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Circular Ocean-bound Plastic

Plastic waste streams into the South Baltic Sea

Report on a country level

December 2024

Report on Plastic waste streams into South Baltic on a country level

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Interreg South Baltic

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“I was confronted, as far as the eye could see, with the sight of plastic. It seemed unbelievable, but I never found a clear spot. In the week it took to cross the subtropical high, no matter what time of day I looked, plastic debris was floating everywhere: bottles, bottle caps, wrappers, fragments”

- Charles Moore when the discovering the Great Pacific Garbage Patch with his sailing boat

Content

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Thank you all for your commitment to addressing plastic waste in our so loved Baltic Sea.

The COP project

This report is part of the EU Interreg South Baltic project Circular Ocean-bound Plastic (COP), which addresses the issue of ocean plastic in the South Baltic Sea. The COP project aims to reduce plastic waste entering into the sensitive ecosystem by identifying its sources and pathways. Over 80% of ocean plastic originates from land-based sources due to improper management or leakages, ending up primarily in rivers and water bodies in urban areas, making their paths to seas and oceans (WWF, 2024).

The project's overall goal is to investigate the collection, reuse, and recycling of ocean-bound plastic. The project is recognized as a "project of strategic importance" by the EU Interreg South Baltic Programme.

The project collaborates and cooperates with 10 partners from four different countries in the program specified region. The partner Clean – The Danish Water & Environmental Cluster serving as the lead coordinating partner. The selected pilot areas include Aarhus (Denmark), Rostock (Germany), and Gdansk (Poland).

This report gathers information on ocean plastic waste, including waste streams, collection methods, treatment options and current legislations.

1. & 2.
Introcution to Ocean-bound plastic

- types and pilot cities

1. Introduction: Ocean-bound Plastic

1.1. What is Ocean-bound Plastic?

Approximately 10 million tons of plastic waste yearly end up in the world's oceans. The total amount of plastic in the world's oceans was estimated to be at 86 million tons (Heinrich-Böll-Stiftung; BUND e.V, 2019).

Ocean-bound plastic (OBP) refers to plastic waste classified as 'at risk of ending up in the ocean' due to the leakage of waste into riverine water bodies. This category includes 'abandoned plastic waste' located within 50 km of coastlines, where waste management systems are either lacking or ineffective. OBP is likely to end up in the seas and oceans due to natural forces such as wind, rain, water flow, tides, as well as human activities like littering and rainwater overflows (Zero Plastic Oceans, 2024).

Marine litter, often referred to as marine debris, is defined as "any persistent, manufactured, or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment" (UNEP, 2005). It encompasses items created or utilised by humans, that enter the sea either intentionally or unintentionally. Sources of marine litter include fishing, shipping, dumping, tourism, and coastal recreation. Additionally, rivers, wind, rain and sewer systems can transport marine litter into the sea.

Marine litter can be found in different parts of the water body, on the sea floor, in the water column, on the water surface and in biota. If the entering of plastics occurs mainly from coastal waters and rivers, then very likely the majority of waste will be trapped in the vegetation or river banks. If we talk about litter entering right into the open ocean, e. g. fishing gear, it is likely, that it sinks to the seafloor overtime, if it does not reach a beach before then.

The German Federal Environment Office (UBA) assumes, that approximately 70% of the total marine litter sinks to the bottom. About half of the remaining 30% lands ashore on the beaches, and the other half drifts on the water's surface and into the water column (Umweltbundesamt, 2024). Another study even suggests, that 94% of the total marine litter ends up on the sea floor (Eunomia, 2016).

1.2. Types of Ocean-bound Plastic

OBP or marine plastic waste includes all plastic litter sizes from nano- to megaplastics as shown in figure 1.

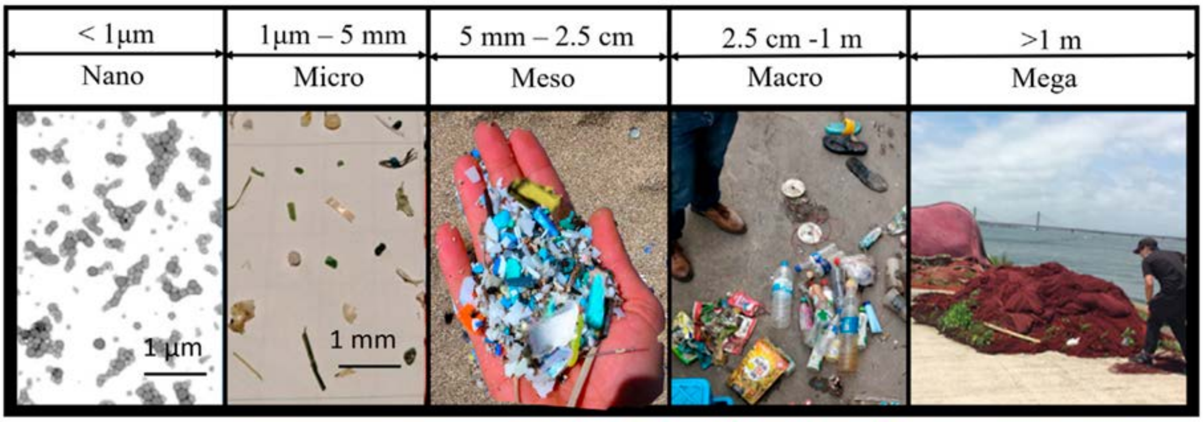


Figure 1: Plastic litter sizes (Source: (Abeynayaka, Amila; et al., 2022))

The OBP Certifications Program defined four categories of Ocean-bound plastic (Zero Plastic Oceans, 2024):

1. **Potential Ocean-bound plastic:** inadequately collected plastic waste located within a 50 km distance of the coastline.
2. **Waterways Ocean-bound plastic:** inadequately collected plastic waste located up to 200 m from rivers as well as directly in rivers.
3. **Shoreline Ocean-bound plastic:** Inadequately collected plastic waste located up to 200 m from shores.
4. **Fishing material:** used fishing gears and plastic bycatch.

This project primary focuses on OBP in waterways, specifically through the examination of litter in tributaries leading to the Baltic Sea. OBP can be found in various locations within the river, such as on riverbanks, flood zones, sediment, near structures like weirs and harbours.

Previous research has revealed that rivers serve as the primary pathways for transporting plastics into the sea (Helinski et al., 2021). There are still knowledge gaps regarding the exact sources and pathways of plastic pollution. Special attention should also be given to understand the impact of heavy rainfall events on the amount of waste entering rivers through sewer systems.

1.3. The problem of Ocean-bound Plastic

To address the challenges of OBP pollution, one has to understand, that marine plastic litter is contributing to a pervasive global pollution issue, that jeopardizes not only the environment but also human health and tourism (UNEP, 2005; Baltic Marine Environment Protection Commission - HELCOM, 2023).

- Marine litter poses a threat to water borne species leading to entanglement and suffocation. Many species mistakenly mix-up the debris for food. The traces of plastics are found in the stomachs of numerous seabirds, marine mammals, etc. The marine environment is susceptible to the influx of toxic substances through plastic waste inputs, as plastic is often treated chemically or coated with toxic substances. Marine litter, particularly plastic debris, can also act as a transport mechanism for invasive species.

- Environmental elements like weather, saltwater, and UV radiation contribute to the degradation of plastic litter, breaking it down into smaller particles known as microplastics. These microscopic fragments have the potential to infiltrate even the human food chain.

- Marine litter in shoreline areas, especially beaches, poses a significant threat to tourism due to its unsightly appearance. The visual impact of litter can deter tourism, impacting the appeal of these coastal destinations and the income-generating activities of the region.

2. Three pilot areas and an associated partner

3 pilot areas were chosen for the implementation of the project activities within the participating countries. Every pilot city is used as a testing ground for new initiatives or technologies to remove OBP from the water column and find mitigating solutions for the generation of the local OBP.
The criteria for the choice were the following:

- 1 pilot area in each participating country.
- River/waterways flowing into South Baltic Sea.
- Close location or adjacent to Baltic Sea.
- Medium-sized city with a population between 100,000 and 500,000 inhabitants.

The 3 pilot areas are:
- Rostock in Mecklenburg-Western Pomerania in Germany
- Aarhus in Central Jutland in Denmark
- Gdansk in Pomerania in Poland

Malmö in Skåne in Sweden is an associated partner area, as they are collaborating closely with the project.

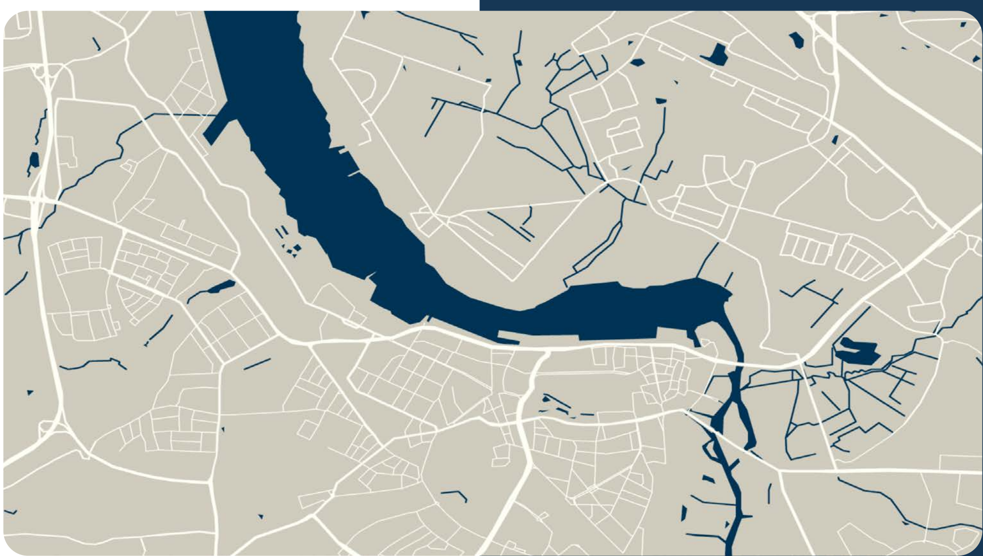
Figure 2: overview of the South Baltic region and the 3 pilot cities location

2.1. Pilot area - Rostock, Germany

Rostock is the biggest city in Mecklenburg-Western Pomerania with over 200,000 inhabitants (Hanse- und Universitätsstadt Rostock, 2024). The Warnow river, originating in the Mecklenburg Lake District, passes through the city of Rostock and ultimately reaches the Bay of Mecklenburg in Warnemünde (Figure 3).

As the river approaches Rostock, it widens up to 3600 m, creating an estuary or inner coast water body. In the Warnow, water depths range from less than 2 m in shallow areas to as deep as 14.5 m in the dredged channel. Flow velocities in the study area rarely exceed values of 0.1 m/s due to the very wide cross-section of the watercourse (Zädow, 2021). Due to the strong influence of winds, even multiple changes in the direction of currents can be expected, possibly several times a day (Behrmann, 2021). In Rostock, the Mühlendamm separates the upper and lower Warnow through a weir and lock. Today, this primarily serves to prevent the intrusion of brackish water from the lower Warnow into the upper Warnow, which is utilized by Rostock as the main source of drinking water. Below the Mühlendamm weir, in the lower Warnow, the typical characteristics of a flowing watercourse are no longer present (Figure 4).

There is, especially during the summer months, lively boat traffic on the Warnow River, ranging from small leisure boats to ferries, cruise ships, and cargo vessels in the northern part. Particularly in Warnemünde, where the overseas port is located, bigger ships are prevalent. Rowing, sailing, fishing, and plenty of other water sports are practiced in the Warnow estuary.



