Nordic Ocean Watch

Microplastic Survey Across the Atlantic Ocean

Research Proposal for the Transatlantic Expedition on board Bark Europa, Autumn 2021

Table of contents

Background and rationale

This project will investigate microplastic abundance and distribution in the Atlantic Ocean on a crossing from Scheveningen, the Netherlands to Montevideo, Uruguay by collecting data from the sea surface using a manta trawl.

Microplastic pollution is a global issue

Plastic pollution has become one of the greatest environmental challenges of our time. It is estimated that 8-10 million tons of plastic waste end up in the oceans every year[1]. The EPA (United States Environmental Protection Agency) has stated that every piece of plastic ever produced still exists. Studies estimate that at this point in history, there are 15-51 trillion pieces of plastic present in the world's oceans. It has been predicted by numerical modelling that by 2060, the current microplastic content in the pelagic zone may increase fourfold.[2]

Resulting from the presence of plastics, such as microplastics, in the marine ecosystem, various studies have been conducted to understand their impact on the health of the ecosystems. Microplastics may enter the ocean via terrestrial pathways, where they migrate with water flow and river channels, and anthropogenic activities at sea such as fishing, shipping etc.[3]

Microplastics are defined as plastic objects with a size < 5 mm. A more recent definition describes microplastic as solid-synthetic particles or polymeric matrices, with regular or irregular shape, and dimensions between 1 µm and 5 mm, of primary or secondary manufacture origin, which are water-insoluble.[4] Primary sources can be sewage or plastic particles used in commercial and industrial products and include fibres from textiles, cosmetics, paints etc. Secondary microplastics are present as a result of the wear and tear of larger plastic debris found in the environment. Secondary microplastics dominate the marine environment due to the constant fragmentation of larger plastics.[5]

Microplastics have been observed in diverse environments across varied geographical areas and have a devastating effect on the marine environment and marine animals.[6] Microplastics also carry certain hazardous substances, and there are two basic reasons for this. One reason is the substances that are being deliberately introduced to the plastics during production to improve it, and the other reason is the substances that are adsorbed to the surface of plastics in nature.[7] The content and concentration of microplastics in the ocean depend on many factors, such as the

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[1] Ellen MacArthur Foundation. The new plastics economy. 2014

[2] Isobe A, Iwasaki S, Uchida K, Tokai T (2019) Abundance of non-conservative microplastics in the upper ocean from 1957 to 2066. Nat Commun 10:417

[3] Fauziah Shahul Hamid, Mehran Sanam Bhatti, Norkhairiyah Anuar, Norkhairah Anuar, Priya Mohan and Agamuthu Periathamby. Worldwide distribution and abundance of microplastic: How dire is the situation? 2018

[4] Frias, J.P.; Nash, R. Microplastics: Finding a consensus on the definition. Mar. Pollut. Bull. 2019, 138, 145–147.

[5] Nithin Ajith, Sundaramanickam Arumugam, Surya Parthasarathy, Sathish Manupoori, Sivamani Janakiraman. Environmental Science and Pollution Research. 2020. 27: 25970–25986

[6] Nithin Ajith, Sundaramanickam Arumugam, Surya Parthasarathy, Sathish Manupoori, Sivamani Janakiraman. Environmental Science and Pollution Research. 2020. 27: 25970–25986

[7] Cole M, Lindeque P, Halsband C, Galloway TS (2011) Microplastics as contaminants in the marine environment: a review. Mar Pollut Bull 62:2588–2597

location of pollution sources, water circulation, atmosphere forcing, particle composition, particle density and buoyancy, biofouling, etc.[8]

Transport of marine microplastic

Microplastics in the marine environment are transported by means of physical processes such as surface drifting, vertical mixing, beaching, and settling. These physical processes are driven by the properties of the ocean and its currents, gyres, and physical oceanographic characteristics such as salinity and temperature. The transport of microplastics is also influenced by the particles themselves, as their size, shape, and physical characteristics affect the way they are transported. While it is known that physical processes facilitate the transport of microplastics, understanding of how microplastics are transported to different parts of the ocean is lacking.[9] Current and historical oceanographic data, especially salinity and temperature, can be used to predict the origin of the microplastic particles, as these factors drive ocean currents. Salinity and temperature determine the density of seawater, and this determines the flow pattern of the ocean currents.[10] In this project, salinity and temperature will be measured at each sample site, and historical data will be used to predict the possible transport pathway of the collected microplastics.

