Scalable full-cycle marine litter remediation in the Mediterranean: Robotic and participatory solutions

SeaClear2.0

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D2.2 Public Demonstrations, Pilot Sites and Showcases Plan

WP2 – Concept design & technical specification

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1 R = Document, report, DEM = Demonstrator, OTHER = Software, technical diagram, etc., DMP = Data Management Plan

2 PU = Public, C-UE/EU-C = EU Confidential under Decision 2015/444, SEN = Sensitive

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Table of Contents

1. Introduction 9
   1.1 Overall objective of the deliverable 9
   1.2 Document structure 9
2. Demo and Pilot site introduction 10
   2.1 Environmental Conditions 10
      2.1.1 Climate and weather 10
      2.1.2 Oceanographic parameters 12
      2.1.3 Seafloor structure 13
      2.1.4 Biodiversity 13
      2.1.5 Litter fractions 15
      2.1.6 Marine Traffic 18
   2.2 Legal framework 19
      2.2.1 Waterborne vehicles 19
      2.2.2 Aviation law 21
      2.2.3 Nature protection 27
   2.3 Demo & Test Site specification 28
      2.3.1 Domain characterization 28
      2.3.2 Potential test sites 29
      2.3.3 Dissemination potential 32
      2.3.4 Infrastructure for deployment and operation equipment 33
      2.3.5 Social spaces, office, and meeting rooms 35
      2.3.6 Stakeholder Options 36
   2.4 Conclusion 36
3. Boundary conditions 38
   3.1 Technical Constraints 38
   3.2 Environmental constraints 40
   3.3 Operational Constraints 40
   3.4 Regulatory and compliance constraints 40
   3.5 Safety and security constraints 40
   3.6 Conclusion 41

Definitions

- **Beneficiary:** A legal entity that is signatory of the EC Grant Agreement no. 101093822.
- **Consortium:** The SeaClear2.0 Consortium, comprising the list of beneficiaries below.
- **Consortium Agreement:** Agreement concluded amongst the SeaClear2.0 beneficiaries for the implementation of the Grant Agreement.
- **Grant Agreement:** The agreement signed between the beneficiaries and the EC for the undertaking of the SeaClear2.0 project (Grant Agreement no. 101093822).

Beneficiaries of the SeaClear2.0 Consortium are referred to herein according to the following abbreviations:

- **TU Delft**: TECHNISCHE UNIVERSITEIT DELFT
- **DUNEA**: REGIONALNA AGENCIJA DUNEA
- **Fraunhofer**: FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG EV
- **HPA**: HAMBURG PORT AUTHORITY
- **ISOTECH**: ISOTECH LTD
- **MDanchor**: M. DANCHOR LTD
- **Subsea Tech**: SUBSEA TECH SAS
- **TECNOSUB**: TÉCNICAS Y OBRAS SUBACUÁTICAS, SLU
- **TUM**: TECHNISCHE UNIVERSITAET MUENCHEN
- **UNIDU**: SVEUCILISTE U DUBROVNIKU
- **UTC**: UNIVERSITATEA TEHNICA CLUJ-NAPOCA
- **VEO**: VEOLIA PROPRETE
- **VLPF**: VENICE LAGOON PLASTIC FREE

Abbreviations

- **EC**: European Commission
- **GA**: Grant Agreement
- **WP**: Work Package
- **ML:** Marine Litter
- **FNU**: Formazine Nephelometric Units
- **FTU**: Formazine Turbidity Unit
- **CNR ISMAR**: Istituto di Scienze Marine osservazione e ricerca
- **UAS**: Unmanned Aerial Systems
- **VLOS**: Visual line of sight
- **AIS**: Automatic Identification System
- **USV**: Umanned surface vehicle
- **ROV**: Remotely operated vehicle
- **BVLOS**: Beyond visual line of sight
- **EASA**: European Union Aviation Safety Agency
- **AESA:** Agencia Estatal de Seguridad Aérea
- **REU:** Tarragona Reus Airport
- **DFS**: Deutsche Flugsicherung (German Air Traffic Control)
- **NABU**: Nature and Biodiversity Conservation Union
- **SASEMAR:** Sociedad de Salvamento y Seguridad Marítima (Spanish sea rescue)
- **CCAA:** Croatian Civil Aviation Agency
- **ENAC:** Ente Nazionale per l'Aviazione Civile (Italian Civil Aviation Authority)
- **UAS:** Unmanned aircraft system
- **GDPR:** General Data Protection Regulation
- **SERA**: Standardized European Rules of Air
- **ALDFG**: Abandoned, Lost or otherwise Discarded Fishing Gear
- **NGO**: Non-Governmental Institution
- **IAPH**: International Association of Ports and Harbors

Executive summary

This deliverable is part of work package 2 defining the overall concept design and technical specification of the SeaClear system. Work obtained within this work package directly contributes to the technical developments and design features of the robotic system. Tailored development work requires a description of the specific areas of use and in terms of technical, environmental, and infrastructural preconditions to deploy the system, prove its functionality and efficiency. In SeaClear2.0 this concerns information from the projects demo locations in Dubrovnik (Croatia), Marseille (France) and Tarragona (Spain) as well as the pilot locations in Ashdod (Israel), Hamburg (Germany) and Venice (Italy). D2.2 gathers all relevant information including end user expectations and requirements by systematically investigating on and defining of suitable areas to perform tests and demonstrations. This will cover specific locations, their infrastructural environment and equipment to enable physical deployment and operation before, while and after the system use. In that regard local challenges, boundary conditions, regulatory and legal requirements will be listed. With the individual use cases definition per location the demo scenarios are shaped. However, this shall be considered as a recommendation towards deploying and operating the systems in each location, as it heavily relies on successful integration and functionality of components developed throughout the project.

An ongoing political and military conflict in the region of Israel has affected our partner MDAnchor. We dearly hope, for the conflict to end soon. Information in this deliverable on the pilot site Ashdod is made available to the best knowledge but may be updated later.

1. Introduction

1.1 Overall objective of the deliverable

This report defines the specifications of the planned demonstrations and closely defines the use cases for each demonstration area and pilot site for the full-scale joint system operation as well as single component use.

The aim is to describe the overall character of each demo and pilot site and define the requirements to operate autonomous systems. This document will be the basis for all technical developments and the planning of system demos and pilots. The boundary conditions established will later be used to formulate design objectives for the robotic system.

The use case specification will define and reveal shortcomings that may be tackled through the involvement of associated regions.

1.2 Document structure

The document is structured in two main chapters introducing the demo and pilot sites, in which the SeaClear2.0 system will be deployed. This is done by describing the environmental preconditions, the local legal framework as well as presenting specific demo and pilot locations. In a second part, the boundary conditions are extracted from the previously described technical, environmental, operational, regulatory and safety aspects, and converted into constraints for the system development.

2. Demo and Pilot site introduction

This chapter serves as an introduction to the local characteristics at the demo and pilot sites by emphasizing their overall conditions impacting the SeaClear System development. The main topics will focus on environmental factors, regulatory requirements, and the demo site specification.

2.1 Environmental Conditions

The following pages contain a description of the natural environment of the demo and pilot locations in which the SeaClear2.0 System will be deployed and operated. Those conditions will help to derive the overall boundary conditions and make choices towards the design and material to include for the system development to ensure successful operation in all those environments.

2.1.1 Climate and weather

Five of the six chosen demo sites are at the Mediterranean Sea, but the local climate and weather varies slightly as summarized in Table 1. The specific conditions will influence the demo planning and implementation. Wintertime is excluded in all locations, as strong winds occur during that period of the year complicating safe and secure drone flights up to prohibiting them from a regulatory point of view. The Bora is a strong winter wind in Dubrovnik reaching up to 180 km/h resulting in interruptions in sea and air traffic. In Marseille and Venice, a similar phenomenon, the Mistral with up to 120 km/h respectively the Scirocco, can be observed. In those cases, the best time for demos and pilot campaigns is from spring and fall.

