310497, p. 31.



Part 2: Reflection of the module according to the RRI criteria

A central requirement for the module is to integrate the six RRI criteria: Engagement, Gender Equality, Science Education, Ethics, Open Access, Governance into the module. In the fifth and sixth lesson of the Elaborate phase the RRI criteria are dealt with in shared dialogue.







Duration: 2 lessons (45 min each)

Comments on the process of the lessons



- 1 Shall micro plastic in cosmetic products be forbidden?
The question is viewed from different perspectives (policy group „**Engagement**“ (Greens) / researcher / industry / citizens). For this, the pupils are assigned to different roles and shall discuss from their perspective.
All pupils need the necessary basic knowledge about the plastic „**Science Education**“ problem in the world’s oceans, in order to argue professionally grounded. The pupils get this in the Explain and Elaborate phase.
- 2 Shall micro plastic in cosmetic products be forbidden?
This question was also discussed in a fictive internet forum. An ethical „**Ethics**“ discussion about this topic should follow the contributions of the three girls.
- 3 There is no need to use micro plastic in cosmetic products, because „**Governance**“ alternative materials exist which also achieve a peeling effect. For this reason the Greens direct their application “Stop the release of micro plastic” dated 14.01.2015 to the German Bundestag. The German Bundestag prompts the Federal Government in the letter, among other things, to actively support the withdrawal from the usage of micro plastic in cosmetics and cleaning agents. From this example it can be understood which position policy has and if such requests can actually be realized.
- 4 The pupils have already learned about further RRI criteria in the teaching unit without knowing this. These are now named and discussed:
One school group was not able to get a paper from the internet „**Open Access**“ without paying for it. This offers the basis to discuss the Open Access of research results.
The pupils name their observations from the film (how many male, „**Gender Equality**“ and how many female scientists). Why is the relation so different? This question is discussed together.

Ethical discussion

	<p>Frieda (16) 8h ago</p> <p>...I find it unacceptable that micro plastic is used in cosmetic products. There is a whole number of alternative peeling materials, though they are significantly more expensive. Up to now it has hardly been researched which impacts micro plastic has on living beings, and still we pollute the oceans on and on with these tiny plastic particles...unbelievable!!...</p>
	<p>Anna (17) 8h 2min. ago</p> <p>...I use peeling products every day to clean my skin. But the problematic is not the cosmetic products themselves, but rather the treatment plants which cannot filter micro plastic. So it is not my fault. I will continue buying these products, because my skin feels much better since I use the products...</p>
	<p>Frieda (16) 8h 4min. ago</p> <p>...You can also get peeling products without micro plastic! Then you have the same effect for your skin and do something good for the environment...</p>
	<p>Lisa (17) 9h 1min. ago</p> <p>...These products are significantly more expensive. I don't have that much money. Also, micro plastic can't be dangerous for animals, because it is also unproblematic for us...</p>

Exchange phase

In order to sensitize other pupils as well as parents and teachers to the topic “Plastic problem in the world’s Oceans”, the pupils create an exhibition about this topic. The preparation of such an exhibition is time-consuming and extensive but very worthwhile. When developing the exhibition, the individual groups work even more intensive with the acquired know-how. By this detailed engagement with the content and due to the exchange of information during the preparation, the learned knowledge will be tightened. Due to conversations with other people, new perceptions will be established and interdisciplinary connections will be drawn. The limited space an exhibition offers forces pupils to reduce their content they want to present to short, very clear statements. Furthermore when preparing the exhibitions, the pupils will thoroughly reanalyze their facts researched and arguments made in a self-critical way, since they don’t want to risk mistakes in a public presentation. “Plastic in the Oceans” is a very important topic, to which every human contributes. The more detailed and extensive the pupils are confronted with the content, and the more efficient they deal with it, the higher is the probability, that they will identify themselves with the fundamental ideas and thus in future contribute to a solution of the problem.

Indeed the teachers work not only with the scientific expertise but also with the social and ethical development of their pupils, which can mainly be stimulated with individual experience. During the preparation of such an exhibition the pupils will be confronted with things that are essential in everyday life and today’s society. The exhibition needs a detailed and efficient work planning: the setup has to be fast, simple and inexpensive. The content presented has to be accessible and understandable for all visitors. Besides a well distinct problem-solving expertise, this calls for high creativity and openness needed to optimize and perfect the presentation. For the group work, skills like convincing argumentation, the ability to assert oneself, and the willingness to compromise are needed. Due to the large dimension of the project, pupils are dependent on each other. Therefore they practice their communication and cooperation expertise as well as their skills in team working and management, their flexibility, frustration tolerance, stress resistance and endurance. Since the pupils develop the exhibition mainly on their own, they have a high degree of personal responsibility.