Rostock - info

Largest city in the state of Mecklenburg-Vorpommern

209,920 inhabitants

River length 155 km

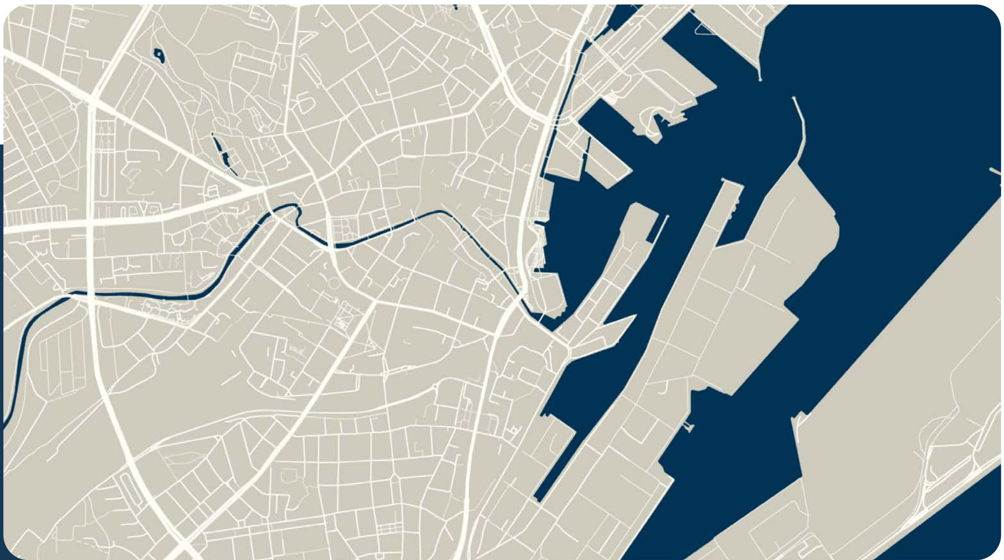
2.2. Pilot area - Aarhus, Denmark

Aarhus is Denmark's second-largest city, with almost 300,000 inhabitants, located on the east coast of the Jutland peninsula with a river running through the city (Figure 5). Aarhus River is a 32 km long stream, that drains 324 km² in East Jutland. The stream originates from Stilling-Solbjerg Lake, southwest of Aarhus, and runs through the inner city of Aarhus, to finally flow into Aarhus Harbor and Aarhus Bay. The bay belongs to the Kattegat.

Despite its connection to Aarhus, the stream quite naturally has most of its course outside the city limits. Within the city, the river resembles more of an artificial waterway, like a canal (Den Store Danske, 2024) (Figure 6).

The water depth varies from 0.1 to 1.1 m. The river is 10 m wide and the water flows with a velocity of about 0.2 m/s (Aarhus Kommune, 2024) (CALYPSO, 2024).

Today, Aarhus River still plays an important role as a recreational area for the city's collective identity. The river divides the city into a southern part and a northern part. In the center of Aarhus, close to Aarhus Bay, Aarhus River is surrounded by many restaurants and cafes.



Aarhus - info

Second biggest city in Denmark

290.589 inhabitants

Founded by Vikings

2.3. Pilot area - Gdansk, Poland

Gdansk is located on the northern coast of Poland along the Baltic Sea (Figure 7). It is part of Pomerania and with approximately 465,200 inhabitants the sixth biggest city in Poland. Nowa Motława is a branch of the Vistula River system, flowing through Gdansk and merging with the Martwa Wisła. It serves as an important navigational route in the city. Water depth is about 1.5-4 m and the water currence speed is about 0.1 m/sec.

The waterways of Gdansk support a range of activities, from commercial shipping and fishing to tourism and recreation. The city's network of canals and rivers also offers numerous opportunities for water-based activities.

Gdansk - info

6th largest city | 465,200 inhabitants | River length 1.5 km

2.4. Associated partner area - Malmö, Sweden

Malmö, with approximately 300,000 inhabitants, is the third-largest city in Sweden and part of the Öresund Region. The pilot area is the city canal in the city of Malmö (Figure 9). Malmö canal consists of several canals and basins linked together into one system. Today, the canal is a total of 4 km long with a width between 16 and 90 m and a depth of 1.6 to 3.6 m. After passing the city, it flows into the Öresund, which is also known as the Sound.

Along most of the canal, the water is bordered by sloping rows of field stones. In the north along the old port and industrial quarters the canal is lined with high stone-clad quays. These straight edges have the advantage that they can be used for boarding for boats. In the western part of the canal there are some stretches, where the edge towards the channel is covered with sand and vegetation. The canal also runs though the Castle Park, a big recreation area, in Malmö center.

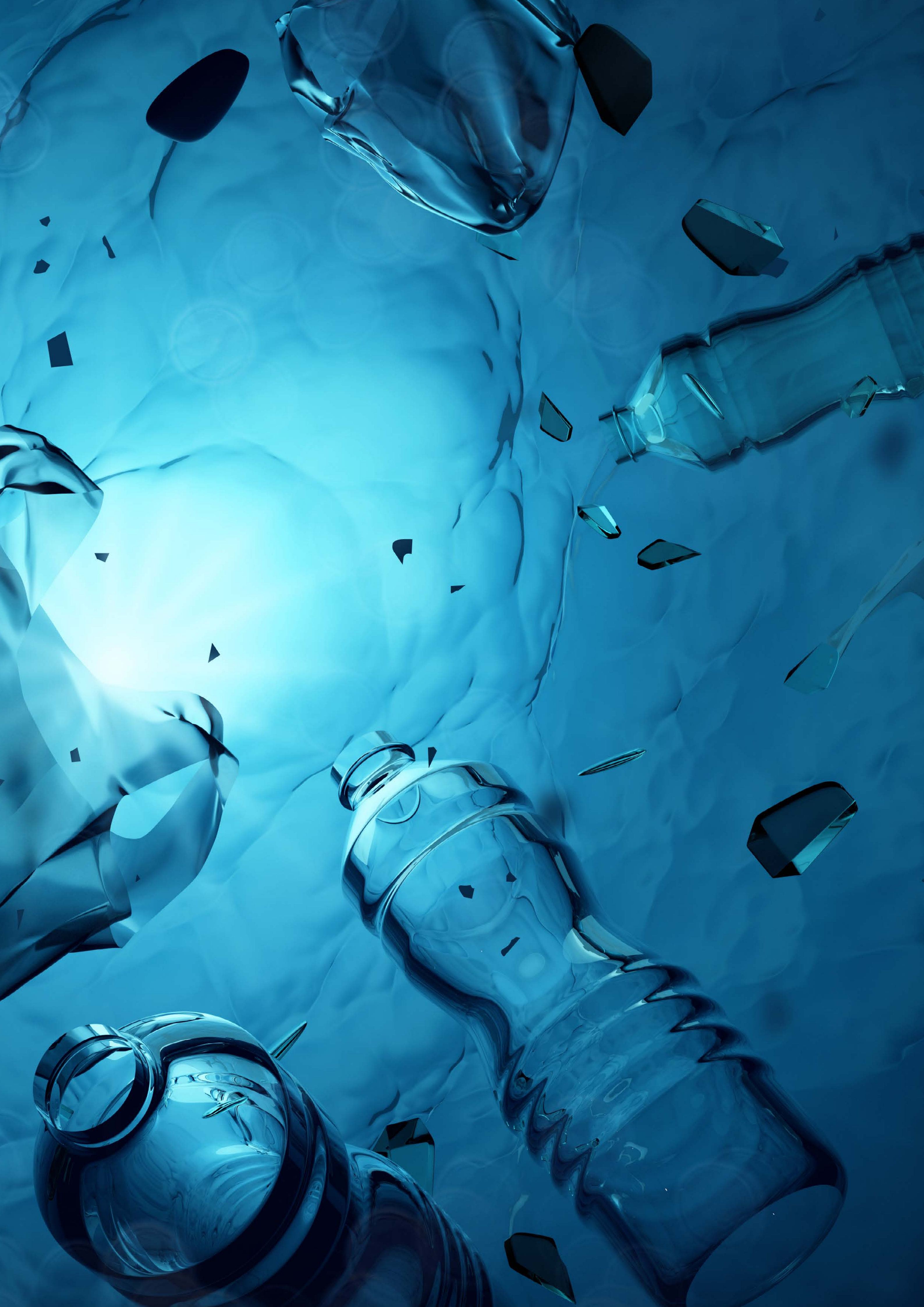
Today, more than 30 bridges lead over the channel. They have different designs in material, shape and colour and some are movable to allow for larger boats to enter the canal. Paddling and rowing in the canal as well as fishing are common pastimes in the canal (VA SYD, 2024).

Malmö - info

Largest city in Skåne county

301.706 inhabitants

Canal length 4 km



2.5. Conclusion

Although the 4 locations were selected based on the same criteria, a closer examination reveals some significant differences, as shown in Table 1. All pilot areas have in common that there is a quite large city with a high population density and a lot of human activity, including society and industry.

On the other hand, the water bodies going through the cities show very different characteristics. In Rostock there is a wide estuary, whereas in Aarhus and Malmö artificial canals are located and in Gdansk both types exist.

	Pilot area	Description	Inhabitants	Population density (people/km²)	Water depth (m)	River width (m)	Water current (m/s)
1	Rostock (Germany)	The lower course of **Warnow River** is not a river in the traditional sense but rather an inner coastal waterbody.	209.920	1157	2-14.5	up to 3.600	~0.1
2	Aarhus (Denmark)	The small river **Aarhus River** within the city center is transformed into an artificial canal.	295.688	2975	0.1-1.1	10	~0.2
3	Gdansk (Poland)	**Nowa Motława** is a river that branches off from the Motława River, flowing through the city.	470.805	1787	1.5-4	15-70	~0.1
	Associated area						
1	Malmö (Sweden)	Several kilometers of small **artificial canals** flow through the city center.	301.706	3915	1.6-3.6	16-90	0.01

Table 1: Comparison of the 3 Pilot Areas and Malmö

3.
Plastic waste streams into the South Baltic Sea
- literature review

3.1. The South Baltic Sea

The South Baltic Sea is the southern part of the Baltic Sea, one of the largest brackish water bodies - with a surface area of about 420,000 km². It has a relatively shallow depth of 55 meters on average and boasts an extensive coastline of around 8,000 kilometers. The Baltic Sea is surrounded by 9 countries, with 85 million inhabitants living in the drainage basin (Matti Leppäranta, 2009). As can be seen on the map in Figure 11, most of the population lives in the South Baltic Sea region, as the population density in the southern part is significantly higher than in the northern part.

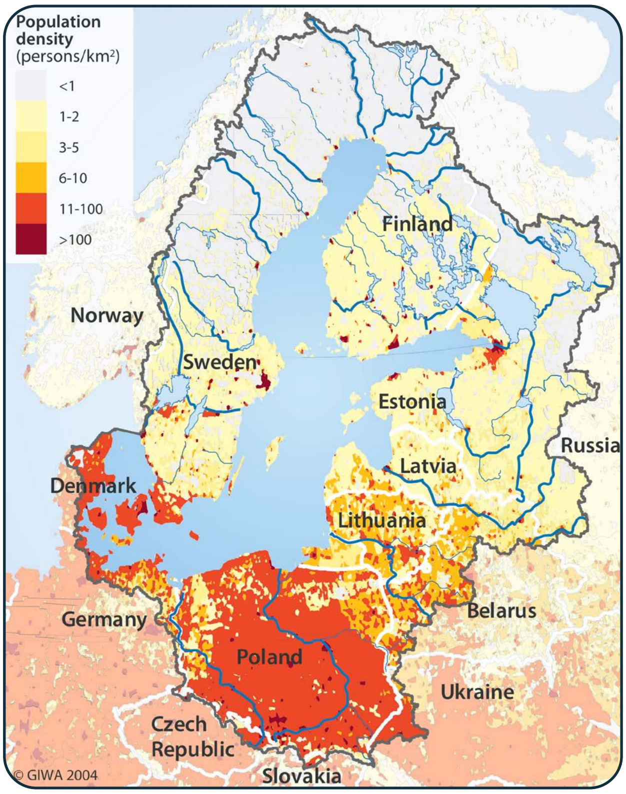


Figure 11: population density in the Baltic Sea region (HELCOM, 2006)

Geography

The South Baltic Sea area includes the coastal waters of the countries Denmark, Germany, Poland, Lithuania, and Sweden. It stretches from the Danish islands in the west to the coasts of Poland and Lithuania in the east, from the southern coasts of Sweden to the northern coast of Germany.