		Demo locations			**Pilot sites**		
		Dubrovnik	**Marseille**	**Tarragona**	**Ashdod**	**Hamburg**	**Venice**
Climate & Weather (average)	Temperature (min/max)	12°C to 30°C	3,6°C to 35°C	11,1°C to 21°C	10°C - 32°C	-1,4° C to 22,2° C	2,5°C to 22,7°C
	Rainfall (ml/m ²)	32,5 (July) to 145,4 (Nov)	10 (July) to 75 (Sept)	1,67 to 153,37 Average 41,5	1 (June, July, Aug) – 66 January	42,4 - 77,7	47 (Jan) to 73,5 (Sept) average 62
	Sunshine (hr/d)	4,3 - 11,68	4,5 - 10,5	7,7 - 11,2	6.5 – 12.2	1,1 - 7,2	9- 16
	Rain (d)	4 (July)-12 (Nov)	1 (July) - 6 (Oct, Nov, Dec, Apr)	4 -7	0 – 9	8,9 - 12,4	9 (July) - 6 (Nov)
	Humidity (%)	60-70%	53%-75%	62% - 75%	56% - 69%	71 % - 87 %	73-77 %
	Wind force	0-180 km/h	0-110 km/h	0 – 17 km/h	0 – 49 km/h	0 – 90 km/h	0-22 km/h
	Weather phenomenon	Strong winter winds Bora (up to 180 km/h)	Strong winter wind (Mistral) - gusts up to 120 km/h	Summer storms	Sandstorms	Storm season from Sept. - March, with floods and strong winds	strong wind from southeast in autumn - Scirocco
	timing for demos	Spring to autumn	Spring to autumn	spring / autumn	May - October	April-August	April - September

Table 1: Summary of the local weather and climate conditions in the 6 demo and pilot locations for the SeaClear2.0 project.

On the other side, high summer temperatures in Tarragona lead to the development of storms due to connective instability, where warm air rises, cools, and forms clouds, often leading to thunderstorms. The increased moisture-holding capacity of warm air, temperature differences between air masses, sea breeze effects near coasts, and upslope flows in mountainous terrain close to the city are all factors that contribute to storm formation during hot summer weather. During July and August those storms

are short and with an amount of precipitation that normally doesn't cause many affectations. If those storms don't occur during the summer, it's highly probable that more intense ones happen in mid late September. Because of high temperatures in summer demos and trials are preferably done in spring or fall.

As for Ashdod, July is supposed to be the windiest month of the year and sandstorms during summer in the overall region also have an impact on Israel. Still, trials are recommended during May-October.

In Hamburg, the official storm season lasts from early September till March of the following year. Strong winds, and storm surges, result in partial flooding of the port and some urban areas in the city of Hamburg. In worst cases, this results in shut down of port terminal operations and ship traffic. Therefore, demos and trials are recommended to be scheduled from April till End of August, where weather conditions are expected to be the most stable.

Venice as a natural and cultural World Heritage Site is a celebrity case of the present and future patterns of climate change. The climate of Venice is related to the exacerbation of interplaying sea and atmospheric phenomena: the sirocco wind from Southeast and the astronomical tide. The latter determines the rise in sea level as a function of the position of the Moon in its Earth orbit. The level of the tides is due to the rise in sea levels, expected to grow in the order of 2-3 millimeters per year. This means that we may expect an increase in the scale and frequency of the well-renowned traditional episodes of high tides in Venice during October, November, and December. This is also confirmed by the modeling applied to the Mediterranean basin by which the topicalization of the climate in the Mediterranean basin will increase temperatures, cyclones, windstorms, storm surges and extreme weather events.

2.1.2 Oceanographic parameters

Besides climate and weather, the specific oceanic parameters like water temperature, salinity, currents, turbidity, tides, waves, and water depth at demo and pilot site will affect the choice of suitable areas for system trials. The general data for each site is accumulated in Table 2.

		Demo locations			Pilot sites		
		Dubrovnik	**Marseille**	**Tarragona**	**Ashdod**	**Hamburg**	**Venice**
Oceanographic parameters	Water depth	01-50 m	01 - 25 m	Up to 20 m	01 - 25 m	up to 18 m, +/- 3.66 m due to tidal currents	average 1.5 m to 25 m at entrance of the port inlets
	Currents	approx. 0.5 - 4 knots	0 - 2 knots	None inside port	0.5–4 knots	max. 2.5 to 3.4 knots	3-4 knots
	Wave height	relatively low waves	0 - 2.5 m (period 6s)	None inside port	-	up to 1.5 m	average of 1.14 m as from the CNR ISMAR scientific platform data located 7 miles offshore
	Water Temperature	12-29°C	11 - 26°C	12.3 – 29.2°C	17.8–29.4°C	0 - 27°C	9 - 30°C
	Salinity	32-38%	36 -38 g/l	-	-	0.5‰	21.1-33.8%
	Oxygen	6,11 - 7.11 mg/l	5.2 mg/l	-	-	9.9 - 12.2 mg/l	80 % saturation: 0.4/20.3 mg/l
	pH value	8	8	-	-	7,8	7.7 to 8.3
	Visual range	up to 25m	2 to 10 m	1 m	-	< 0.5 m	< 1 m
	Turbidity	low - medium	low - medium	high	Low-medium	high: 25 to 50 FNU (max. 100 FNU)	high: 13 FTU

Table 2: Overview on the oceanographic parameters in the demo and pilot site impacting the SeaClear2.0 System development regarding design objectives as well as material and component choices.

Overall, the expected water depths in in the semi enclosed areas of Tarragona Port (20m), Ashdod Port, Hamburg Port (18m) and Venice (25m) will not exceed 25 m, which is also the limit for Marseille. Dubrovnik offers depths of 50 m contributing to the project's envisioned operation depth of 200 m. The maximum currents to expect, whether resulting from sea or tides, range around four knots and can be experienced in Venice, Dubrovnik, and Hamburg. Especially the visual range and turbidity may be a limiting factor occurring in Tarragona, Hamburg, and Venice due to the natural conditions, and additional effects from sedimentation and ship traffic. In In Marseille, turbidity increases drastically with Mistral wind (around 50 days per year, mostly during winter).

2.1.3 Seafloor structure

The overall seafloor structure in the Mediterranean Sea region is comparable composing of silt sand and seaweed like Posidonia. The slopes may be characterized mostly flat to moderate in all sites.

The shores around Dubrovnik are rocky limestones that changes from larger to smaller sized rocks with increasing depth and shift to *Posidonia oceanica* seagrass meadows at 5-10 m depth. In some areas, coastal limestones form submerged or partially submerged sea caves. At depths between 20 and 100 meters, we often encounter unique underwater reefs coraligen. The rocky coast of Mali Ston Bay overlaps by a moving sediment of sand, silt and/or mud with scarce individual smaller rocks (<0,5 m diameter) protruding from the bottom. In places, the bottom is covered with discarded or naturally occurring bivalve shells.

A large part of the seafloor in Marseilles Bay is covered by seagrass (essentially Posidonia), the rest composes of sand, mud, silt, and specific rocky bottoms. Similar underwater conditions can be found in Tarragona where silt and sand are common, including rocky formations. The seafloor structure Ashdod is mostly comparable again composing of sand, mud, silt, and sporadic rocky bottoms. Venice varies from sand to muddy clay from the inlet to the inner part of the lagoon, sometimes even organic or artificial rocky formations may be found.

The situation in the port area in Hamburg proves to be different. High tide currents carry sediments form the North Sea, which settle in the riverbed, as the river currents are too weak to carry the sediments back to the North Sea estuary. Therefore, the ground is a heterogenous area sometimes with sandy seamounts and respective valleys, and in other parts a sludgy and silty structure with occasional occurrence of larger stones. Litter sinks deep into the sludge, making it hard to detect.