Research aim

This project aims to investigate the presence and abundance of microplastics on a transect across the Atlantic Ocean, and to use both current and historical oceanographic data to predict how the microplastic may have been transported to that area.

Research methodology

The current interest in environmental issues and the increasing amount of microplastic research has led to the development of standardized methods for sampling and analysis.[11] In this project we will be using the 5Gyres protocol as a base for sample processing of microplastics > 1 mm.[12] Sample processing of microplastics < 1 mm will be carried out using an onboard stereoscope. Further sample analysis will be carried out in a laboratory in collaboration with Aalborg University, Department Of The Build Environment.

Study site

The study will be conducted throughout the voyage from Scheveningen, the Netherlands (52.1024°N, 4.3022°E) to Montevideo, Uruguay (34.9011°S, 56.1645°W) (Fig. 1). Covering a latitudinal range of 87°, the study spans both the North and South Atlantic Ocean, as well as

[8] Van Sebille, E., Aliani, S., Law, K.L., Maximenko, N., Alsina, J.M., Bagaev, A., Delandmeter, P., 2020. The physical oceanography of the transport of floating marine debris. Environmental Research Letters 15 (2), 023003.

[9] Li, Y., Zhang, H., & Tang, C. (2020). A review of possible pathways of marine microplastics transport in the ocean. *Anthropocene Coasts*, *3*(1), 6-13.

[10] http://ocean.stanford.edu/courses/bomc/chem/lecture_03.pdf

[11] Kershaw, P., Turra, A., Galgani, F., 2019. Guidelines for the monitoring and assessment of plastic litter in the ocean-GESAMP reports and studies no. 99. GESAMP reports and studies.

[12] https://www.5gyres.org/

crossing the English Channel, Celtic Sea and Río De La Plata Gulf. Stops will be taken in Seville, Spain; Tenerife, Spain; Sal, Capo Verde; and Montevideo, Uruguay. The voyage route, here represented as the survey area, spans just over 8000 nautical miles, during which samples will be collected periodically.

Figure 1: Map of the study site with the survey area highlighted, leading from Scheveningen, the Netherlands (52.1024°N, 4.3022°E) to Montevideo, Uruguay (34.9011°S, 56.1645°W), spanning a total of just over 8000 nautical miles.

Equipment

Onboard equipment

- 1 x Manta trawl
- 1 x HydroBios mechanical flowmeter
- 3 x Manta trawl cod ends
- 3 x Steel sieves (5mm, 1mm, 0,3mm)
- Metal forceps
- Wash bottle
- Handheld magnifying glass
- Soldering iron
- Data sheets
- 6 x Glass jars 0,5 L
- GF filters (1,6 µm)
- SDS solution
- H202 solution
- Porcelain funnel
- Glass funnel
- 100 x metal jars (100 ml, 50 ml, 25 ml, 10 ml)
- Stereo microscope
- Glass petri dish

Manta trawling

A manta trawl is a net system for sampling the surface of the ocean. It resembles a manta ray, with wings and a broad mouth. The net has a mesh size of 500 µm, while the cod end has a mesh size of 333 µm, and the whole trawl is towed behind the vessel. The manta trawl is useful for collecting samples from the surface of the ocean, such as sampling microplastic.