Last but not least, such an exhibition presents the school in society. The more important the addressed theme and the more informative, far-reaching and impressive the exhibition, the more positive is the image of the school in public.

You can find more detailed information about the planning and structure of the exhibition at the following internet address:

<http://www.exponeer.de/index.php/de/>

Evaluate phase

In this phase the know-how of the pupils is checked by a test. This includes questions about the global as well as about the local view of the problem.

Such a test should lead pupils to once more engage with the topic of the teaching unit in an efficient and extensive way, thus securing the knowledge gained. At the same time it proves if the pupils have actually learned the intended content, or if several pupils have withdrawn from the group work and the elaboration and development of the exhibition and thereby didn't get important learning contents. Furthermore such a test is a great tool for reflection: on pupil's side with focus on the adsorption, understanding und utilization of the content learned; on the teacher's side with the question if the content was presented in an didactically useful and for the pupils understandable way.



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Continuative materials for the topic you can find on following sources:

World Ocean Review – Live with the sea: This four-volume publication shows different marine processes – amongst others fishing and marine raw materials –, describes its changes and considers human influence on it. (accessed: 11.05.2016)

<http://worldoceanreview.com/wor-1/>

<http://worldoceanreview.com/wor-2/>

<http://worldoceanreview.com/wor-3-uebersicht/>

<http://worldoceanreview.com/wor-4-uebersicht/>

The textbook “Abenteuer Weltmeere” looks at the ocean, its living environment and its role for the climate change from different perspectives and takes pupils to an exciting and all-round expedition.

Krastel, S. et al. (2011): Abenteuer Weltmeere. 1. Auflage, 1. Druck. Berlin: Cornelsen Verlag.

The topic “plastic in the ocean” is integrated in a bigger context and is analyzed with regard to changes of sediment due to the pollution of the environment.

<http://www.bbc.com/news/science-environment-35259194> (call: 11.05.2016).

In different inland waters micro plastic particles can be found too, as is shown by the study “micro plastic in the discharge of wastewater treatment plants”. This topic is dealt with in several articles of different newspapers. (accessed: 11.05.2016)

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Abschlussbericht: Mikroplastik in ausgewählten Kläranlagen des Oldenburgisch-Ostfriesischen Wasserverbandes in Niedersachsen – Probenanalyse mittels Mikro-FTIR Spektroskopie. (2014): http://www.dwa-bayern.de/tl_files/_media/content/PDFs/LV_Bayern/Abschlussbericht_Mikroplastik_in_Klaeranlagen-3.pdf.

Special Issue Life and the sea – teaching biology regarding the topic “plastic in the ocean”:

Schöps, K., Hansen, S. & Knickmeier, K. (2013): Der Plastik Ozean. Unterricht Biologie - Leben & Meer, Heft 384.

Bachelor Thesis on the concept of exhibition regarding the topic “plastic waste in the sea”:

Thielisch, Anna (2013): „Plastikmüll im Meer – Eine didaktische Inszenierung für die Kieler Forschungswerkstatt, Bachelorarbeit im Zweifach-Bachelor-Studiengang, Fach Geografie des Geografischen Instituts der CAU.

5

Appendix

Appendix

Teaching Unit „Plastic – Bane of the Oceans“

Survey for Teachers

This shall be a short sum-up guide of the teaching unit “Plastic – Bane of the Oceans” for teachers. For each area, you can write down questions that have remained unanswered or further questions that evolved after the Unit. These notes can be used for the preparation of the next lesson. As a reminder, the relevant materials are also listed.

□ Plastic in Daily Life

Relevant materials: worksheets

Questions that have remained unanswered:

Further questions after the unit:

Plastic Garbage in the Ocean

□ Engage-Phase: Summary of the impact of plastic in the marine system

Relevant materials: PowerPoint presentation (Slideshow)
worksheets

Questions that have remained unanswered:

Further questions after the unit:

□ Explore-Phase: Decomposition of plastic

Relevant materials: envelope with cards and the exercise for the method Mystery
worksheets
film „Bane of the Oceans – Plastic“ (M. Mönch, F. Hottenbacher)

Questions that have remained unanswered:

Further questions after the unit:

□ Explain-Phase: Properties of micro plastic, entry into and danger to the environment / ocean

Relevant materials: worksheets

Questions that have remained unanswered:

Further questions after the unit:

□ Elaborate-Phase: Group work – Dispersion of micro plastic

Relevant materials: experimental set for experiment 1

experimental set for experiment 2

text „Micro plastic in cosmetics: What is doing the politics?“

text „Micro plastic in wastewater treatment plant: Too small for the filter system of the wastewater treatment plants of Kiel?“ (source 19)

text „Micro plastic – Danger for marine animals?“

laptop with WLAN

Questions that have remained unanswered:

Further questions after the unit:

□ **RRI-Aspects**

Questions that have remained unanswered:

Further questions after the unit:

□ **Exchange: Building the exhibition**

Relevant materials: materials for the exhibition

Questions that have remained unanswered:

Further questions after the unit:

☐ **Evaluate: Examination of own achievement**

Needed materials: test

Questions that have remained unanswered:

Further questions after the unit:

Teaching Unit „Plastic – Bane of the Oceans“

Survey for Students

☐ Plastic in Daily Life

Reflective summary:

Questions that have remained unanswered:

Further questions after the unit:

Plastic Garbage in the Oceans

□ Engage-Phase: Summary of the impact of plastic in the marine system

Reflective summary:

Questions that have remained unanswered:

Further questions after the Unit:

□ **Explore-Phase: Decomposition of plastic**

Reflective summary:

Questions that have remained unanswered:

Further questions after the Unit:

☐ **Explain-Phase: Properties of micro plastic, entry into and danger to the environment / ocean**

Reflective summary:

Questions that have remained unanswered:

Further questions after the Unit:

□ **Elaborate-Phase: Group work – Dispersion of micro plastic**

Reflective summary:

Questions that have remained unanswered:

Further questions after the Unit:

□ RRI-Aspects

Reflective summary:

Questions that have remained unanswered:

Further questions after the Unit:

□ **Exchange: Building the exhibition**

Reflective summary:

Questions that have remained unanswered:

Further questions after the unit:

☐ **Evaluate: Examination of own achievement**

Questions that have remained unanswered:

Further questions after the Unit:

Instruction

Teaching method: Mystery

Preparation: For carrying out the teaching method “Mystery”, the students should work in groups of 3 or 4. For each group, an envelope with the task and the Mystery cards should be prepared.⁶

1. The Mystery question (*here: “Is the health of the Larsson family living on Greenland threatened because people dispose plastic garbage into the oceans since decades?”*) is presented on the board. The students make assumptions (*here: regarding the correlation between plastic garbage in the ocean and the health of family Larsson on Greenland*).
2. The class is divided in groups of 3 or 4. Each group receives an envelope with the task and the Mystery cards.
3. The Mystery cards are to be split up among the students of the group (*here: 4-6 cards per student*). Each student works out his / her specific contents due to the cards and presents his / her findings to the other group members in a short presentation.
4. The whole group then decides which cards are useful and important for solving the Mystery.
5. Based on the chosen cards, each group creates a flow chart⁷ which provides an overview of all processes in the ocean. It should be visualized with a poster.
6. Through the teaching method “window shopping”, the students look at all the Mysteries of the other groups and add missing information to their own chart with a pencil.
7. One group finally presents the completed solution.

⁶ **Note:** It’s advisable to cut out and to laminate the cards for using them several times.

⁷ **Note:** In case the students do not know what a flow chart is, this must briefly be explained on the board.

Experiment 1: Investigation of Cosmetics regarding Micro plastic ingredients

Materials for the experiment:

2 100-ml-beakers

funnel

filter paper (tea-, coffee- or lab filter)

cosmetic products (*at least one with micro plastic and one without micro plastic*): e.g. peeling cream, toothpaste, shower gel, shampoo etc. (compare at table 1 und figure 1)

50 ml water for each cosmetic product



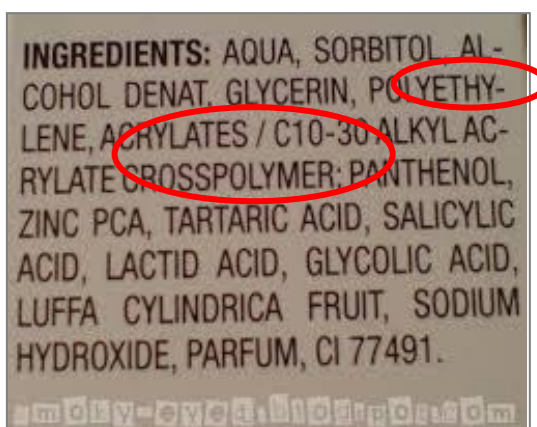
Carrying out the experiment:

1. In a beaker, mix a pea-sized amount of each product with 50 ml of water.
2. Then filter the inhomogeneous solution through a tea- or coffee filter (pore size: 10-60 μm)⁸ and collect the filtrate in a second beaker.
3. Check the label of the package for plastic components (e.g. polyethylene). Afterwards compare the content with the result of the experiment.