2.1.4 Biodiversity

The Mediterranean Sea presents a rich marine underwater life, which differs in the specific demo environments of the SeaClear2.0 project. The City of Dubrovnik, which is part of the southernmost county in Croatia, Dubrovnik Neretva County, is listed as UNESCO World Heritage site. More than 80% of the county surface is marine area with over 713 islands and reefs. There are more than 40 designated nature protected sites, and an overall 60% of Dubrovnik Neretva County is protected under NATURA 2000 ecological network including various specific NATURA 2000 species. The area has abundant habitats of *Posidonia oceanica meadows* and unique *coralligenous biocenosis – coraligen* (coralline algae with corals, sponges, bryophytes, mollusks, crabs, and fishes). These formations are a specific characteristic of the Adriatic Sea, and due to its biological diversity and sensitivity, the European Union and Croatia have included it in endangered and rare habitats - an endemic habitat of outstanding value for the Mediterranean Sea. The Adriatic Sea is also home to marine turtles, altogether seven species among which the Loggerhead Sea turtle (*Caretta caretta)* is most frequent. Sea turtles are recognized as one of the most endangered groups in the world and all species are included in the IUCN Red List. West of the city of Dubrovnik, in 2023 the scientist from The Blue World Institute, noticed the dolphin species Risso's dolphin (*Grampus griseus*), and concluded that this southern part of the Adriatic, is an important habitat for these dolphin species. In Dubrovnik Neretva area, there have been recent notes of the Mediterranean monk seal (*Monachus monachus*), which is one of the most endangered mammals in the world, and plastic waste poses a large threat to its habitat. The specific area of Mali Ston is included in the Natura 2000 network, with the main habitat being type 1160 Large shallow inlets and bays and the remainder habitats type 1170 Reefs, 1120 *Posidonia* beds, and 1110 Sandbanks. The sea bottom in Mali Ston Bay includes a rocky, as well as sandy and muddy bottom with settlements of seagrasses *Posidonia oceanica* and *Cymodocea nodosa*.

Benthic communities formed under the impact of shellfish farms are characterized with reduced vegetation and small rocky areas densely inhabited by sessile invertebrates. Construction elements and farm facilities are densely overgrown with invertebrates and algae, but with low biodiversity of macroscopic species in this area. Similarly, marine litter is often overgrown by fouling organisms. A total of 17 protected species (5 algae, 2 seagrasses, 3 bivalve mollusks, 2 cnidarians, 4 sponges and 1 species of fish) were recorded in Mali Ston Bay, among which endemic brown algae *Fucus virsoides*. This area was also abundant with the bivalve *Pinna nobilis*. The noble pen shell (*Pinna nobilis*) is especially common inside the settlements of *Posidonia.*

Figure 1: Posidonia Oceanica, a widely spread and protected species in the Mediterranean Sea.[3]

Around Marseille Sea bream, wrasse, sea bass, grouper (P), seahorse, urchins, squid, octopus, red coral (protected species), gorgons are common. The flora there also hosts the protected Posidonia as well as lithophyllum, cystoseira, padina pavonica.

The Venice lagoon has a vast number of fishing species as well, in particular the groups of gobies pipefishes, pupfishes, the sand smelt, and the peacock blenny. The Mediterranean killifish, the Adriatic lagoon goby and, above all, the black-spotted goby are some of the most typical species associated with these environments. Transitional water habitats also represent a nursery area for juveniles of marine migrant species, such as the European flounder and mullets of the genera Mugil and Chelon.

Due to the close vicinity to the North Sea, the Elbe River in Hamburg is home to eleven diadromous migratory fish species that can live in both salt and fresh water eco systems. 40% of the counted types are Aland, bream, European eel, flounder, river perch, white bream, claw fish, roach, smelt and pikeperch. Besides the fish, different mammals like otters, beavers, muskrat, and nutria are spotted within the city´s waters. Especially beavers are nowadays considered an established species. Beavers and muskrats are mainly seen in the southern parts of the port that are less affected by the tidal flows. In rare cases seals find their way from the Elbe estuary to the most western beginnings of the port. Harbor porpoises are more regularly spotted while following the smelts upriver.

[3] https://www.iloveelba.it/2019/12/23/le-praterie-di-posidonia-oceanica-una-risorsa-per-lelba-e-il-mediterraneo/

2.1.5 Litter fractions

Extensive knowledge on the litter types and quantities has been gathered in Deliverable D2.1 – Marine Litter Occurrence Domains Report. According to that, marine litter (ML) is a specific kind of waste, defined as any persistent, manufactured, or processed solid material discarded into the sea, rivers, or on beaches. It can be brought indirectly to the sea with rivers, sewage, stormwater, or winds, or intentionally discarded at sea. ML fractions are extremely diverse and depend directly on the human activities implemented, which, in the first case, caused the waste production. Underwater litter fractions are subject to biofouling eventually becoming part of the marine habitat itself and decomposes into smaller fractions and microplastics in the end.

The marine litter occurrence in the demo and pilot sites of the SeaClear2.0 project have been investigated and grouped in fraction sizes according to the protocol defined in the Guidance on Monitoring of Marine Litter in European Seas (A guidance document within the Common Implementation Strategy for the MSFD)[4], which divides ML fractions in following categories:

A. < 5cm*5cm = 25cm² - e.g., plastic cups & lids, cigarette butts, corks, ice cream sticks

B. < 10cm*10cm = 100cm² - e.g., glass or ceramic fragments

C. < 20cm*20cm = 400cm² - e.g., bottles (<0,5 l), cosmetic containers, plastic bags, phones, tetra pack

D. < 50cm*50cm = 2.500cm² - e.g., bottles (>0,5 l), floats for fishing nets, hats, helmets

E. < 100cm*100cm = 10.000cm² = 1m² - e.g., fish boxes, ropes, buoys, car parts

F. > 100cm*100cm = 10.000cm² = 1m² - e.g., nets, fishing line, sunbeds, bicycle, tractor tire, scooters

Litter findings in each demo and pilot location have been analyzed and categorized. An overview of the categories, materials, and dimensions, as well as quantities are summarized in Table 3.

		Demo locations			**Pilot sites**		
		Dubrovnik	**Marseille**	**Tarragona**	**Ashdod**	**Hamburg**	**Venice**
Litter	Categories	cigarette butts, plastic plugs, fishing gear	tires, bikes, cans, household, bags, chairs, bottles, appliances, scooters	tires, steel parts, plastic bottles, ropes, containers	plastic bags, cups, aluminum cans, jute bags, car tires	tires, electronic devices, steel parts, bikes, rivets	Glass bottles, tires, construction materials, plastic
	Material	mostly plastics, paper, metal, wood	mostly plastic, rubber, glass, steel, metal, wood	plastic, metal, rubber	plastic, metal, natural, rubber	plastic, rubber, steel, metal, wood	Plastic, glass, construction material, rubber
	Dimensions	A (<25 cm²) - F (>1 m²)	A (<25 cm²) - F (>1 m²)	A (<25 cm²) - E (<1 m²)	A (<25 cm²) - E (<1 m²)	A (<25 cm²) - F (>1 m²)	A (<25 cm²) - E (<1 m²)

Table 3: Litter types and fractions to be found in the demo and pilot site exposing the range of items to be tackled with the SeaClear2.0 system.

The greater Dubrovnik Neretva County area is under the influence of ML, as severe amounts of waste are carried by marine currents and waves reaching the shores. Considering analysis by origin, most

[4] MSFD Technical Subgroup on Marine Litter - Guidance on Monitoring of Marine Litter in European Seas, 2013

items are connected to inland tourism activities and mariculture activities. Litter collection is currently done through beach and diver based clean ups with volunteers.

Summary of main ML fractions that will be subject of the SeaClear 2.0 use case in Dubrovnik:

- Sea surface – various floating plastic items, floating ML hotspots washed away from land
- Seafloor – various plastic items entangled in protected Posidonia meadows, specific ML from shellfish farms (oyster and mussel pergolas tangled in large patches, plastic crates from shellfish farming, farming construction pieces, etc.) and ALDFG.
- ML fractions size estimations: from A. < 5cm*5cm = 25cm² to F. > 100cm-100cm = 10.000cm² = 1m²

In Marseille, at present time, litter is detected and collected also through several annual volunteer events, beach based with school children for example or with apnea divers for submerged litter. In 2022, the cleaning actions coordinated by the Mer Terre association involved 1.434 volunteers and 64 associations, cleaning a total 4.9 Tons (79 m³) in 39 sites around Marseilles Bay.

Summary of main ML fractions that will be subject of the SeaClear 2.0 use case in Marseille:

- Sea surface – various floating plastic items.
- Seafloor – heavier ML fractions, plastic, rubber (car tires and similar), and metal, all connected to the port activities.
- ML fractions size estimations: from A. < 5cm*5cm = 25cm² to F. > 100cm*100cm = 10.000cm² = 1m²

In depth knowledge on the marine litter occurrence around Tarragona was obtained through the help of Tarragona´s university research group and the Tarragona Port Authority database. ML has been collected via trawl collection in summer and autumn.