The trawl is deployed outside of the wake zone as turbulence inside the wake zone can push plastic deep underwater. A boom is used to position the trawl tow line away from the side of the ship. A steady linear course is maintained during trawling. The vessel should travel at < 3 knots while towing the manta trawl. If the trawl is leaping out of the water or ploughing under a wave, then the speed is too fast. It should travel smoothly across the water surface. The trawl is monitored during sample collection to observe its performance and adjust the length of the tow line and vessel speed if it is bouncing along or dipping below the surface. The manta trawl is deployed for 30 minutes, ideally in a straight transect. This is repeated 3 times directly in a row, providing 3 samples at each station.

”Start/Stop Data” and “Sea and Boat Conditions” as well as Sea State, Boat Speed, Boat Direction, Wind Direction, and Wind Speed will be recorded at deployment and recovery of each trawl. Furthermore the saltwater concentration as well as the water temperature is recorded during trawling. A flowmeter attached to the manta trawl and the onboard knot metre is used to determine boat speed. The Beaufort Scale of Sea State is used to determine the wind and sea state (enclosed as annex).

Sample preparation and sorting

The material collected by the manta trawl is transferred to the sieves. Sieving is a simple technique for separating particles of different sizes. Sieves with 3 different mesh sizes are used for this project.

- The sample is transferred from the cod end of the manta trawl into the stacked sieves with the largest mesh size (5mm) on top, the medium (1mm) in the middle, and the lowest on the bottom (0,3mm).
- The cod end of the Manta is rinsed using the wash bottle and filtered fresh water so that all particles are included.
- All the items which are non-putative plastic debris (plant and algae residues, wood, other solid materials) are discarded using a forcep, the debris are flushed onto the sieve using the wash bottle with filtered fresh water before discarding them.
- The forceps and magnifying glass are used to remove all recognizable pieces of plastic from the sieves of the mesh size 5 mm and 1 mm, starting with the largest mesh net. All plastic materials are transferred directly into a 0,5 L glass jar. The sieves are examined thoroughly to ensure that no plastic particles are missed during visual sorting.
- The entire content from the sieve with mesh size 300 µm is flushed from the sieve into the same glass jar using the wash bottle with filtered fresh water.
- All glassware is flushed 3 times with filtered water (using 1,6 µm glass fibre filters) before use.
- The glass jar is marked with date and time and the specific sample number and letter.

Plastic identification

Research has shown that visually identifying plastics is only reliable for plastics 1 mm and larger.[13] In this project we will be using the Spotter's Guide to Plastic Pollution to visually identify microplastic from organic material from surface water.[14]

- The sample can be divided into subsamples to concentrate on smaller parts.
- Filtered fresh water is allowed to slowly move over the sample. Plastics move differently than organics.
- After the first identification process the sample is then filled with saltwater to refloat, and swirl around, to see if any missed plastics float to the top with the increased salt concentration. The saltwater is filtered with a GF filter 1,6 µm to avoid contamination.
- To identify plastic from organic material:
    - The item can be tapped against glass with forceps as plastics sound different from organic material.
    - The item can be cut and looked under the microscope to look for differences between the outside and inside.
    - Look for changes in shape, size, elasticity, etc. after drying. If it changes, it's more

[13] Young Kyoung Song, Sang Hee Hong, Mi Jang, Gi Myung Han, Manviri Rani, Jong myoung Lee, Won Joon Shim. A comparison of microscopic and spectroscopic identification methods for analysis of microplastics in environmental samples. 2015

[14] https://civiclaboratory.files.wordpress.com/2017/12/spotter_s-guide-to-plastic-pollution-trawls.pdf

likely to be organic.
- The item can be touched with a soldering iron or any burnt with a lighter as many plastics melt.

SDS treatment and oxidation

Examining microplastics (< 1mm) requires high resolution microscopy. Using a stereo microscope on board, it is possible to investigate microplastics < 1 mm. However, its effectiveness increases tremendously when combined with infrared spectroscopy and chemical treatment. To be able to clearly identify plastic particles below 1 mm a solution of Sodium Dodecyl Sulfate (SDS), which is a surfactant that helps separate the microplastics from other particles and organic material, and simple oxidation using hydrogen peroxide (at 10% concentration), are used.