Skagerrak, Kattegat, Belt Sea and The Sound are seen mostly as an intermediate area between North Sea and Baltic Sea. The South Baltic Sea features highly diverse types of coastal landscapes, including soft moraine cliffs, sandy beaches/dunes, rocky cliffs, meadows, and organic wetlands (Labuz, 2015). Moraine material dominates in the south and southeast and hard bottom rocky shores are most common at the northern coasts (Schiewer, 2008).

Climate

The climate in the South Baltic Sea region is a maritime humid climate, with mild summers and cold, wet winters. It is influenced by the proximity to the sea, which moderates temperatures and brings regular precipitation. Only in some coastal areas the South Baltic Sea tends to freeze over during the winter, particularly in the eastern parts, while in summer water temperature can reach up to 22 °C (Bundesamt für Seeschifffahrt und Hydrographie, 2024).

Economy

Shipping: With 2,000 ships sailing on the Baltic Sea at any given time, it is considered one of the most heavily trafficked seas in the world (Umweltbundesamt, 2024). There are several important ports in the South Baltic, such as Rostock in Germany, Gdansk and Gdynia in Poland, and Klaipeda in Lithuania. They work as key gateways for goods entering and leaving Central and Eastern Europe.

Fishing: The region has a rich history of fishing, with local communities relying on it for their livelihoods. Fishing industry today faces a lot of challenges due to overfishing and environmental changes (Bund für Umwelt und Naturschutz, 2024).

Tourism: Coastal tourism is a major economic factor in the South Baltic Sea region. Sandy beaches, historic towns and natural landscapes attract millions of visitors annually, particularly during the summer months.

Environment

The South Baltic Sea is home to a range of marine and coastal ecosystems, including unique brackish water habitats, which support diverse species of fish, birds, and marine plants. The sea is known for its relatively low salinity compared to other seas. There is a salinity gradient from West to East. The South Baltic Sea is an enclosed micro-tidal (<15 cm) inland sea. Only limited water exchange with the North Sea takes place. The South Baltic Sea faces significant environmental challenges, including pollution from agriculture and industry, eutrophication (excessive nutrients leading to algae blooms), overfishing and plastic pollution.

3.2. Sources and pathways of plastic waste streams in general

Sources of plastic waste streams into the ocean can be generally divided into three sources: land-based and sea-based. Below is a list over some of the sources for plastic waste.

Land-based sources

- **Storm water runoff:** Rainwater can wash litter from urban areas, roads, and industrial sites into rivers and seas. This runoff often carries plastic debris and other pollutants.
- **Waste water and sewage:** Inadequately treated sewage and waste water can introduce microplastics and other debris into marine environments. This includes both domestic and industrial sources.
- **Improper waste disposal:** Littering and poor waste management practices, such as illegal dumping and inadequate landfill management can lead to plastics and other waste materials being transported to marine environments.
- **Agricultural practices:** Plastics used in agriculture, such as mulch films and pesticide containers, can be washed into water bodies through runoff or wind.
- **Coastal development:** Construction and land alteration near coastlines can result in debris being directly deposited into the sea. Sediment from construction sites can also carry plastic and other pollutants into marine waters.

Sea-based sources

- **Fishing gear:** Lost or discarded fishing nets, lines, and other equipment contribute significantly to marine litter. These items can entangle marine life and degrade over time, adding to the pollution.
- **Shipping and boating:** Debris from cargo ships, cruise ships, and recreational boats, including waste and cargo spills end up in the ocean. Even though regulations exist to prevent such pollution, enforcement is often inadequate.
- **Offshore platforms:** Platforms for oil and gas extraction can contribute to marine litter through spills of oil and other pollutants, which can carry plastic and other waste materials into the sea.

Sewerage systems play a significant role in the management of litter, with their impact varying based on their design. Many European cities utilize combined sewer systems due to historical practices, where both waste water and storm water are channeled through a single sewer network. During heavy rainfall, the hydraulic capacity of waste water treatment plants is often exceeded, making it impossible to treat all incoming water. As a result, storm water runoff in these combined systems must either be discharged through combined sewer overflows into receiving waters or stored temporarily in reservoirs. When excess flows are released through CSOs, there is a risk of pollution, as the discharged water may carry debris and contaminants if not properly managed (Quaranta & Pistocchi, 2022, Cools, Banfi, McNeill, Zamparutti, & Vaes, 2016).

Pathways for marine litter

Marine litter, particularly plastic waste, enters marine environments through various pathways. Each pathway involves different mechanisms for transporting litter from its source to the sea.

- **Human direct pathways:** Direct littering and illegal dumping contribute to marine pollution through immediate and uncontrolled release of waste into the environment.
- **Wind:** Wind can transport and disperse especially lightweight plastics and other litter, exacerbating pollution in coastal areas.
- **Drains and rivers:** Storm water drains, runoff from streets, and sewer overflows channel significant amounts of litter into rivers and eventually the sea.

3.3. Plastic pollution in the South Baltic Sea in a global context

Researching plastic waste entering the South Baltic Sea via rivers presents significant challenges. As a result, the assessment has also utilized data also from beach monitoring and seabed waste collection. Beach monitoring is particularly effective and straightforward method for quickly evaluating the pollution situation and understanding its extend. However, it is important to recognize that beach litter is estimated to account for only about 15% of total marine litter (UNEP, 2005).

A review of literature from Germany, Denmark, Poland, and Sweden conducted by the project partners reveals, that most available data focusses on beach monitoring. This highlights a notable gap in research related to riverine litter, underscoring the need for more comprehensive studies on how plastic waste from rivers contributes to marine pollution in the South Baltic Sea.

Pollution Levels in the Baltic Sea Compared to other Seas

Example 1: Beach Pollution

The average pollution level of Baltic Sea beaches is relatively low compared to other global regions, with an average of 0.91 pieces per square meter. This contrasts sharply with higher pollution levels reported elsewhere (Haseler & et. al., 2020).

Examples of high beach pollution:

1. **Portugal**: Reports indicate 185 plastic pieces per square meter, with sizes ranging from 2.5 to 3.5 mm) (Martins & Sobral, 2011).
2. **Canary Islands:** Pollution levels exceed 430 to 1600 micro-litter pieces per square meter (Herrera, et al., 2018).
3. **South Korea:** Some beaches report over 19,000 plastic pieces per square meter, with sizes between 1 and 5 mm (Lee, et al., 2013).

Example 2: Sea Floor Pollution in marinas

In German marinas, the average pollution level was 0.1 particles per square meter of the sea floor, with a range of 0.04 to 1.75 particles per square meter. In contrast, marinas in North Africa exhibited significantly higher pollution, with an average of 0.7 particles per square meter—seven times greater than the pollution levels observed in German marinas (Schernewski & al, 2023).

3.4. Results from selected studies related to plastic waste streams

The selection of the following 4 studies is based on their comprehensive coverage of the Baltic Sea region.

3.4.1. Final report of Baltic Marine litter project Marlin

The Baltic Marine Litter Interreg-Project MARLIN (2011-2013) conducted a comprehensive monitoring over 2 years of 23 reference beaches across Sweden, Finland, Estonia, and Latvia with 138 beach litter assessments (Figure 12).
Even though this study focuses on the central Baltic Sea, it can be assumed that the distribution of waste in the South Baltic Sea is similar. Due to the higher population density and more touristic and commercial activities the amount of waste probably will be higher. The MARLIN project sought to understand the extent, sources, and impacts of marine litter, with a particular focus on plastic waste. The report highlights that household-related waste contributes 48% of marine litter in the Baltic Sea, with an additional 33% attributed to recreational and tourism activities.

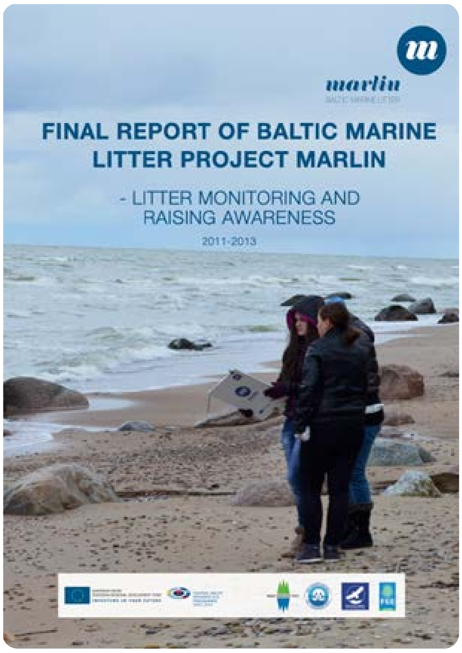


Figure 12: Cover of the final report from projet Marlin

The report underscores the significance of local waste management practices and recreational activities in influencing plastic waste streams. The project reported the following findings:

- **Rural Beaches:** The average number of litter items was 76 per 100 meters.
- **Urban Beaches:** The average number of litter items was 237 per 100 meters.

The distribution of waste by material categories shows, that plastic constituted the largest fraction of the litter found on these beaches, as seen in figure 13. Plastic makes up for 62% of all wastes at urban beaches and 54% at rural beaches.

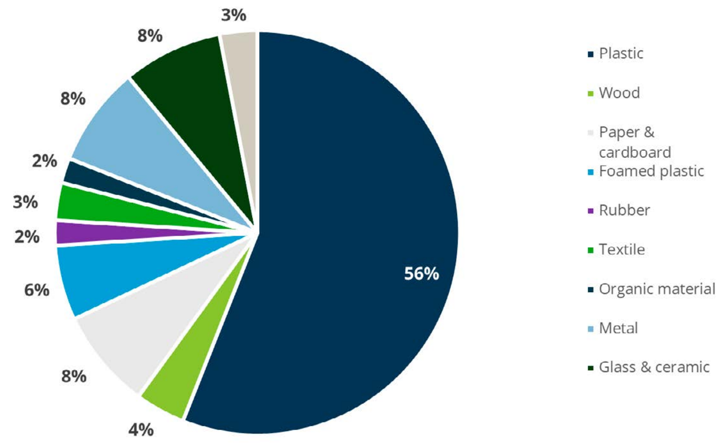


Figure 13: distribution of waste by categories at Baltic Sea beaches (Data Source: Final report of Baltic marine litter project Marlin)

The average number of cigarette butts found on Baltic Sea urban beaches is at a ratio of 301.9 butts per 100 meters, whereas at peri-urban beaches its at 111.5 butts per 100 m. Rural beaches show a lower ratio of 49.4 butts per 100 meters. Other common litter items include glass fragments, plastic bottle caps and lids, plastic bags, foamed plastic, food containers, and candy wrappers.

The majority of the litter is associated with modern take-away lifestyles and consists of plastic materials. It appears that litter from beach visitors or waste that flows from nearby cities is the primary source of marine litter, while sea-based sources such as shipping contribute less to the visible litter found on Baltic Sea shores.