Summary of main ML fractions that will be subject of the SeaClear 2.0 use case in Tarragona:

- Sea surface – various floating plastic items.
- Seafloor – plastic items up to 100m depth, specifically plastic bags, and sanitary products. It is estimated that in the relative port area, heavier ML fractions, plastic, rubber (car tyres and similar), and larger metal items will also be found, all connected to the port activities.
- ML fractions size estimations: from A. < 5cm*5cm = 25cm² to E. < 100cm-100cm = 10.000cm² = 1m²

Ashdod is a city in the southern coastal plain of Erez Israel. It is one of Israel's two industrial ports. Israel coastal waters have major litter hotspots. Litter analysis was done as part of two scientific papers giving insights in quantities and materials.

Summary of main ML fractions that will be subject of the SeaClear 2.0 use case in Ashdod:

- Sea surface – various floating plastic items (bags, cups, caps, etc.)
- Seafloor – various plastic items (Yuta bags and big industrial bags with possible marine life inside), metal items and specifically various plastic items heavily accumulated in depths of 200 to 500 m. It is estimated that heavier ML fractions will also be found in near proximity of the

port, such are various plastic and construction items, rubber (car tires and similar), and metal, all connected to the port activities.

- ML fractions size estimations: from A. < 5cm*5cm = 25cm² to E. < 100cm-100cm = 10.000cm² = 1m²

In Hamburg the urban channels are cleaned by several volunteers either passing with kayaks and stand-up paddles collecting especially floating litter and divers taking care of the collection at the seafloor. Litter in the Elbe River is washed ashore especially during the storm season and storm surges. It is then collected by initiatives like NABU (Nature And Biodiversity Conservation Union) organizing clean up days with youth groups. Besides that, litter on the seafloor of the Elbe River is most likely detected during regular monitoring and surveying processes. The removal of the mostly large items is facilitated with divers and respective equipment.

Summary of main ML fractions that will be subject of the SeaClear 2.0 use case in Hamburg:

- Sea surface – various floating plastic items from onshore activities.
- Seafloor – mostly heavy items (lost tools and equipment from operation and maintenance works on infrastructure and ships, tires, etc.)
- ML fractions size estimations: from A. < 5cm*5cm = 25cm² to F. > 100cm-100cm = 10.000cm² = 1m²

Venice has several factors playing a part in plastics pollution due to its unique features, in terms of morphological setting and density of resident (decreasing) and transient population (increasing). Ten rivers flow into Venice Lagoon bringing in plastic litter along their path. Finally, Venice has its port that stretches over an area of more than 2,045 hectares to 5% of the total surface of the Municipality of Venice. ML knowledge has been gathered during a research-based dredging process in the Grand Canal.

Summary of main ML fractions that will be subject of the SeaClear 2.0 use case in Venice:

- Sea surface – various floating plastic items brought by river inflow.
- Seafloor – various plastic items, metal, specifically glass bottles and glass fragments, car tires.
- ML fractions size estimations: from A. < 5cm*5cm = 25cm² to E. < 100cm-100cm = 10.000cm² = 1m²

In summary, the largest items to collect for the SeaClear2.0 system will be found in Dubrovnik, Hamburg, and Marseille reaching sizes of more than 1 m² mostly connected to fishing or port related activities.

2.1.6 Marine Traffic

Due to their location at the Mediterranean Sea, the chosen test sites Dubrovnik, Marseille, Tarragona, Ashdod, and Venice do not only attract a lot of yearly visitors but note different waterside commercial and leisure activities. Besides sportive engagement like e.g., surfing, sailing, diving, and canoeing, ship traffic needs to be taken into consideration when planning SeaClear Demos. Table 4 gives an overview of what may be expected in each location.

		Demo locations			Pilot sites		
		Dubrovnik	**Marseille**	**Tarragona**	**Ashdod**	**Hamburg**	**Venice**
Marine Traffic and Activities	Container vessels	no	yes	Yes	-	yes	yes
	Cruise ships	yes	yes	Yes	-	yes	yes
	ferries	yes	yes	Yes	-	yes	
	working class vessels	yes	yes	Yes	-	yes	yes
	gondolas	no	no	No	-	no	yes
	Sailing boat	yes	yes	Yes	-	yes	yes
	motorboats	yes	yes	Yes	-	yes	yes
	Dinghy/ inflatable boats	yes	yes	Yes	-	yes	yes
	canoes /rowing boat	yes	yes	No	-	not in the port, but in urban canals	yes
	(kite) surfers	yes	yes	not in port area	-	no	yes
	stand up paddles	yes	yes	not in port area	-	yes	yes
	diving/ snorkeling	yes	yes	not in port area	-	mostly commercial	yes

Table 4: Summary of the sea traffic to expect in the demo locations highlighting leisure and commercial activities.

Tourism is a driving factor for Dubrovnik and the Croatian coast with the various islands nearby. Cruise ships and ferries are common in the area, but the picture is dominated by sailing ships, motorboats, lots of canoes, stand up paddlers and diving activities.

Between the Marseille harbor site, which will see mostly large vessels, and the tourist site, which hosts different types of leisure boats and recreational devices, all kinds of traffic can be expected. The Tarragona Port scenery is characterized mostly by container vessels, cruise ships, and working-class vessels as well as motorboats, and sailing ships. The Port of Hamburg at the Elbe River is approached mainly by large cargo vessels and cruise ships. Besides those, inland barges, public ferries connecting the two sides of the river as well as smaller motorboats and sail boats contribute to the busy traffic in the port area all year long. Towards the city, smaller channels are entered frequently by harbor cruise ships and the inland waterways are popular and equally busy for water activities like canoeing, stand up paddling, rowing, and sailing especially from spring till fall.

Venice has its port that stretches over an area of more than 2,045 hectares to 5% of the total surface of the Municipality of Venice. Within the port, there are two very distinct areas, namely Porto Marghera - which hosts the logistics, commercial and industrial activities -, and the Port in Venice, which has mainly risen around the Marittima passenger port and minor berths, where passenger services are organized and supplied to cruise ships, hydrofoils, and yachts. In 2022, Venice got 13

million tourists with an increasing trend, that requires a terrific logistic effort on the water to provide whatever is necessary in terms of their physical transport and delivery of goods and services required for their stay. The water traffic is therefore very high, with an uncertain estimation of their number (about 24.000 boats belonging to residents only) and many other transient vessels operating for leisure or business with peaks in summer characterized by persistent wave motion and engorged channels, starting from the Grand Canal the most famous and visited in the city center.

Figure 2: Typical image of the traffic at the Venice channels ranging from gondolas to motor and tender boats.

Information on the specific traffic conditions in Ashdod will need to be added later.

2.2 Legal framework

Even though all demo locations are found in Europe, the specific local rules, regulations, and legislation may affect the operation of autonomous systems. This section lists the requirements and documents needed to gain permissions by local authorities about the use of unmanned waterborne and aerial vehicles and environmental concerns connected. It points out the challenges arising in the application process for permits and highlights recommendations from the end-user point of view to handle them early on. Lastly, stakeholder opinions are gathered.

2.2.1 Waterborne vehicles

The use of waterborne vehicles in real time environment in the participating partners member states is subject to detailed conditions from local authorities and ministries, which grant permissions. To do so, they mostly all ask for documents describing the planned mission, the vehicles operated, risk and mitigation measures as well as insurance policies. However, there is so far no distinguishing between USVs and AUVs. The requirements, permissions to obtain, and limitations in each of the demo and pilot sites are summarized in Table 5.

		Requirements	Permissions to obtain /Limitations
Demo locations	**Dubrovnik**	● vehicle specifications ● name of facility monitoring the operation ● name of the operator ● specification e.g., on the exact mission, area, and speed.	● approval from Dubrovnik Port Authority, issued by the Ministry of the Sea, Transport and Infrastructure
	Marseille	● tender boat to secure operations ● insurance ● AIS, nav lights ● VLOS operation ● No night operation	**For harbour:** Permission from harbor master **For recreational area:** Permission from maritime prefecture + marine park
	Tarragona	● tender boat to secure operations ● area marking with buoys ● insurance	● Port Authority permission ● Spanish Authorities ● Guardia Civil ● Staff on site needs to wear safety equipment (shoes, life vest helmet) ● Aerial drone operation
Pilot sites	**Ashdod**	-	-
	Hamburg	● tender boat to secure operations, with operator holding boat and radio operation license ● insurance ● AIS, ship horn ● VLOS operation in distance of 500 m during daylight ● Staff on site needs to wear safety equipment (Shoes, life vest, helmet)	● Permission from Harbor Master, Port Authority, and site operator ● Port operations have priority
	Venice	● Professional tender boat to secure operations, with marine operator holding boat, listening to the VHF safety channels and an authorized mooring place for the set up. ● insurance ● AIS, ship horn and VHF ● VLOS in open areas operation need authorization from ENAC	● Permission from the Harbor master, port authority/ Municipality or Ministry of Transport and Infrastructure (PIOPP) depending on the location of the test site.