⁸ **Note:** Alternatively lab filters with a pore size of 100 μm can be used. They are a bit stronger and give the experiment a professional character. Such filters can be bought in variable length – e.g. at Hydro-Bios (<http://www.hydrobios.de/>) – at the price of about 90 Euro per m^2 .

Table 1: Most frequent plastic in cosmetics ⁹.

plastic	abbreviation
polyethylene	PE
polypropylene	PP
polyethylenterephthalate	PET
nylon-12	nylon-12
nylon-6	nylon-6
polyurethane	PUR
ethylen-vinylacetat-copolymere	EVA
acrylates copolymere	AC
acrylates erosspolymere	ACS
polyquaternium-7	P-7

**Figure 1:** Description of a package of a peeling cream (photo: Ruppertsberg, K.).

⁹ The union of environment and nature protection of Germany (2016), micro plastic – the invisible danger: the BUND-shopping adviser.
http://www.bund.net/fileadmin/bundnet/pdfs/meere/131119_bund_meeresschutz_mikroplastik_produktliste.pdf (Aufruf: 22.05.2016)

Experiment 2: Investigation of marine sample regarding micro plastic

Part 1: Investigation of sand- and sediment samples regarding micro plastic

What is underneath my beach towel?

Material for the experiment:

10 100-ml-beakers
 dropping pipette
 5 watch glasses
 funnel
 5 polycarbonate filter (pore size: 0,2 μm)
 50 g sand from the beach and/or sediment
 325 g sugar
 500 ml water



Carrying out the experiment:

1. To get a realistic result, 5 samples should be tested. Each sample should consist of 10 g sand and / or sediment and should be thoroughly dried in a beaker.

2. Prepare a saturated solution of sugar in water. For each sample completely dissolve 65 g of sugar in 100 ml of water. The prepared solution has a density of $1.33 \frac{\text{g}}{\text{cm}^3}$.

Note: Other solutions with higher densities can also be used. In this case more plastic particles will move into the liquid phase (see table 1). A saturated solution of sodium thiosulfate (75 g sodium thiosulfate pentahydrate in 100 ml water) has a density of $1.4 \frac{\text{g}}{\text{cm}^3}$ and a saturated solution of zinc chloride (700 g zinc chloride in 100 ml water) has a density of $1.7 \frac{\text{g}}{\text{cm}^3}$.

Note: The saturated solutions need to be prepared **before** the lesson using a magnetic stirrer and a magnetic stir bar because the preparation can take nearly an hour.

3. Create a suspension of each sample in 100 ml of the prepared solution. Due to the fact that plastic has a lower density than sand, the plastic particles will swim in the solution above the sand. (see table 1).

Table 1: Density of some plastic type ^{10, 11.}

material	density $\left[\frac{g}{cm^3}\right]$
polystyrene (foamed)	ca. 0.1
polyethylene	0.92 – 0.964
Polypropylene	0.9 – 1.0
polystyrene (unfoamed)	1.05
rubber hose (lab)	1.07
polycarbonate	1.0 – 1.2
plasticized PVC	1.2
unplasticized PVC	1.4
sand / sediment	1.5 – 1.62

4. Remove the inhomogeneous liquid phase above the sand with a pipette from the beaker and filter it using a funnel and a polycarbonate filter. Collect the filtrate in another beaker.

5. Wash the filter cake with distilled water and dry it on a watch glass at room temperature.

6. Finally, investigate the residue using a binocular.

Note: Check each component of the residue carefully and distinguish plastic particles from other particles such as wood or parts of mussels.

¹⁰ Table changed of: Brückmann, J. et al. (2012), plastics in class, Munich, p. 151.

¹¹ <http://wiki.polymerservice-merseburg.de/index.php/Dichte> (call: 22.05.2016).

Part 2: Investigation of water samples regarding micro plastic
What is swimming next to me in the water?

Materials for the experiment:

5 250-ml-beakers

5 watch glass

funnel

5 polycarbonate filter (pore size: 0,2 μm) or
cellulose nitrate filter (pore size: 0,45 μm)

500 ml water sample



Carrying out the experiment:

1. To get a realistic result, 5 samples should be tested. Each sample should consist of 100 ml of the investigated waters.
2. Filter the sample using a funnel and a polycarbonate or cellulose nitrate filter. Collect the filtrate in another beaker.
3. Wash the filter cake with distilled water and dry it on a watch glass at room temperature.
4. Finally, investigate the residue using a binocular.

Note: Check each component of the residue detailed and distinguish plastic particles from other particles like wood or parts of mussels.