3.4.2. Marine litter pollution in BalticSea Beaches - application of the sand rake

Between July 2017 and October 2019, a total of 197 sandrake method surveys, illustrated in figure 14, were conducted across 35 regions around the Baltic Sea (Haseler & et. al., 2020). During these surveys, 9,345 litter pieces were collected from an area of 10,271 square meters. Of these, 69.9% were between 2 and 25 millimeters in size. The predominant type of litter found was artificial polymers, with 4,921 pieces recorded, which constituted a mean of 52.7% of the total litter, followed by cigarette butts with a collected mean of 15.3%. The average litter abundance was 0.91 pieces per square meter. The most prevalent litter types included:

Industrial pellets:	19.8%
Non-identifiable plastic pieces (2–25 mm):	17.3%
Cigarette butts:	15.3%
Paraffin:	11.9%

Denmark has the lowest macro litter density among the countries, with 0.09 pieces per square meter. Sweden follows closely, with a density of 0.17 pieces per square meter. Germany shows a moderate level of macro litter density at 0.31 pieces per square meter and Poland has the highest macro litter density, with 0.55 pieces per square meter (Table 2).

	Macro litter in pieces/m²
Sweden	0.17
Denmark	0.09
Germany	0.31
Poland	0.55

Table 2: litter density on Baltic Sea beaches (Data: Haseler & et. al., 2020)

In the Top Litter Item List (Table 3) it is observed, that cigarette butts are a significant litter item across all the countries. In Denmark, Germany and Poland it is the most common litter item.

Sweden	Plastic pieces (meso)	22.6
	Industrial pellets	15.6
	Cigarette butts	10.6
Denmark	Cigarette butts	36.1
	Plastic pieces (meso)	10.1
	Crisp packets/ sweet wrappers	4.4
Germany	Cigarette butts	42.1
	Plastic pieces (meso)	7.8
	Bottles incl. pieces	5.4
Poland	Cigarette butts	21.5
	Plastic pieces (meso)	15.9
	Industrial pellets	11.4

Table 3: Top Litter Items on Baltic Sea Beaches (Data: Haseler & et. al., 2020)

Plastic pieces (meso) are also notably present in all 4 countries. Industrial Pellets are significant in Sweden and Poland. These items are not a top litter item in Denmark or Germany. Crisp packets/ sweet wrappers are only significant in Denmark. Bottles (including pieces) are notable in Germany but are not listed as a top litter item in other countries.

3.4.3. Case study: The plastic cycle and its loopholes in the four European regional seas areas

The case study by ARCADIS (2012) "Case Study on the Plastic Cycle and Its Loopholes in the Four European Regional Seas Areas" provides a comprehensive analysis of plastic pollution across four key European regional seas: the Baltic Sea, the North-East Atlantic, the Mediterranean Sea, and the Black Sea (Figure 15). The study, commissioned by the European Commission DG Environment, aims to identify key gaps in the management of plastic waste and offers recommendations for improving plastic waste management strategies.

The summary of the distribution of plastic waste sources are shown in figure 16. Sewage is a dominant source of plastic waste in the Baltic Sea region with 29%, indicating significant concerns related to sewage management and its impact on litter.

Coastal/Beach Tourism remains also a major source across the Baltic Sea (25%) highlighting the impact of tourism on litter accumulation in coastal areas.

General household contributes with 12%, and also waste collection/treatment has a notable impact with 7%, suggesting changes in waste management processes. Recreational boating and ports also contribute, with a share of 5 or 6%.

Construction and demolition, other industrial activities, and agriculture have lower percentages, indicating less impact on plastic waste pollution.


ARCADIS

Pilot project '4 Seas' - plastic recycling cycle and marine environmental impact

Case studies on the plastic cycle and its loopholes in the four European regional seas areas

European Commission

Project number BE011102328 | Final report | 10-01-2012

Figure 15: ARCADIS (European Commission, 2012)

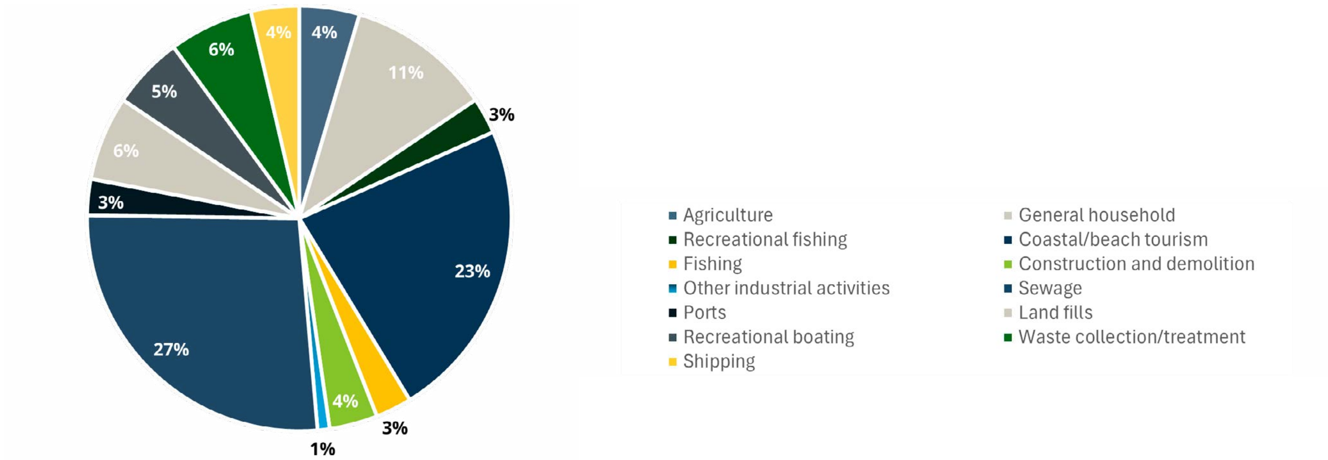


Figure 16: Plastic waste distribution by sources (ARCADIS, 2012)

3.4.4. Floating macro litter in European rivers - Top items

The Joint Research Centre (JRC) exploratory project RIMMEL focuses on the issue of litter, primarily plastic waste, entering European Seas through river systems. The project aimed to understand and quantify the amount and types of riverine floating macro litter entering the sea (Figure 17).

The data was collected with visual observations and the JRC Floating Litter Monitoring Application for mobile devices. The study compiled data on riverine floating macro litter and developed Top Items lists based on the total number of litter items identified. The lists were detailed for four European regional seas: Baltic Sea, Black Sea, Mediterranean Sea, and North-East Atlantic.

For the Baltic Sea case, the study examined, how much plastic waste is transported into the sea by the Vistula River. The Vistula River is the longest river in Poland, flowing approximately 1,047 kilometers from its source in the south of the country to its mouth on the Baltic Sea. It flows into the Baltic Sea into the Gulf of Gdansk, near the city of Gdansk in northern Poland.

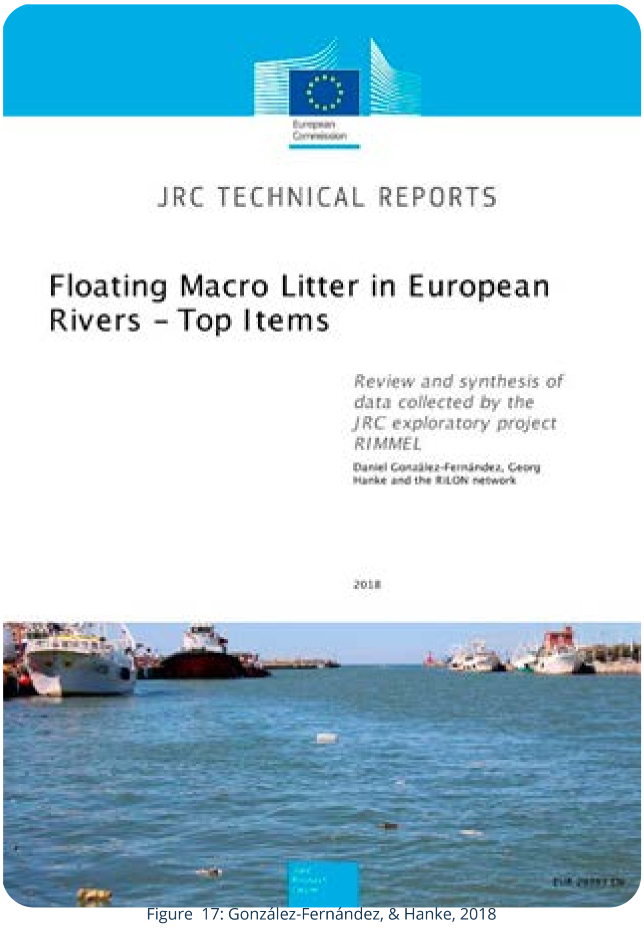


Figure 17: González-Fernández, & Hanke, 2018

The top litter items (Table 4) entering the Baltic Sea region via the river highlight a strong presence of plastics, particularly in the form of bottles and synthetic ropes. Metals and paper/cardboard also contribute to the litter profile, though to a lesser extent (Table 4).

The litter sorted by material categories show, that plastic is the most common waste entering the sea (Figure 18).

Bottles	Plastic	33.7%
Other (metal)	Metal	13.6%
Synthetic rope	Plastic	10.0%
Paper packaging	Paper/card-board	6.8%
Bags	Plastic	5.8%

Table 4: Top Litter Items (González-Fernández, & Hanke, 2018)

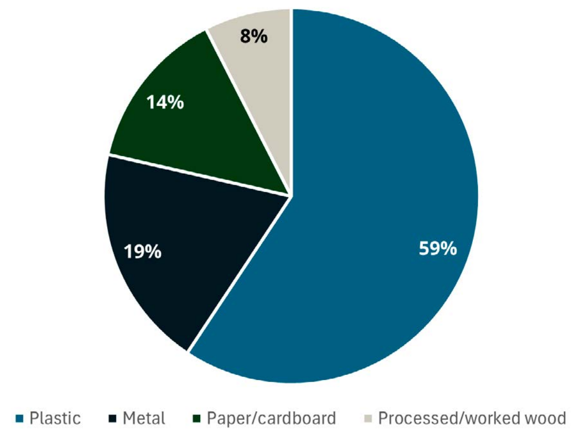


Figure 18: Waste distribution by categories (González-Fernández, & Hanke, 2018)

3.5. Conclusion

The South Baltic Sea is a large, shallow brackish water body bordered by Denmark, Germany, Poland, Lithuania, and Sweden. It features diverse coastlines and has a high population density. The area is vital for shipping, fishing, and tourism. It faces environmental challenges, including pollution and plastic waste inflow.

Plastic waste streams into the South Baltic Sea come from both land-based and sea-based sources, with significant contributions from urban areas and maritime activities. It travels via direct littering, wind, and runoff.

Research of all project partners on plastic waste in the South Baltic Sea reveals, that most data focusses on beach pollution, indicating a need for more riverine litter studies. Pollution levels in the Baltic Sea beaches have lower pollution levels (0.91 pieces/m^2) compared to regions like Portugal, the Canary Islands and South Korea. Marinas in German waters have less sea floor pollution (0.1 particles/m^2) than those in North Africa.

The MARLIN (2013) project found that plastic makes up a large part of marine litter in the Baltic Sea, with urban beaches showing higher litter densities (237 items per 100 meters) than rural ones (76 items per 100 meters). Plastic constitutes 54-62% of the litter. Haseler et al. (2020) reported an average litter density of 0.91 pieces per square meter on Baltic beaches, with plastics at 52.7% of the total. Denmark had the lowest density (0.09/m^2) and Poland the highest (0.55/m^2). ARCADIS (2012) identified sewage as a major source of plastic waste in the Baltic Sea, contributing 29%, with coastal tourism adding 25%. The JRC study noted that the Vistula River significantly contributes plastic waste to the Baltic Sea, including especially bottles and synthetic ropes.

The current data highlights a need for improved research on riverine litter in Baltic Sea tributaries and effective waste management strategies to address plastic pollution in the region.

4.
Marine litter collection methods

Introduction

The COP project focuses on waterways ocean-bound plastic, specifically targeting macro litter-sized particles. These particles can be present at the shoreline, in the water column, on the surface, and at the sea floor. The information provided for each collection method is based on a literature review and personal communication through interviews and has not yet been tested within the project.