Table 5: Overview on the requirements and permissions to obtain prior to deploying autonomous waterborne vehicles in the environment of the demo and pilot sites.

In Dubrovnik USV and ROV operations are approved by the Dubrovnik Port Authority and permissions granted by the Ministry of Sea, Transport, and Infrastructure. The formal application must contain information on the operator and the institution leading the campaign. The vehicles parameters as well as the planned mission, specifying on the operation area and use case must be named.

In Marseille, regulations are evolving fast. From 2022, unmanned vessel navigation is now covered by a specific ordinance which defines maximum dimensions and weight beyond which maritime prefecture authorization is compulsory (SeaCat falls in this category). Authorization files include USV description, intervention area coordinates, risk assessment and mitigation measures, planned dates and duration, specification of tender vessel, description of supervising team. It is soon expected to also see a compulsory USV pilot license delivered by a certified training center.

Besides Port Authority authorizations, Spain Authorities must be informed in Tarragona. The Guardia Civil (Police) might be present during operations. It is advised to calculate two to three months to prepare formal application documents. A report outlining the mission's objectives and timeline, specifying the precise operational site, and including a risk evaluation with plans for risk reduction would be requested to obtain the permit to proceed. Additionally, documentation regarding the system and proof of insurance must be provided. A tender boat is essential for operational safety. Start and end of operations would have to be daily notified with port control and SASEMAR. The use of the SeaClear2.0 System would be authorized if it doesn't interfere with normal port operations and takes place within a delimited area.

The use of unmanned waterborne vehicles within the port of Hamburg is like the Spanish regulations and has developed accordingly with the more frequent use and demo of such vehicles. Standard procedures currently require a formal request and permission by the harbor master, which issues a maritime police permit. Applications should be sent three months ahead of the planned demo and consist of a document describing the planned operation and duration, the exact location where missions take place and a risk assessment also containing mitigation measures. Data sheets to the vehicles deployed must be submitted alongside proof of insurance. Operations require a tender boat for safety reasons and there should be no interference or hindrance of general port activities. Once the permission is granted, operations must be registered with the harbor master and the regional port district responsible prior to launching unmanned surface and underwater vehicles. The marine police and Habor Master may stop by for an unannounced visit checking for documents and proper implementation. After completion missions must be signed out with the harbor master and district. In case of loss or damage to the USV, ROVs or port infrastructure, the harbor master and property owner must be informed immediately. Operations need to stop, until the harbor master allows to proceed.

In Venice formal permission is requested and granted by the Harbor Master, Port Authority and/or the Ministry of Transport and Infrastructure. The safety measures resemble the ones in the other locations asking e.g., for a tender boat to secure maneuvers, radio communication and visual line of site (VLOS) operations.

2.2.2 Aviation law

Unlike in the case of unmanned waterborne vehicles, the EU has drawn up specific regulations to govern the commissioning of flying drones within the EU Regulations 2019/947 and 2019/945, that apply for all the member states.

According to the European Union Aviation Safety Agency (EASA) civil drone operations are classified in three categories estimating the risk-profile individually:

- The *open category* does not require operational authorization as the risk is considered low and given that the operator complies with the relevant requirements.
- In drone operations that fall in the *specific category*, safety is ensured by the drone operator by obtaining authorization from the national competent authority based among others on a risk assessment before starting the operation.
- The *certified category* with a considerably high risk requiring a certification of the drone operator and drone as well as licensing of the pilot. [5]

[5] https://www.easa.europa.eu/en/domains/drones-air-mobility/operating-drone

The drones operated in SeaClear2.0 fall under the open category, that is divided into three subcategories A1, A2 and A3. The difference between the subcategories lies mainly in the weight of the UAV, which is the lowest in A1 and highest in A3. Within the subcategories different drones can be operated. They are classified by weight in groups C0-C4.

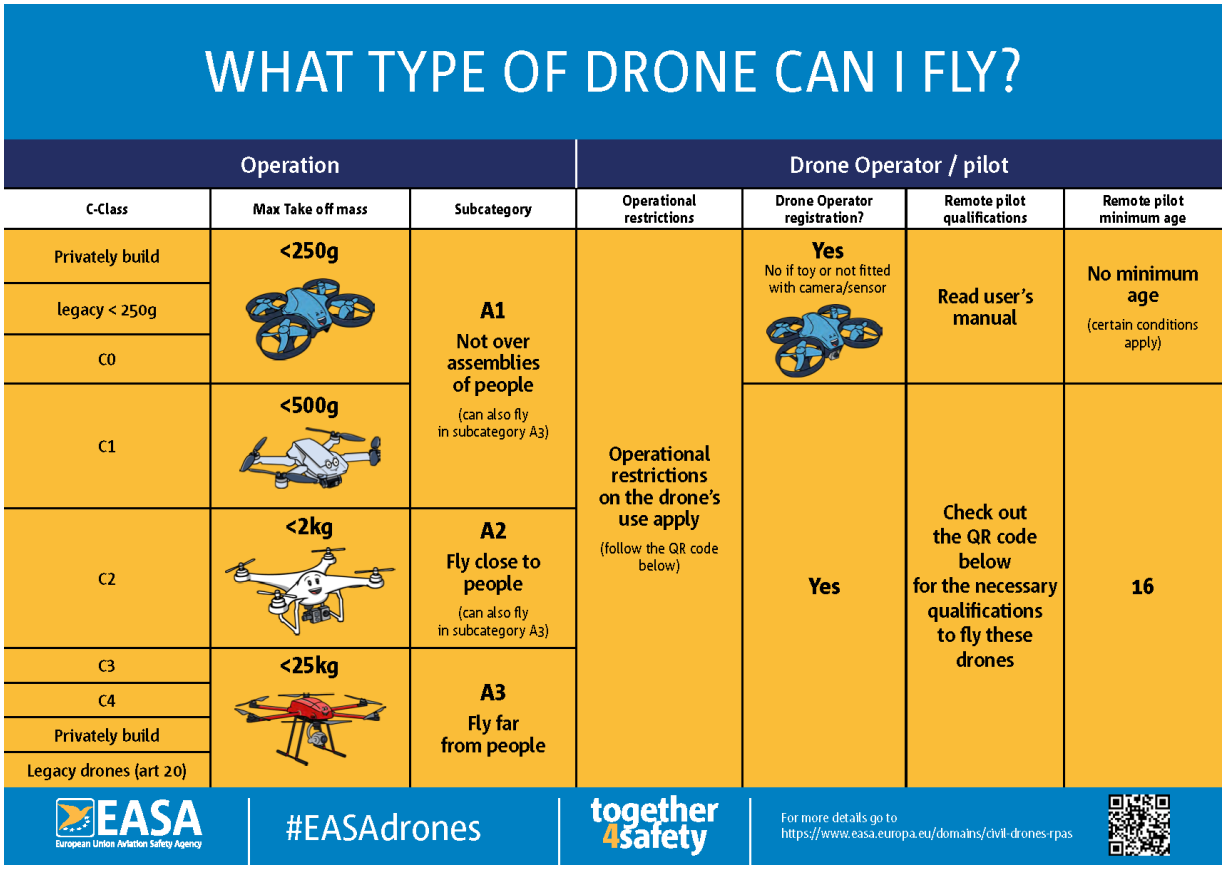

Figure 3: Overview on drone types and operations and requirements on operators and pilots.[6]

Apart from the EU regulations, more restrictions can requirements come from the authorities in the member states. A summary is supplied in Table 7.