- The sample in the 0,5 L glass jar is sieved through the 300 µm sieve and flushed back into the jar using filtered fresh water to minimise the amount of water in the sample.
- The SDS solution is then added to the sample in the glass jar and left to incubate in a dark place such as a closed cupboard away from light sources.
- After incubating in SDS for at least 24 hours at room temperature, the sample is flushed back into the 300 µm sieve using filtered fresh water. Then it is flushed from the sieve into a 0,5 L jar. Hydrogen Peroxide (H202) 6% is added to the sample so that the ratio of liquid/solid is about 2-3.
- The particles in the solution then incubated from 24 h to 72 h. Important to check the status of the reaction, and if it has ceased (no more bubbling) we added more concentrated Hydrogen Peroxide (H202) 6% until the reaction started again.
- After incubating in H_2O_2 the sample is sieved through a 300 µm sieve and rinsed thoroughly with filtered fresh water and placed in a glass Petri Dish.
- All glassware is flushed 3 times with filtered water (using 1,6 µm glass fibre filters) before use.
- The Petri Dish is looked thoroughly through under a stereomicroscope onboard and all plastic particles are picked out with forceps, dried and placed into a metal jar.
- The metal jar is marked with date and time and the specific sample number and letter.

Laboratory analysis

After disembarkation the samples were analysed in a laboratory in collaboration with Aalborg University, Department Of The Build Environment. All particles are photographed and individually counted and weighed and their polymer type is analysed using infrared spectroscopy.

Sample imaging

The Ocean Cleanup has developed an algorithm to detect, count and characterize individual plastic particles from an image. The plastic particles above 1 mm in size are photographed using this protocol. Plastic particles below 1 mm are photographed individually using a stereo microscope.

- The plastic-looking particles are picked out from the metal jar under an optical microscope using forceps.
- The plastic sample is carefully placed onto a white background surface, ensuring an even

spread of particles over the area.

- Using forceps, the particles are separated from each other, not touching each other.
- A size reference is placed somewhere on the background surface. An image is taken of the contents of each of the samples 20-30 cm away from the surface. The images should be taken near a light source, after the plastic has dried. Ensure that all particles are captured on the image and there is minimal interference from light and/or shadows. The sample is photographed including the date and time and the specific sample number and letter.

Sample weighing

All particles are individually weighed using a weight scale to 0,00000 grams. Particles weighing below 0,00000 grams could not be weighed using this weight scale and their weight is therefore calculated using a mathematical calculation.

Polymer identification

All particles are analysed using ATR-FTIR-spectrometer for polymer identification. Infrared spectroscopy offers reliable identification of polymers.

Plastic classifications

Plastic can be categorized into different categories depending on type and components. In this project we use 7 plastic categories: Fragments (bits of hard plastic), film (like bags), foam (like polystyrene), line (like from fishing gear), industrial pellets (also called nurdles), microbeads (from cosmetics), and microfibers (from synthetic clothing– much thinner and kinkier than threads). (enclosed as annex)

Disadvantages and limitations of the method

There are many difficulties associated with the methods of microplastic identification[15]. Plastic concentrations on the surface can vary greatly even in the same study area as they move with the currents, disperse quickly, or aggregate in calm zones. Nevertheless, the lack of plastic contamination measurements in the open oceans makes the visual based method suitable for large area distribution research. Furthermore, visual analysis is sometimes the only possible option on board, given the available equipment. For the best possible sample collection, trawling in sea state 4 or above should be avoided as well as winds above 16 knots as turbulence inside the wake zone can push plastic deeper underwater.