Collecting marine litter is a complex and labor-intensive process; it is far more effective to prevent pollution at its source. This can be accomplished through initiatives such as raising public awareness or implementing political decisions, such as reducing the use of single-use plastic as well as implementing proper waste management reducing leakages.

An analysis of the market situation has been carried out to identify the current methods or technologies currently available for the collection of ocean plastic in Europe.
While numerous manufacturers and methodologies are available for collecting marine litter, they can all be categorized into 4 groups: manual collection, booms/barriers, bins and drones (Figure 19).

Figure 19: 4 Different solutions to collect marine litter (COP, 2024)

The following section will briefly introduce these 4 groups, providing examples for illustration. It is important to note that, these methodologies described here represent only a selection intended to offer a concise overview for a deeper understanding of the topic.

The various technologies will be introduced by explaining the requirements for their installation and discussing their respective advantages and disadvantages. This information can assist decisionmakers in selecting an appropriate methodology based on the prevailing environmental conditions.

4.1. Manual collection

Waste collection can be carried out manually through various methods:

- **On foot:** Collecting litter from the shoreside
- **By boat:** Gathering litter from the water surface and upper water layers
- **By divers:** Retrieving litter from the water column and the sea floor

Various entities, including public authorities and private companies, can undertake manual waste collection. However, a significant portion of this work is carried out by volunteers, such as Beach Clean Ups.

In the city harbor of Rostock, Germany, the city employs a private company to clean the water surface. This involves the straightforward process of collecting waste from the pier using landing nets. Complementing this effort, divers from the fire brigade routinely incorporate litter collection into their training dives, targeting the harbor floor (Figure 20). As an example of collective efforts in manual waste collection of OBP in the city of Rostock, please refer to figure 21.

Figure 20: a) Beach Clean-Up (NABU, 2024), b) Divers of the fire department (Stadt Rostock (Foto: Marcel Knaak), 2024)

In several cities, innovative models have emerged to engage the community in waste collection. For example, there is a trend of promoting free paddling for litter collecting. In this model, individuals can rent a kayak for 2 hours at no cost, provided they collect litter during that time (Figure 22).


Figure 22: Green Kayak (Stadt Hamburg, 2024)

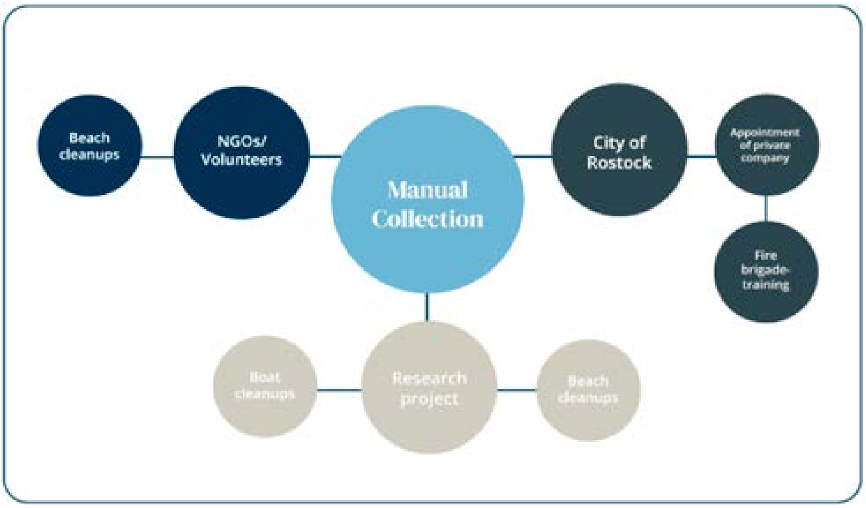


Figure 21: Example of manual collection efforts in the Warnow river, City of Rostock (COP, 2024)

4.2. Booms/barriers

Booms or barriers are utilized to guide marine litter or impede its movement, with various versions available as fixed or floating installations. These structures can be of different forms and sizes based on the water channel dimensions and flow characteristics.

The different forms can be 1) rotatable arm as seen in Aarhus, Denmark, which can open to accommodate small vessels like kayaks, or they manifest as floating options anchored with moorings on the seabed which can either span the whole river width, serve as partial barriers to guide the floating trash into a specific area or to entrap a particular area of the river (such as around a rainwater overflow outlet), 2) constructing a barrier from air bubbles that directs waste particles to a specific corner for collection. Most litter booms effectively gather litter on the water surface and upper water layers.

However, the “Great Bubble Barrier” stands out by collecting litter throughout the entire body of water, reaching even deeper water layers (Figure 23). Constant river flow speeds are necessary for using barriers and booms for waste collection.

Figure 23: a) Great Bubble Barrier (The Great Bubble Barrier, 2024), b), Sea Protector One (Artlinco A/S, 2024) c) DESMI boom (DESMI, 2024)

4.3. Booms/barriers

Litter collection bins consist of a litter collection container and an underwater pump powered by a small electrical engine. The created downward suction pulls in nearby floating waste items, effectively containing them within the bin's interior depository.

The bins can be installed using various possibilities, such as 1) direct installation under a floating dock and 2) a mechanically elevating variant (Figure 24).

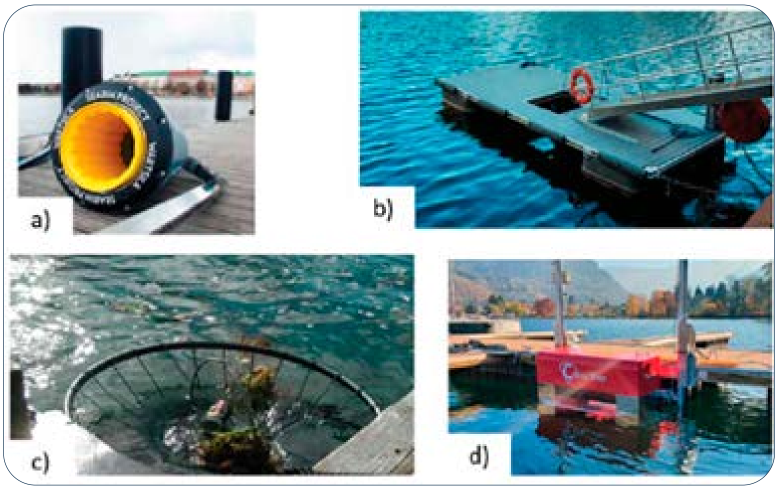


Figure 24: a) SeaBin (NiedersachsenPorts), b), Aquapod (Clean Sea Solutions, 2024), c) Portbin (SpillTech, 2024), d) Collecthor (PORALU Marine, 2024)

These bins are designed to collect litter on the water surface and from the upper water layers. The installation of the bins should be strategically decided based on the flow characteristics, possible locations for the accumulation of the upper layer water debris (litter hotspots, debris bays), ease of emptying, and energy access.

4.4. Drones

Waste collection drones, as shown in figure 25, are uncrewed vehicles that operate autonomously or are remotely controlled on the water surface, actively gathering litter. The drones achieve this either by pulling a net behind them or by using collecting arms to push the waste and channel it to their integrated collection bin. Small waste collection drones, measuring 80 x 80 cm, as well as larger drones with dimensions of up to 1,60 x 2m, are readily available in the market. These drones efficiently collect litter from the water surface and upper water layers. The size of the collected debris depends on the mesh size of the deployed net. Robots designed for collecting litter on the seafloor are still in the research and development phases and are expected to be available in the near future (SEACLEAR, 2024).

Rough weather conditions and high river flow speeds are not suitable, as the drones might drift away (higher suitability for harbors and bays).

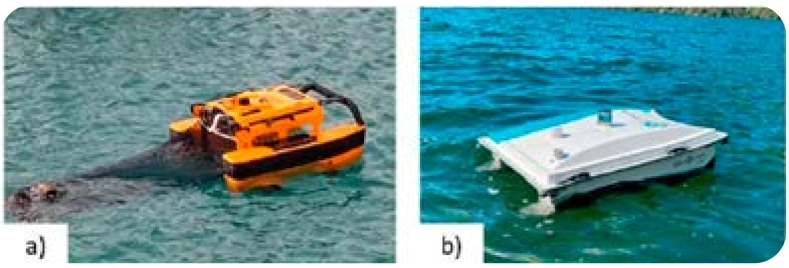


Figure 25: Jellyfishbot (IADYS, 2024), b) Pixie Drone (PORALU Marine, 2024)

4.5. Conclusion

In conclusion to the overview of waste collection methods, table 5 compares the 4 presented options. It is important to note, that the costs vary widely, mainly depending on the characteristics of the river and the specific waste collection device itself. For instance, barriers must be customized to fit the river, and drones can exhibit varying capabilities.

However, determining the best method is not straightforward, as the choice depends on various factors, such as the river's geography, flow speed, wind conditions, existing ship traffic, and the type and volume of litter. A combination of different methods might be the most effective solution.

For example, a litter boom could yield excellent results in narrow rivers with a constant water flow and minimal ship traffic, given its high collection rate. This technology might not be suitable in wider rivers or rivers with heavy ship traffic.

	Manual	Booms/ barriers	Bins	Drones
Installation costs (in EUR)	Non	up to 700,000	6,000-25,000	12,000-70,000
Ship traffic	Mostly not hindered	Hindered	Not hindered	Almost not hindered
Collecting rate	Depends	Very good	Only at one point	Good
Energy needs	Depends	Depends	Electricity	Electricity
Location	Various	In flowing waters	In a litter corner	Harbors and bays

Table 5: Comparison waste collection technologies

The decision tree in figure 26 provides a rough orientation for deciding on the selection of appropriate collection technology.