[6] https://www.easa.europa.eu/en/the-agency/faqs/open-category#category-requirements-under-the-%E2%80%98open%E2%80%99-category

		Requirements	Permissions to obtain /Limitations
Demo locations	**Dubrovnik**	● Liability Insurance of the owner	● Certificate from the CCAA
	Marseille	Considering that Marseille test sites can be classified as non-populated areas, scenario 2 (see below, equivalent STS-02 from EU) can apply: • drone weight < 25 kg •VLOS -1 km horizontal distance • vertical distance of 50 m or 120 m if drone weight < 2kg • Requires a pilot certificate (BAPD) • EU member country equivalent certificates shall be accepted • Certificate not required for captive drones!	● EU drone registration ● Pilote certificate (Brevet d'Aptitude de Pilote de Drone), category open. A3 (UAV class C3 and C4)
	Tarragona	• max. altitude 120 m • visual line of sight (VLOS) • Liability insurance	•Registration in Agencia Estatal de Seguridad Aérea (AESA) • Pilot certification • Port Authority permission
Pilot sites	**Ashdod**	-	-
	Hamburg	• VLOS - 50 m horizontal distance • vertical distance of 50 m towards watercraft • take-off and landing from land only, unless tethered	• permission from landowner • registration with DFS
	Venice	• Pilot certification: specific license • Application 35 days ahead of operation	• UAS Operation over the historic centre of Venice (populated area) are strictly forbidden (Red Area), even on the Marghera is required a permission from ENAC due to the nearby Marco Polo Airport. • For both areas it is necessary to fill out a form (ATM-09A) to send to ENAC containing all the information relating to the area, the drone and the pilot. The form must be invited at least 35 days before the requested dates. • For cable driven drones only a safe zone to indicate with buoys for a distance equivalent to 1.5 times the cable length

Table 6: Summary of local air traffic regulations regarding the use of aerial drones in the demo and pilot sites.

In Dubrovnik the current EU regulations apply to operate an aerial drone. Insurance needs to be supplied in any case and a certificate from the Croatian Civil Aviation Agency (CCAA) obtained.

There are now 4 scenarios for flying a drone in France, conform with EU regulations:

- Scenario 1 is the most basic: it involves a visual flight outside a populated area. In this case, your flying machine must not weigh more than 25 kg and fly at a height of more than 120 m and 200 m from its remote pilot.
- Scenario 2: just like No. 1, this involves a flight in a rural, unpopulated area. The flying machine can weigh up to 25 kilos if it does not exceed a flight height of 50 m. On the other hand, between 50 m and 120 m in height, its weight is limited to 2 kg. It can stay 1,000 m from his remote pilot.
- Scenario 3 is the only one that allows you to drive in an urban area. Your drone must not weigh more than 2 kg. If its mass is between 2 and 8 kg, you will need to equip your aircraft with a short circuit system, as well as a parachute. It can fly up to 120 m high and must never be out of sight. In addition, it must not be more than 100 m from the remote pilot.
- Finally, scenario 4, active in an unpopulated rural area, is the most interesting. Certainly, the droner cannot fly the drone at a height of more than 120 m, but his distance from his drone is unlimited. The condition is to use a drone weighing no more than two kilos.

Flying authorization depends on the scenario selected, the flying height and distance, and the type of drone. Exhaustive information can be obtained here:

https://www.easa.europa.eu/en/downloads/110913/en

The airspace of the Port of Tarragona, located in the Catalonia region of Spain, falls under the jurisdiction of Spanish aviation authorities, specifically the Agencia Estatal de Seguridad Aérea (AESA), due to its proximity to Tarragona-Reus Airport (REU).

In order to obtain permission to fly drones on the area following laws and regulations would have to be considered:

- Royal Decree 1036/2017: This decree establishes the basic regulatory framework for the civil operation of drones in Spain. It covers various aspects of drone operations, including registration, pilot certification, flight rules, and safety requirements.
- AESA Resolution on Drones: Agencia Estatal de Seguridad Aérea (AESA) has issued specific resolutions and guidelines related to drone operations. These resolutions provide detailed information on registration procedures, pilot certification requirements, and operational rules.
- Air Navigation Law (Law 21/2003): The Air Navigation Law in Spain sets out general rules for aviation, including drone operations. It covers issues related to airspace use, air traffic control, and safety in aviation.
- Data Protection Laws: Drone operators in Spain must comply with data protection laws, particularly the General Data Protection Regulation (GDPR), when capturing and processing personal data using drones. Consent and privacy considerations are essential.
- Insurance Requirements: Depending on the size and purpose of the drone, liability insurance may be required to cover potential damage or accidents caused by the drone.
- Remote Identification Requirements: AESA has been working on regulations related to remote identification systems for drones to enhance safety and security.

The port of Hamburg is in the controlled airspace of two airports. Hamburg Airport is the fifth largest in Germany with about 110.000 in and outbound flights per year, located in the northeast of the city. Additionally, a special airfield is located on the premises of Airbus Operations GmbH in the south-west of the city. It is used for company purposes only, e.g., material transportation and test flights.

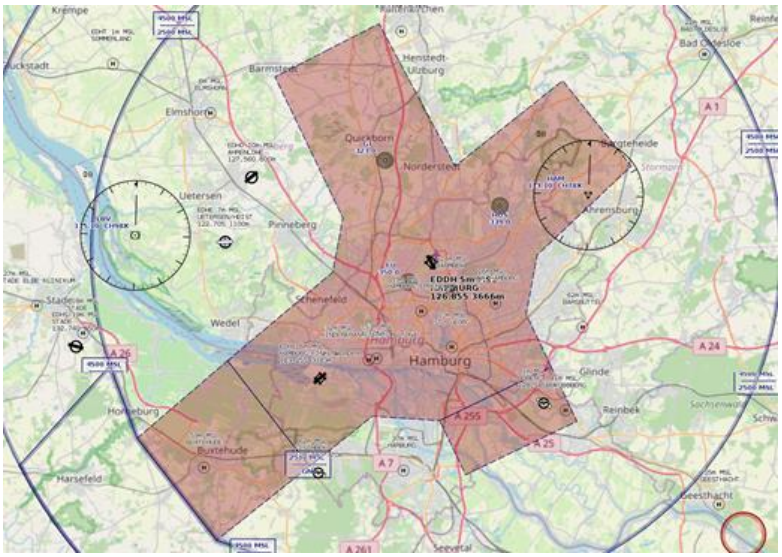

Figure 4: Image of the controlled airspace in the city of Hamburg established through Hamburg's commercial passenger airport and the airfield on the premises of Airbus Operations GmbH.

Regarding the operation of unmanned aerial drones, the following regulations apply:

- Standardized European Rules of Air (SERA)
- Commission Implementing Regulation (EU) 2019/947 of May 24, 2019, on the rules and procedures for the operation of unmanned aircraft[7]
- COMMISSION DELEGATED REGULATION (EU) 2019/945 of March 12, 2019, on unmanned aircraft systems and third country operators of unmanned aircraft systems[8]
- **Flights** within the controlled airspace marked in Figure 4 **require registration with the Deutsche Flugsicherung GmbH**, Tower Hamburg (DFS) if the following criteria are met:
    - Visual weather conditions permitted (see SERA-DVO 923/2012; lower cloud limit 1.500 ft, visibility more than 5 km, official aerodrome weather applies).
    - DFS does not provide remote pilots with traffic information on air traffic.
    - **Ascent at night** is only permitted if the aircraft is equipped **with position lights** that are clearly visible to other air traffic participants in accordance with SERA.