[15] Kershaw, P., Turra, A., Galgani, F., 2019. Guidelines for the monitoring and assessment of plastic litter in the ocean-GESAMP reports and studies no. 99. GESAMP reports and studies.

Plan of work and time schedule

Timeline

The duration of the research project will be from Monday, 13th of September to Monday, 8th of November 2021. Although Bark Europa embarks on the 6th of September 2021, the first couple of days will be used to prepare and set up the scientific equipment, as well as to get to know the facilities on board. Days of not collecting data will be acceptable, as possible interruptions such as storms or malfunctioning equipment might impact the working schedule. Days at port will also be excluded. The first week will serve as a trial week to evaluate potential flaws in the protocol and possibly alter methodology, aims or objectives to suit the conditions on site. If no alterations are made and everything runs according to schedule, the data will however be included. The aim is to have a minimum of 15 days recording for macroplastic and a number of 15 x 3 (A;B;C) samples collected by manta trawl in total, and 5 blank samples to test for secondary contamination.

The data will be analysed and processed continually throughout each week, with backups being made on an external hard drive during the voyage, so that further work can be undertaken after disembarkation.

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- **Bark Europa**
  https://www.barkeuropa.com/

Research partners

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- **Claudia Lorenz**
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- **Kristian Syberg**
  Associate Professor, Department of Science and Environment, Roskilde University
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  https://www.safinacenter.org/
- **Ocean Mission**
  https://oceanmissions.org/
- **Ekspedition Plastik**
  https://www.ekspeditionplastik.dk/

Collaborations

Thank you to all our research collaborators who have contributed with their experience in the field of plastic research as well as with research equipment.

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  https://theoceancleanup.com/
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- **Nordic Ocean Watch Denmark**
  https://www.nordicoceanwatch.dk/

Annex

Beautfort Scale of Sea State

Beaufort Scale of Sea State		
Beaufort Force 0-12	Wind Speed	Sea Criterion
Force 0	Less than 1 knot	Sea like a mirror
Force 1	1-3kt	Ripples with the appearance of scales are formed, but without crests.
Force 2	4-6kt	Small wavelets, still short, but more pronounced – crests have a glassy appearance and do not break.
Force 3	7-10kt	Large wavelets. Crests begin to break. Foam of a glassy appearance. Perhaps scattered small white caps.
Force 4	11-16kt	Small waves, becoming longer, fairly frequent small white caps.
Force 5	17-21kt	Moderate waves taking a more pronounced long form, many small white caps are formed. Chance of some spray. If you are in the open ocean, you should not trawl during high seas and wind.
Force 6	22-27kt	Large waves begin to form; the white foam crests are more extensive everywhere. Probably some spray. If in the open ocean, you should not trawl during high seas and wind.

Data Recording sheet

Automated visual observation of macroplastic

Recording #	Vessel name	Location	Date
START DATA SUNRISE	TIME START	LAT (N/S) START	LONG (W/E) START
STOP DATA SUNSET	TIME END	LAT (N/S) END	LONG (W/E) START

SEA & BOAT CONDITIONS							
	SEA STATE	VESSEL SPEED (KNOTS)	VESSEL DIRECTION (DEGREES)	CURRENT SPEED (KNOTS)	WIND DIRECTION & SPEED	WEATHER CONDITIONS	PRECIPITATION

START DATA							
STOP DATA							

Remarks

Manta trawling for microplastic

TRAWL #	Vessel name	Location	Date
START DATA	TIME START	LAT (N/S) START	LONG (W/E) START
STOP DATA	TIME END	LAT (N/S) END	LONG (W/E) START

SEA & BOAT CONDITIONS									
	SEA STATE	VESSEL SPEED (KNOTS)	VESSEL DIRECTION (DEGREES)	CURRENT SPEED (KNOTS)	WEATHER CONDITIONS & PRECIPITATION	WIND DIRECTION & SPEED	FLOWMETER	SALINITY	WATER TEMP
START DATA									
STOP DATA									

Remarks