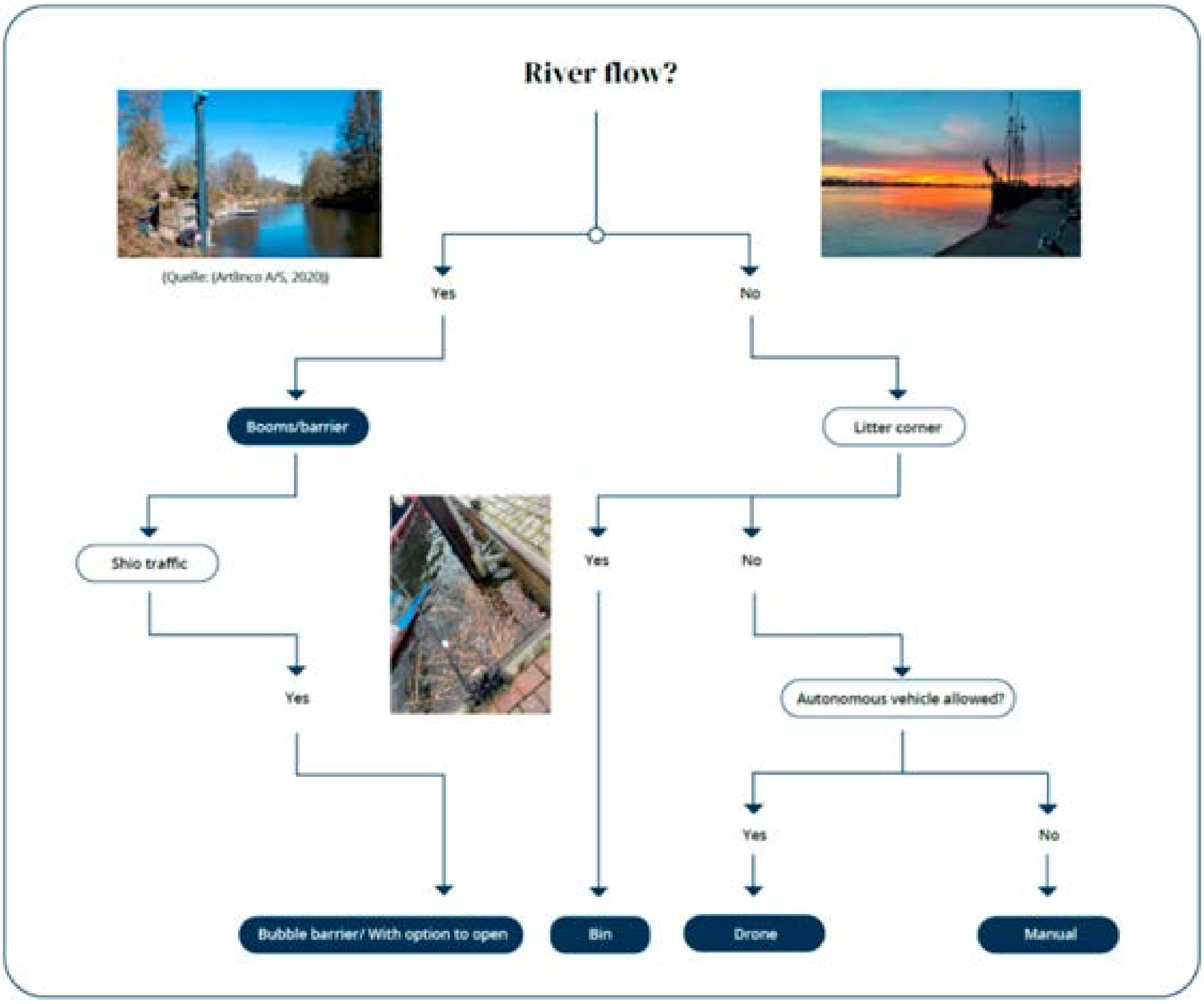


Figure 26: decision tree for methodology choice for waste collection

Currently, the market only offers technological solutions for waste collection on the water surface. The technologies for collection at the sea floor or shoreline are currently under development. Despite the majority of marine litter sinking to the seabed, there is currently no mass-scalable technology for its collection. Developing such a technology appears far more complex than developing a device for collecting waste on the water surface, necessitating further research. This emphasizes the need to raise public awareness and underscore the fact that the visible portion of the trash is just the tip of the iceberg.

In general, reducing littering at its source is more effective than relying on collecting waste as an end-of-pipe solution.

5.
Mapping on plastic utilization infrastructure and identification of recycling methods

Introduction

This chapter gives an overview of the regional plastic waste generation in the participating countries, with a special focus on the 3 pilot cities and Malmö. A description of the current waste management practices, especially the plastic recycling infrastructure, will give a first idea on the plastic waste streams in the 4 countries.

Global context

Plastic has many advantages. It is cheap, lightweight, long lasting and can be used for many different products. We will most probably see an increase (rather than a decrease) in its possibilities and range of use. In the last 72 years, the global production of plastics increased significantly, from about 2Mt in 1950 to 400.3Mt in 2022 (Plastics Europe, 2023). It is estimated that 51Mt of plastics were generated in the year 2022 in Europe. Of this amount, 30Mt were collected as plastic waste with 30% of the amount collected being recycled (Figure 27).

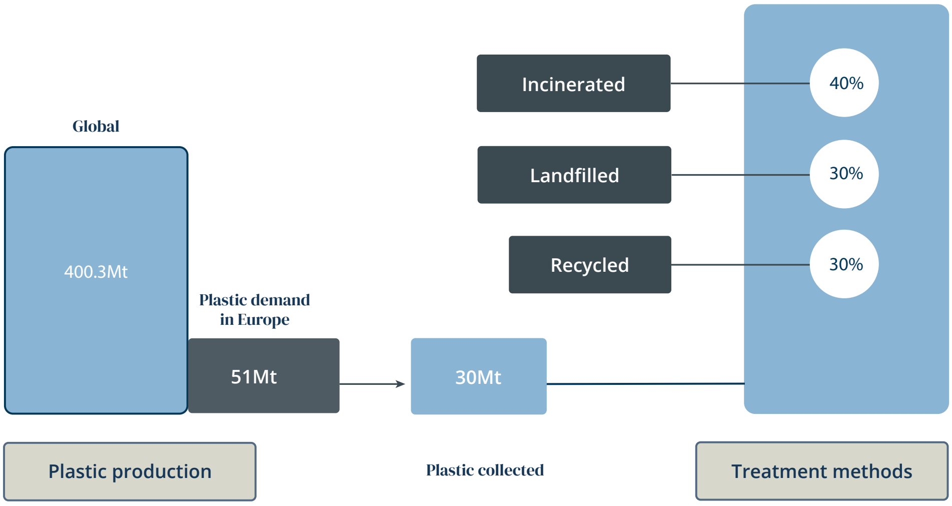


Figure 27: Treatment methods for collected plastics in Europe (Christensen & Baelum, 2023)

Packaging is the largest and dominant contributor to plastic waste due to its short product lifetime. Typically, packaging plastic becomes waste within 6 months. Plastic pollution poses a significant threat to ecosystems and wildlife. Discarded plastic items often end up in oceans, rivers and landfills, where they can persist for hundreds of years, harming marine life and terrestrial habitats. The amount of plastic waste entering natural environments can be reduced by recycling plastic and preserving biodiversity as well as ecosystem health (IUCN, 2024).

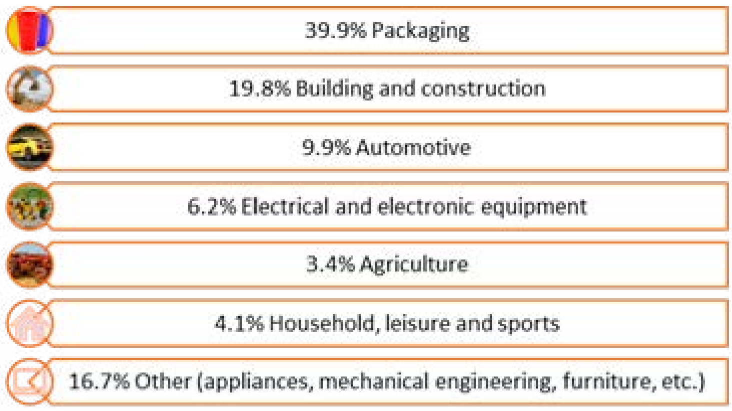


Figure 29: Mechanical recycling of plastic waste process (Christensen & Baelum, 2023)

There are 3 forms of plastic recycling methods – mechanical, chemical and energy recycling. Majority of Europe's plastic wastes are recycled through mechanical recycling. Figure 29 shows a schematic diagram of the mechanical recycling process.

One report estimated that, an amount of 8.2Mt of plastic waste were recycled in the year 2021 via mechanical recycling (AMI Consulting, 2022).

The remaining are treated using methods such as chemical recycling (i.e., pyrolysis, gasification, etc.), dissolution recycling, among others (REPETCO, 2022). Figure 30 depicts the 2021 plastic packaging recycling rate by each Member State in the European Union (EU-27).

In the COP-project participating countries, the generated plastic packaging waste is being recycled up to 48.40% in Germany, 22.90% in Denmark, 23.80 % in Sweden and 31.70% in Poland.

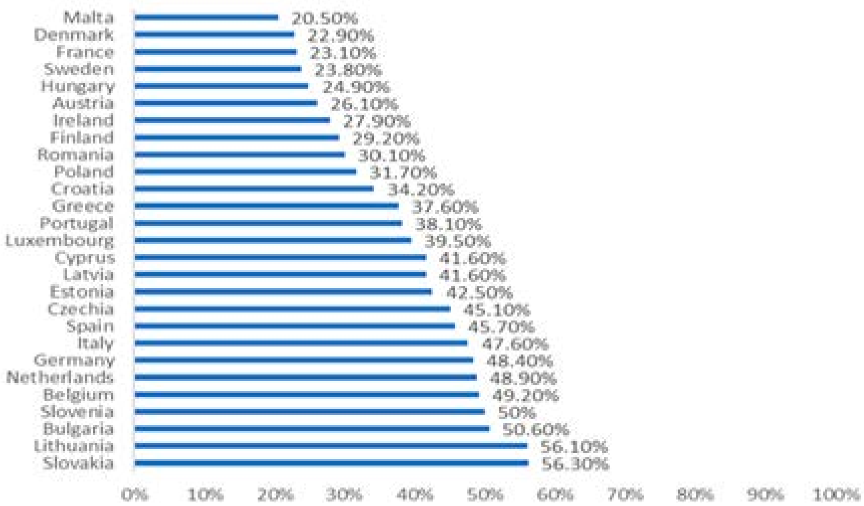


Figure 30: Plastic packaging recycling rate by country in 2021 in the EU (Eurostat, 2023)

5.1. Overview of waste management

In the next pages, a short overview of the waste management practices with a focus on the plastic recycling infrastructure is presented for the 4 pilot areas in order to better understand the recycling options for ocean-bound plastic in the South Baltic region.

Pilot area - Rostock, Germany

Rostock follows German national regulations and imposes mandatory waste sorting policies. Residents are required to separate their waste into different categories: general waste, paper, plastic, clear glass, colored glass and compostable/biological waste. Yellow colored bins are used specifically for plastics (or so-called lightweight packaging), where residents place recyclable packaging materials such as plastic bags, containers and other packaging materials.
The share of plastic waste was 5.67Mt in 2021 in Germany. Of this amount, almost 99.4% were recovered and treated via mechanical recycling (35%), energy recycling (64%) and feedstock recycling (0.4%). The remaining 0.6% were disposed to landfill (UmweltBundesamt, 2023). Figure 31 shows the plastic waste flow in Germany in 2021.

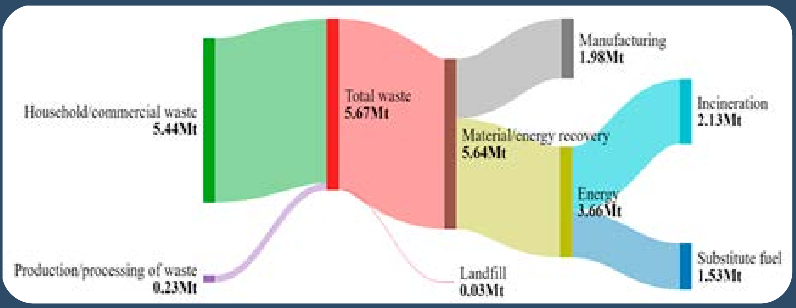


Figure 31: Plastic waste flow in Germany in 2021

There are 196 plastic recycling plants operating in Germany with one of them located in Mecklenburg-Vorpommern. For more details please visit (ENF, n.d.). Another report (Christensen & Baelum, 2023) lists twenty-seven plastic recyclers in Germany. Nineteen of them employ mechanical recycling technology in processing the waste and the remaining eight recyclers employ chemical and dissolution technologies like pyrolysis, chemolysis, etc. The capacities of the plant range from 6,000 – 95,000 tons/year.

The total amount of produced waste materials in the city of Rostock was recorded to be around 101,300 tons in the year 2018. Around 96,500 tons came from private households and around 4,800 tons from other sources (street cleaning and public waste bins). The approximately 4,800 tons of waste from other sources were sent to a composting plant and a mechanical-biological waste treatment plant being managed by Veolia Umweltservice Nord GmbH, EVG mbH (Hanse- und Universitätsstadt Rostock, 2024).

The approximately 96,500 tons of waste from private households, around 51,300 tons were recycled and around 45,200 tons were processed in the mechanical-biological waste treatment of Veolia Umweltservice Nord GmbH, EVG mbH.

Pilot area - Aarhus, Denmark

In Aarhus, as well as the rest of Denmark, household waste is managed by an efficient infrastructure in close collaboration with the municipalities and waste management companies. Since 2021, the Waste Executive Order ("BEK nr. 2512 af 10/12/2021") has obliged the Danish municipalities to collect ten waste fractions (Retsinformation, 2021).