Additionally, the Hamburg Port Authority, as the body responsible for the management of federal waterways in the territory of the Free and Hanseatic City of Hamburg, announces: From the shipping police point of view of the HPA, the **operation of drones** around the federal waterway and other port waters **is not expected to endanger the safety and ease of shipping traffic** if the following requirements are met:

[7] Commission implementing Regulation (EU) 2019/947 of May 2019 on the rules and procedures for the operation of unmanned aircraft; http://data.europa.eu/eli/reg_impl/2019/947/oj
[8] Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems; http://data.europa.eu/eli/reg_del/2019/945/oj

- Operation of UAS within sight of the remote pilot (VLOS - Visual Line of Sight): A **minimum horizontal lateral distance of 50 m** (250 m for military warcraft) must be maintained **from watercraft** (stationary or moving)
- In all cases, **watercraft must be given right of way**; in particular, watercraft mooring and casting off must not be obstructed.
- **Watercraft**, with the exception of military vessels, **may be flown over at a vertical distance of at least 50 m**, provided that the maximum authorized flight altitude permits this and the **UAS is equipped with a parachute safety system or a comparable safety system** that can safely prevent damage to the property of third parties at a drop height of 50m. Watercraft may deviate from the stated distances if their owner or the ship's command has expressly agreed to this in advance. The written form is recommended. **Take-offs from and landings on moving ships or floating devices in motion are prohibited for safety reasons**.
- Operation of UAS beyond the visual line of sight of the remote pilot (BVLOS - Beyond Visual Line of Sight): **BVLOS flights are not possible in the OPEN category**. The **UAS must be equipped with a parachute or comparable safety system that can safely prevent damage to the property of third parties at a drop height of 50m**.
- If the operation of drones affects the rights of the HPA as the owner of (unleased) land, further regulations regarding approval are reserved.[9]

In Venice UAS operations over the historic center of the city, a highly populated area, are strictly forbidden as highlighted in red in Figure 5. Even on the Marghera site permission from ENAC due to the nearby Marco Polo Airport is required. For both areas it is necessary to fill out a form (ATM-09A) to send to ENAC containing all the information relating to the area, the drone, and the pilot. The form must be submitted at least 35 days before the requested date.

[9] Behörde für Wirtschaft und Innovation, Flugbetrieb – Einsatz von Drohnen in Hamburg : Sonderregelungen für das gebiet der Freien und Hansestadt Hamburg; https://www.hamburg.de/bwi/drohnen/

Figure 5: Restricted areas for drone operation in the city of Venice highlighted in red.

2.2.3 Nature protection

In each demo and pilot site several regulations and laws are in place to manage, maintain and protect the environment and especially the marine sphere. Nonetheless, for various reasons litter is found in the demo and pilot sites. Either it is discarded illegally, lost accidentally, carried in by currents and maritime streams.

More than 60% of Dubrovnik Neretva County area in Croatia is under Natura 2000 protection with 40 protected natural areas, pursuant to the Nature Protection Act. Additionally, the following regulations are in place:

- Nature Protection Act (NN 80/13, 15/18, 14/19, 127/19)
- Law on Maritime Property and Seaports (NN 158/03, 100/04, 141/06, 38/09, 123/11, 56/16, 98/19)
- Law on Sustainable Waste Management (NN 94/13, 73/17, 14/19, 98/19)
- Marine Strategy Framework Directive (2008)
- Ecological network regulation Natura 2000

The French laws protecting the marine environment are contained in the “Environment code”, Book II - Physical media, Title 1 - Water and marine environment, Chapter IX - Policies for marine environment, Section 2: Protection and preservation of marine environment (Articles L219-7 to L219-18).

In Tarragona three major laws are in place to protect the marine environment. Depending on the nature of the planned demonstration activity in SeaClear2.0, the planning may need to undergo an environmental impact assessment to evaluate and mitigate potential environmental effects.

- Spanish Environmental Protection Act (Law 26/2007).
- Spanish Environmental Impact Assessment (EIA) Law (Law 21/2013).
- Catalan Coastal Law (Llei 4/1986, de 4 de març, de costes).

A similar procedure is in place in Hamburg. If the planning of a demo campaign involves e.g., the placing of samples, as has been done in the previous EU project SeaClear, additional approval from the Port Authority is necessary. Other than that, the following laws apply to protect the marine ecosystem.

- Hamburg Ship Disposal Act (Hamburgisches Schiffsentsorgungsgesetz (HmbSchEG) vom 26. Januar 2022) regulates the discarding of litter gathered on ships during their passage towards Hamburg port
- Directive (EU) 2019/883 on port reception facilities for the delivery of waste from ships, amending Directive 2010/65/EU and repealing Directive 2000/59/EC of 17 April 2019
- The Federal Nature Conservation Act (BNatSchG) regulates the protection of nature and landscapes in Germany and includes the protection of marine environments.

In Venice the main law that manages the Lagoon is the law n° 171 (16 April 1973) "Interventi per la salvaguardia di Venezia" and the "Piano Direttore 2000, which represents the main programmatic plan of the lagoon.

2.3 Demo & Test Site specification

This includes the domains characterization that has been established in the SeaClear2.0 proposal and matching to the real time environments of Dubrovnik, Marseille, Tarragona, Ashdod, Venice, and Hamburg. The latter are further described and combined with dissemination potential, as stakeholder involvement and activation play a major role in the project. The overall description of infrastructure required to conduct system demonstrations covers marine facilities as well as social spaces and the like.

2.3.1 Domain characterization

The SeaClear2.0 platform will provide a new service of robotic underwater cleaning in a variety of marine conditions, including the industrial and tourism value chains. Five project showcase domains for the project demo/pilot sites have been predefined in the project proposal also specifying the use cases connected to it. They will be the base for the formulation of the system requirements.

1) Tourism in coastal areas and recreational freshwater lakes: The use case focuses on marine litter (especially plastic from land & water-based tourism activities) caught in protected habitats. The challenge will be the removal while protecting biodiversity and leaving habitats undamaged.
2) Ports: The specific challenge here is the monitoring of the water quality, detecting and removing of bulky sea debris found at various depths. The items are not removable by human divers.
3) Fisheries & Aquaculture: Traditional aquacultural activities with extensive fish farming (freshwater and marine) facing challenges from lost fishing gear, aquacultural equipment and impacts of water quality (nutrients, microplastic). SeaClear2.0 system challenge will be finding and the removal of Abandoned, Lost or otherwise Discarded Fishing Gear (ALDFG) waste and specific waste from shellfish farms.
4) Protected natural areas: Natura 2000 areas, marine reserves, Volcanic Islands, marine debris is found here in demanding retrieval conditions; protecting ecosystems ranging from microorganisms to ocean mammals (whales, dolphins) and their habitat.
5) Rivers and channels in urban areas: Urban canal system heavily used by public and touristic boats/ within a city, strong exposure to small to large scale litter (scooters/ bikes).

Table 7 summarizes the domains and their connection to the demo and pilot sites of the SeaClear2.0 project. The boxes ticked in blue indicate the most probable showcase domain in each location, which are ultimately subject to the approval of the local authorities.

	Dubrovnik	Marseille	Tarragona	Ashdod	Hamburg	Venice
Coastal Tourism / freshwater lakes	X	X	X			**X**
Ports		X	**X**	**X**	X	
Fisheries & Aquaculture	**X**					
Protected Natural Areas	X	**X**				
Rivers & urban channels					**X**	

Table 7: Applicable project domains in the demo and pilot sites. The focused domain during the demo and pilot campaigns are highlighted in blue. Changes may be made according to the final demo plan.

Regarding the further development of the showcases plan in each demo and pilot location, the system demonstration will concentrate on coastal tourism in Venice as none of the other domains fit the city´s specific environment. The port domain is most likely a topic for Ashdod, as here none of the other domains apply. Since there are six demo and pilot sites, but only five domains, Tarragona may be suitable for both topics, costal tourism, and ports. The Port Tarragona combines maritime traffic/port operations and tourism, giving rise to large amounts of marine litter and therefore is an opportunity for demonstration/tests on different spots to cover all potentialities of SeaClear2.0.

Dubrovnik is renowned for coastal tourism and the protected natural areas. However, the domain connected will be fisheries and aquaculture as this industry plays a major role in the region. Marseille will serve as a demo location with the background of a nature protected area in the Calanques National Parc. As the port domain is covered by potentially two other project partners, Hamburg´s domain allocation is river and urban channels.

2.3.2 Potential test sites

As far as it is possible, this section indicates the favorable places to deploy the SeaClear2.0 System and introduces the character of the environment to expect during demo campaigns. The locations in Dubrovnik and Ashdod will be chosen during the project and in dependence on the specific demo requirements.

Identified test sites within Marseille are the commercial harbor (largest harbor in the Mediterranean Sea) and touristic areas such as Corbières beach or the Frioul islands, located in the Calanques National Park. They are part of the European network of protected Natura 2,000 area[10] and preferred test site for the respective domain characterization.