The 10 waste fractions in the private households and companies are source segregated in waste bins which are then delivered and emptied by the waste management companies. The waste management companies are either directly operated or contracted by individual municipalities. As it is difficult to manage ten waste bins in the households, some fractions are collected together, later to be sorted by the waste management companies. These fractions vary from one municipality to another, which is why the waste bins vary in the municipalities. The waste collection is performed periodically depending on the waste fractions (ibid).

In Aarhus municipality, Kredsløb A/S is responsible for the collection of waste from households and industries. An average household in Aarhus pays a fee of DKK 2,585 (€346) in total to have their waste containers emptied.

Total waste generated in Denmark in the year 2022 was 12.2Mt. Of this amount, 195,441 tonnes came from plastic waste and tires (Figure 33).

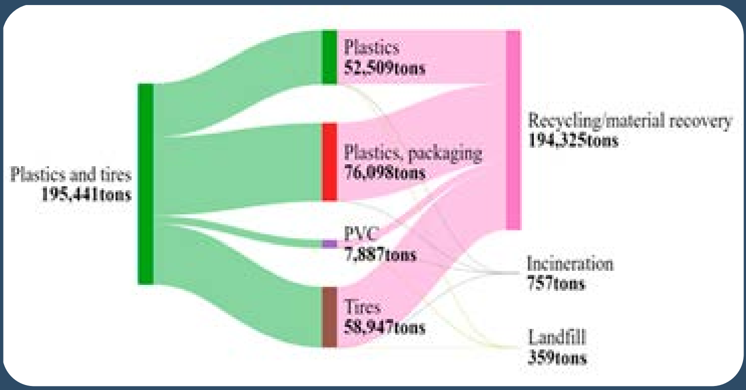


Figure 33: Plastic waste flow in Denmark in 2022

The numbers of plastic recycling in Denmark are continually rising. Denmark has seventeen mechanical plastic recycling plants, focusing on different polymer types. There are seven chemical plastic recyclers in Denmark, but only one plant of them is labelled as full-scale plant, while the others are either pilot plants or still under construction. The primary technology applied is pyrolysis and focus on PE and PP. Two of the plants are using solvolysis (for PUR polymers) and dissolution (for PET and cotton) respectively. All the recycling companies are registered as private companies (Christensen & Baelum, 2023).

Pilot area - Gdansk,Poland

Poland's journey towards an organized, modern recycling system began in the early 2000s, following its accession to the EU in 2004. EU membership brought stringent environmental regulations and target standards that Poland was required to meet, prompting the country to overhaul its waste management practices. The implementation of the EU Waste Framework Directive and the Packaging Waste Directive provided the legislative framework for Poland's recycling efforts.

Collecting and Sorting Systems

The collection and sorting of plastic waste in Poland are managed through several systems, designed to cater for both urban and rural areas such as:

- Curbside Collection: Municipalities provide households with separate bins for different types of wastes including packaging/plastics. This system facilitates source separation, which is crucial for maintaining the quality of recyclables.
- Recycling Points: Public recycling points (Punkty Selektywnego Zbierania Odpadów Komunalnych, PSZOK) are established in many communities where residents can bring various recyclable materials, including plastics (Codex, 2019).
- Extended Producer Responsibility (EPR): Producers are required to take responsibility for the end-of-life management of their products including collection, recycling and disposal. This is facilitated through systems like the Green Dot, where producers and retailers pay fees based on the type and amount of packaging they introduce to the market.
- Deposit Return System (DRS): Poland is in the process of implementing a nationwide DRS for beverage containers, including plastic bottles. This system is expected to significantly increase the recycling rates of these items.

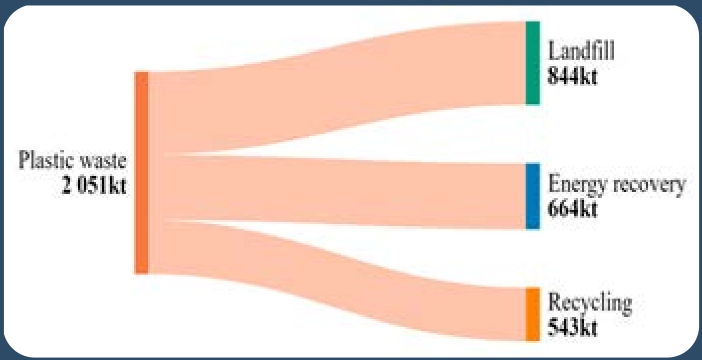


Figure 34: Plastic waste flow in Poland in 2020

Poland generated about 2,051kt of plastic waste in the year 2020. Figure 34 shows the flow of plastic waste treatment methods in Poland in the same year (Plastics Europe, 2024).

Pilot area - Malmö, Sweden

Under the Swedish Environmental Code, each Swedish municipality is responsible for ensuring that municipal waste is transported, recycled or disposed of appropriately. Municipal waste refers to waste from households and waste that is similar in nature and composition to waste from households, such as from restaurants, shops, offices, etc. (Avfall Sverige, 2023).
The municipalities must choose how waste management is organised. There are several organizational structures available:

- Self-administration
- Municipal enterprise, owned independently or jointly with other municipalities
- Joint board
- Municipal association

Sweden generated approximately 1.71Mt of plastic waste in the year 2016/2017. Figure 35 shows the flow of plastic waste in Sweden in the same year (ibid).

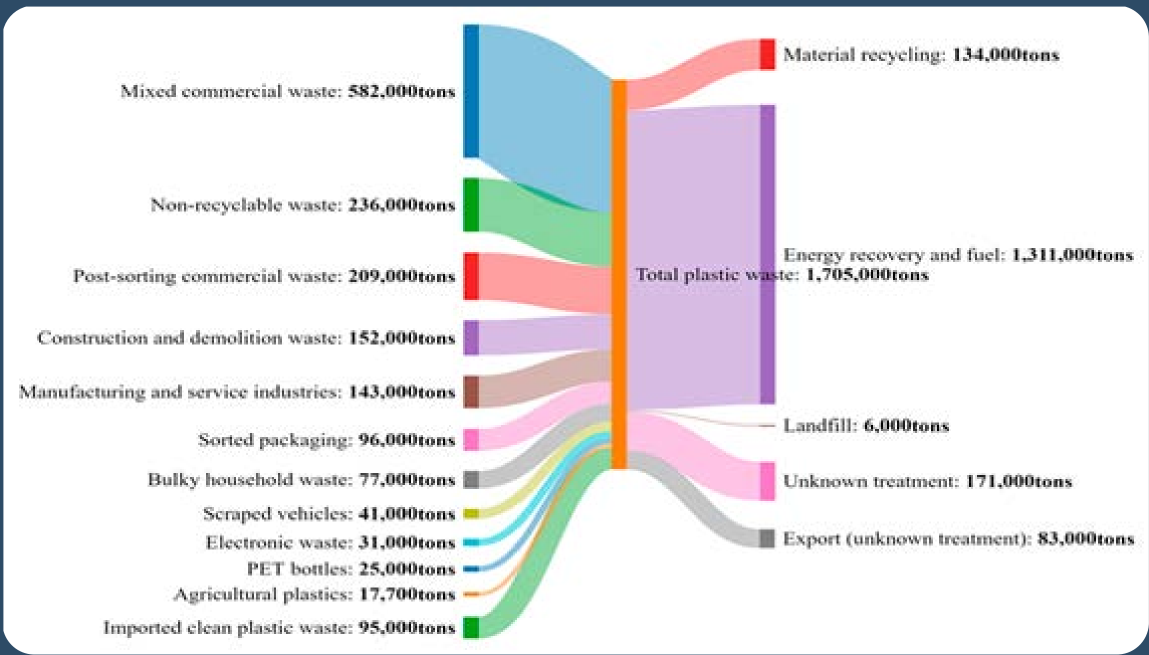


Figure 35: Plastic waste flow in Sweden in the year 2016/2017

According to (ENF, n.d.), there are eleven plastic recyclers operating in Sweden with one of them located in Malmö.

5.2. Conclusion

All 4 pilot cities (and the respective countries) implement mandatory waste sorting policies, ensuring that residents separate their waste into various categories including plastics. This practice is fundamental to improving the quality and efficiency of recycling processes.

Regarding the technological infrastructure, Denmark and Sweden have advanced recycling technologies including chemical recycling methods. Gdansk and Rostock rely more on mechanical recycling and energy recovery methods.

In order to improve the plastic recycling situation in the South Baltic Areas the following measures could be implemented:

1. **Harmonization of Recycling Standards:** Developing unified standards and practices across regions can streamline recycling processes and improve efficiency.
   Investment in Advanced Technologies: Increasing investment in advanced recycling technologies, such as chemical recycling, can expand the types of plastics that can be effectively recycled.
2. **Educational campaigns:** Strengthening public education on the importance of recycling and proper waste sorting can increase participation rates and improve the quality of recyclable materials.
3. **Collaborative approach** in addressing the leakages of plastics in to the environment mitigating ocean bound plastic.
4. **Technology and burden sharing** with the boundary states/countries would further enhance the recycling.

The most important strategy is to start on top of the waste pyramid with the avoidance as well as minimization of the waste. In most countries the per capita generation of waste, especially plastic and packaging waste is still increasing. Manufacturers and consumers need to amend their behavioural changes and limit/reduce the needed plastic packaging amounts.

By adopting these measures, regions can move closer to a circular economy thereby reducing the environmental impact of plastic waste and promoting sustainable development.

6.
Policy analysis

Introduction

This chapter focuses on investigating policies and legislations regarding plastic waste by analyzing the current legislations in the European Union (EU) and the legislation on the national, regional and local levels in Denmark, Sweden, Germany and Poland.

6.1. Plastic waste policies and legislations on a European Union level

The Single-use Plastics Directive (Directive (EU) 2019/904)

From July 3rd 2021, the Directive (EU) 2019/904 bans the ten (10) most common single-use plastics (SUPs) found on Europe's beaches and seas causing 50% of marine litter. Figure 36 shows the list of the affected products. Further, all SUP bottles must have tethered caps and lids effective of July 3rd 2024 (Directive (EU) 2019/904, Article 5 and 6).

The Plastic Bags Directive (Directive (EU) 2015/720)

Directive (EU) 2015/720 aims to dwindle the consumption of lightweight plastic carrier bags among Member States in the EU. To achieve this, Member States are urged to set rules that ban the provision of free lightweight plastic bags in shops by December 31st 2018. Further, Member States are entreated to ensure that lightweight plastic bags consumption does not exceed 90 bags per person per year by December 31st 2019 and this must be reduced to 40 bags per person per year by December 31st 2025 (Directive (EU) 2015/720, Article 1).

European Strategy for Plastics in a Circular Economy

The European Strategy for Plastics in a Circular Economy was published by the EU on January 2018 and has the following targets: (a) all EU plastic packaging products should either be reusable or recycled economically by 2030, (b) more than 50% of Europe's plastic wastes must be recycled by 2030, (c) a sharp reduction of plastics leakage into the environment, (d) encouragement of innovative, sustainable and alternative materials for plastic production in Europe, among others (Watkins & Schweitzer, 2018).

Figure 36: SUPs banned by the EU (Scyphus, 2019)

Microplastics Policy

The Microplastics policy framework was proposed by the EU to decrease the release of microplastics into the environment by 30% by 2030. Microplastics are plastics <5mm in dimension. They are intentionally added to numerous products like cosmetics, household and industrial detergents, fertilizers, products utilized in the petroleum industries and many more for several reasons. Due to the high risks microplastics pose to the environment and marine ecosystem, measures have been adopted by the European Commission to restrict intentionally added microplastics into consumer products, among others, including the ban on loose glitter and microbeads by October 2023 (Tsang & Kvedar, 2024).

The Marine Strategy Framework Directive (MSFD, 2008/56/EC)

The MSFD is the most important current legislative tool for addressing marine litter in the EU. The main goal of this Directive is to ensure that marine waters attain a good environmental status in the EU and to subsequently guard the marine ecosystems. Good Environmental Status is defined as:
“The environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive.” The Directive requests Member States to take responsibility of their marine waters through the development of national marine strategies to maintain a good environmental status by 2020. To help visualize the new marine environment after the implementation of the Directive, 11 qualitative descriptors have been outlined (figure 39).

Figure 39: The 11 descriptors by the MSFD (Copernicus, 2021)

6.2. Germany: Plastic waste policies and legislations

Packaging Act (Verpackungsgesetz)

Reducing packaging waste and increasing recycling rates for sales packaging are the primary goals outlined in the new German Packaging Act which seeks to make significant contribution to environmental protection. The Act contains comprehensive obligations for retailers and manufacturers dealing with packaged goods. Some of the obligations are paid participation in a dual system and registration with the Central Agency Packaging Register. Failure to comply with the obligations attracts a fine ranging from €100,000 to €200,000 (www.lizenzero.de; Blank et al., 2024).

Single-Use Plastic Ban Regulation (Einwegkunststoffverbotsverordnung)

On July 3rd 2021, Germany implemented the EU's SUPs Directive (Directive (EU) 2019/904) which bans certain single-use plastic types including cutlery, plates, straws, etc., for which eco-friendly alternatives already exists. It should be mentioned that all products made from oxo-degradable plastics and food packaging containers such as styrofoam are banned under this regulation. A fine of up to €100,000 will be paid by people who doesn't comply with this regulation (Blank et al., 2024).

Single-Use Plastic Labelling Regulation (Einwegkunststoffkennzeichnungsverordnung)

This regulation ensures that SUP products, that have not yet been banned in Germany, like tobacco filters, wet wipes, beverage cups, and so on, must bear the pictograms, as shown in figure 40 to educate customers on the presence of plastics and also to encourage proper disposal (Blank et al., 2024).

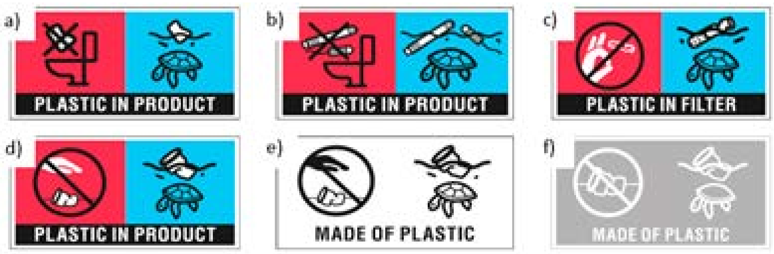


Figure 40: a) Sanitary towels and wet wipes, b) Tampons and tampon applicators, c) Tobacco products with filters, d) Beverage cups made partly from plastic, e) Beverage cups made wholly from plastic printed, f) Beverage cups made wholly from plastic embossed (Commission Implementing Regulation (EU) 2020/2151)

Deposit return system (DRS)

Germany's DRS for plastic and other beverage containers has proven to be an effective way to collect and recycle large tons of empty packaging and beverage containers. It is estimated that DRS in Germany reached a record high of 98% return rate being the largest and highest-performing system in the World (Tomra, 2023). Figure 41 shows container labels that are eligible to be returned for refund in Germany's DRS. The system will extend to cover milk and dairy product containers in 2024 per reports.

Figure 41: Return me for your money (ibid)

Extended producer responsibility (EPR)

In the EPR system of Germany, manufacturers are held accountable for the waste generated by their products. Hence, promoting sustainable packaging design and waste management.

6.3. Denmark: Plastic waste policies and legislations

Regulations on free plastic bags and thin plastic carrier bags

On January 1st 2021, the Danish government placed a ban on the distribution of free plastic bags to customers when shopping from various markets in the country. Instead, Danish citizens are expected to pay DKK 4.00 for the plastic bags regardless of size and material. This is to promote the reuse of plastic bags. Thin plastic carrier bags, which cannot be reused were banned by the Danish government (Figure 42). The exemption to this ban is the use of very thin plastic carrier bags for packaging fruits, meat and vegetables, owing to hygiene reasons (www.euromeatnews.com).

Extended Producer Responsibility (EPR) for SUP

In Denmark, the new EPR Directive for packaging items ensures that manufacturers bear the cost of collecting and sorting household waste, promote recycling and to support programs aimed at reducing plastic pollution. This policy is expected to start fully by January 1st 2025 (RLG, 2024).

Deposit return system (DRS)

Denmark has a DRS for plastic bottles and cans, which encourages recycling and decreases marine litter. The DRS in Denmark is among one of the best performing systems for upcycling plastic waste in Europe. For instance, in 2021, the DRS in Denmark recorded its highest recycling return rates of 92%, making it one of the best performers in the area (www.plasticactioncentre.ca).

Figure 42: Very thin plastic carrier bags (www.starlightpackaging.co.uk)

6.4. Poland: Plastic waste policies and legislations

SUP Ban

Starting from May 2023, the ten (10) most commonly found plastics on Europe's beaches and seas, as mentioned in the Directive (EU) 2019/904, are banned in Poland. This includes oxodegradable plastics and expanded polystyrene like shopping bags, among others.

Labelling requirements

In Poland, certain plastic types that are not banned yet such as tobacco products, tampons, wet wipes, inter alia, are mandated to be labelled according to the prescribed pictograms by the EU.

Extended Producer Responsibility (EPR)

The EPR system in Poland was implemented in January 1st 2020. The main aim of this system is to standardize the practice of packaging and packaging waste management nationally. Producers, importers, distributors, and online sellers of packaging products are held accountable under this system.

The EPR system in Poland classifies steel, aluminium, plastic, wood, glass, paper and cardboard as packaging products. The parties held accountable under the system are required to register with BDO (Baza Danych o Odpadach) so that they can be made responsible for the products they put on the market (Lovat, 2024).

Recycling fee law

This law requires companies operating in Poland to pay a recycling fee ranging from €0.1-0.6/kg of packaging products placed on the market. The law has been operational since 2018 and the main aim is to prevent packaging waste.

6.5. Sweden: Plastic waste policies and legislations

National Plastic Action Plan

The Government of Sweden announced on February 21st 2022 the country's roadmap to stop plastic pollution through the implementation of the national plastic action plan. The following are the targets set to end plastic waste and pollution in the action plan:

- Consumption of plastic bags should be limited to 40 bags per person per year by 2025.
- SUP cups and food containers should be reduced by 50% by 2026.
- By 2027, the country aims to increase the use of reusable packaging products by 20%.
- Collection of waste from fishing gear to be increased to 20% by 2030.
- Reduction of SUP packaging products, cigarette butts, wet wipes, etc. by 50%
- Plastic packaging must include at least 30% recyclable materials on average (United Nations, n.d.).

In addition, other measures in the Swedish legislative framework include:

- **Producer responsibility:** Producers are responsible for the costs of awareness-raising measures, collection and cleaning up their products after the end of use.
- **SUP Tax:** Taxes (SEK 3 per bag for big bags and SEK 0.3 per bag for small bags) have been put on SUP carrier bags which started from March 2020 (www.thepaperbag.org).

6.6. Conclusion

In this section, plastic waste regulations in the EU and implemented by the 4 member states including Germany, Denmark, Sweden and Poland have been reviewed. Marine litter consists up to 70% of disposable plastic products and fishing gear. The major policies analyzed in this chapter include SUP bans, free plastic carrier bags ban, plastic tax, labelling requirements, EPR and DRS. The analyses show that some countries lag behind in the implementation of the relevant EU policies.

By implementing these strategies at all levels in the 4 member states, good disposal and recycling habits will be formed and plastic waste pollution on the Baltic Sea can be reduced.

7.
Summary
- and Outlook

7.1. Summary

The COP project, being part of the EU Interreg South Baltic initiative, addresses the issue of ocean-bound plastic in the South Baltic Sea. The overarching goal of the project is to reduce plastic waste entering the sea by analyzing its sources and pathways, with a focus on collection, reuse and recycling. This initiative covers Germany, Denmark, Sweden and Poland focusing on pilot areas in Aarhus, Rostock and Gdansk.

Ocean-bound Plastic is defined as waste at high risk of reaching the ocean, primarily from land-based sources within 50 km of coastlines. It is carried by rivers, wind, rain, and human activities. The report highlights the urgent need to address plastic waste to protect marine ecosystems and human health.

The COP project focuses on 3 pilot cities and one associated city, each selected for their connection to the South Baltic Sea and their significant waterways. The selected pilot areas, despite their similar criteria, display distinct characteristics. Rostock features a broad estuary, Aarhus and Malmö have artificial canals, and Gdansk combines both types of water bodies.

For collecting marine litter there are 4 main types of technologies: manual collection, booms/barriers, bins and drones, each with its own advantages and disadvantages.

The South Baltic Sea, bordered by Denmark, Germany, Poland, Lithuania, and Sweden, is vital for shipping, fishing, and tourism but faces pollution challenges, particularly from plastic waste. Plastic enters from land and sea sources, including urban areas, maritime activities and runoff. Most research focuses on beach pollution, underscoring the need for more studies on riverine litter and improved waste management to combat plastic pollution in the region.

Mapping on plastic waste streams and the corresponding recycling methods in the four pilot cities have been outlined. Mechanical recycling is the commonly used treatment method for recycling plastics in the EU. 30,000 tons of the generated plastic waste in Germany goes to landfill. In Denmark, 359 tons of the generated plastic waste goes to landfills. 6,000 tons of plastic waste in Sweden goes to landfill whereas the number of plastics deposited in landfill in Poland is 844,000 tons. The plastic packaging recycling rates in all four countries are below the set target. This should be improved to reduce the amount of plastic waste deposited in landfills and subsequent leakage into marine bodies.

The review and implementation of EU policies and legislations protecting the placing on the market of disposable plastic packaging materials have been investigated in the four pilot cities. The EU has targeted ten of the most single-use plastics causing 50% of marine litter. Based on this, the four pilot cities have implemented several Directives including placing a ban on certain single-use plastics. The other types of single-use plastics such as wet wipes, and beverage cups, among others, have labels either printed or embossed informing consumers about their proper disposal. The speedy implementation and enforcement of these Directives in all the pilot cities will reduce plastic litter in the sea and marine bodies.

All 4 pilot cities (and the respective countries) implement mandatory waste sorting policies, ensuring that residents separate their waste into various categories including plastics. While landfilling plastic wastes is nearly abolished in Germany, Denmark, and Sweden, it still makes up a huge proportion of plastic waste treatment in Poland. Landfilling poses a higher risk of the plastic material being harmful to the environment and the sea. A harmonization of treatment options and minimization of plastic use are suggested and started to be implemented with the respective EU directives which are being adopted by the member states.

7.2. Outlook

The idea is, to do the litter assessment over a period of minimum one year in each pilot area to gain a detailed understanding of the situation and to propose improvements. The aim is, to determine also the influence of weather conditions or local celebrations. Various waste collection devices were installed and tested for this purpose, as figure 43 shows.

- **Rostock:** 3 Port Bins will be placed in areas known for high litter accumulation.
- **Aarhus:** A Sea-protector One, a fixed but openable barrier over the river has been installed over the Aarhus river.
- **Gdansk:** In addition to 1 Port Bin and 2 Seabin, kayaks will be provided to enable residents to paddle and collect litter.

Another focus will be on investigating, how the plastic waste collected in the pilot areas can be effectively used or recycled. Stakeholders involved in plastic waste management will be analyzed and strategies for mitigating plastic pollution developed.

Figure 43: a) Port Bin in Rostock b) Seaprotector One in Aarhus c) Port Bin in Gdansk d) Kayaks in Gdansk

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