[10] https://www.marseille-tourisme.com/en/discover-marseille/nature/the-calanques-of-marseille/which-calanques-to-discover/le-parc-national-des-calanques/the-islands-of-frioul-and-chateau-dif-if-castle/

Figure 6: Corbiéres Beach at Marseille[11] and Frioul islands[12]

Tarragona Port is strategically positioned on the northeastern coast of Spain, offering direct access to the Mediterranean Sea. Even if it can't be considered one of the major ports in Europe regarding its total volume in the Mediterranean, it must be taken in consideration when talking about liquid Bulk (petrochemicals, oil products, chemicals, and liquid gases).

Figure 7: Aerial view on the potential test locations in the Port of Tarragona and nearshore.

There are different potential sites shown in Figure 7 meeting the requirements of a SeaClear2.0 demo location.

[11] https://www.marseille-tourisme.com/en/discover-marseille/nature/beaches-and-swimming-in-marseille/
[12] https://www.marseille-tourisme.com/en/discover-marseille/nature/the-calanques-of-marseille/which-calanques-to-discover/le-parc-national-des-calanques/the-islands-of-frioul-and-chateau-dif-if-castle/

The Port of Hamburg lies in the heart of the city and occupies almost one tenth of the area of the city, touching a total of ten districts. The heavy ship traffic and high turbidity due to regular tidal currents pose a challenge towards underwater detection, determining the origin, and removing waste from the river Elbe. Besides the port operation in respectively dimensioned waterside infrastructure, small channels that form the beginning of the city´s port history are potentially interesting for a SeaClear2.0 system demonstration in the urban channels domain. The map in Figure 8 serves as an overview of the port with four locations marked for a demo.

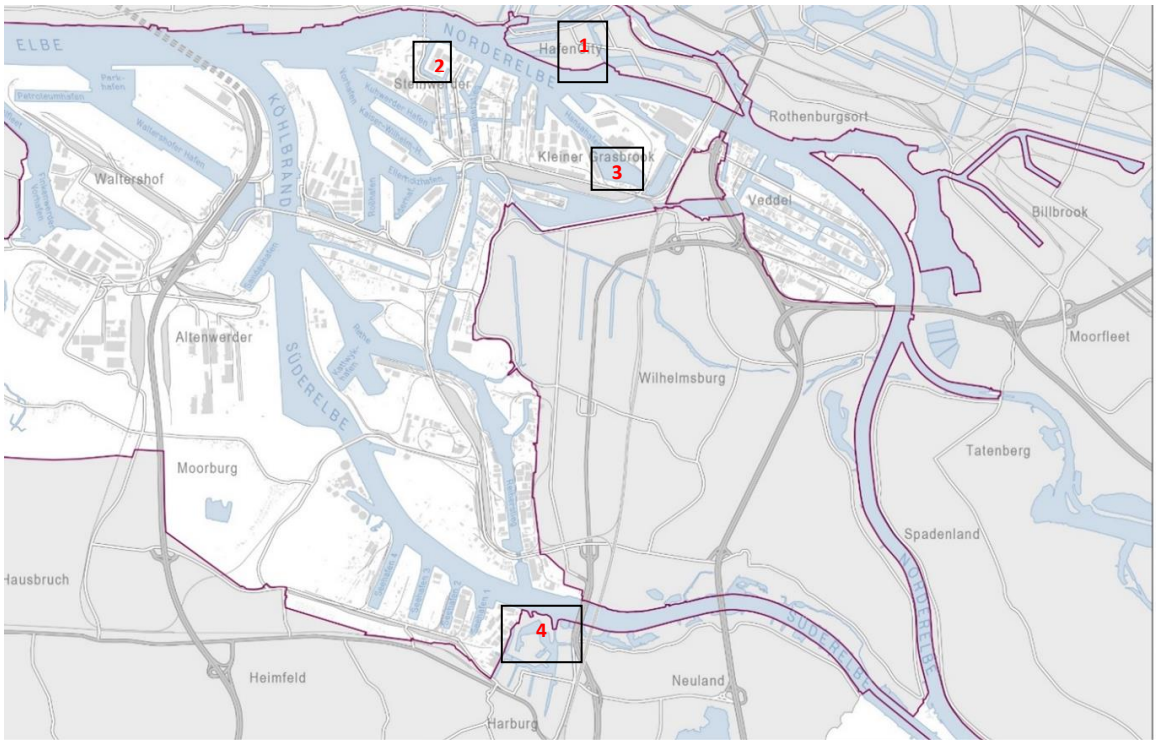

Figure 8: Potential test sites for the Hamburg pilot within the port.

Location No. 1 is the historic warehouse district, with the smaller channels, that can potentially host a SeaClear2.0 demo, further depicted in the aerial view in Figure 9.

Figure 9: Aerial view of urban channels in Hamburg as potential locations for a pilot campaign.

Lastly, the VLPF team will seek to get the SeaClear system in performance at the very city center of Venice, the Grand Canal, possibly during nighttime, due to traffic density in the daytime. As the demo will preferably take place in connection to the Venice boat show, a demonstration will be scheduled during the event, if possible. The venue for that is in the Arsenal in the historic city center highlighted withing the yellow box in Figure 10.

Figure 10: Venice city aerial image highlighting the two test locations in the Arsenal, where the Venice boat show takes place (yellow box) and the grand canal (yellow arrow) crossing through the city.

2.3.3 Dissemination potential

Alongside the demo activities, the activation and involvement of the public is a vital part of the SeaClear2.0 project. Therefore, the potential to engage with stakeholders from industry, scientific experts, local and regional authorities, networks, and the public is closely connected to the demo planning. The events may range from holding e.g., a public demo, scientific or industry workshops, press conference to public engagement events like making art from litter or holding an educational workshop with kids, students, or residents to raise awareness and call for action to preserve the marine environment.

Dubrovnik has great dissemination potential with the historic old town of the city, where many international tourists will be reached. The close cooperation with the University Dubrovnik offers access to a wide variety of departments, scientific expert networks, and suitable locations to gather and reach a broad professional audience. Additionally, the city´s active community includes local stakeholders from the municipality and civil society.

Marseille is the second largest city in France with many event facilities to be selected according to the dissemination plan. The city also hosts international trade shows related to marine environment like Euromaritime held annually in January and Seanergy and FOWT every second year.

Part of Tarragona's port are the Port Yacht marinas and the fishermen port. The whole area is totally integrated into the city and part of its touristic attractiveness. The dissemination potential may range from citizen engagement events, press conferences or a public demo to industry events.

Hamburg city is the second largest city in Germany counting roughly 1.89 Mio inhabitants and attracting over 3,3 Mio. tourists per year. Numerous universities and scientific institutes give access to the respective expert communities. The Hamburg Port Authority is connected to ports worldwide and has taken over the two-year presidency of the International Association of Ports and Harbors (IAPH) in November 2023, with potential to disseminate the SeaClear2.0 project on a worldwide level. Within the homePORT community a broad network of business experts, scientists, start-ups, and industry players gather regularly to discuss maritime and innovation topics. An active promotion and involvement of the SeaClear2.0 project at a respective event may be arranged. Apart from that, if the indicated location in section 2.2.2 is the final choice for the Hamburg demo, the exposure to the public will be included, as the aera is frequented by residents, tourists, and employees from the businesses of the district. Either way, the potential for dissemination activities in Hamburg is broad and will be further refined in the upcoming planning process.

Venice is visited by 13 million tourists per year on the rise and intends to fully seize the opportunity offered by this UNESCO property to multiply the demo visibility impact by organizing the SeaClear2.0 operation on site during the International Boat Show of Venice.

Figure 11: The venue of the Venice boat show in the Arsenal.

The SeaClear2.0 system will benefit from the visibility of the international event that registered 30.000 visitors in 2023. VLPF will organize a press conference for the event with the participation of the SeaClear2.0 partners, along with an international workshop hosted at the same boat show on “marine litter monitoring, removal, and circular economy” in cooperation with other mission ocean projects. Finally, VLPF will also organize a clean-up event with the use of the SeaClear 2.0 app at the World Environment/World Ocean Day (2-6 June). This will combine social and technological demo activities, joining forces with local citizens and volunteers. The overall work will be documented by a professionally conducted video documentary produced by VLPF and later promoted widely online through the consortium and project socials.

2.3.4 Infrastructure for deployment and operation equipment

The deployment and operation of the full or partial SeaClear2.0 system comes with specific demands to enable the installation of equipment. As large and heavy system components are arriving from various partners, parking spaces for trailers and transport boxes is needed. Especially the USVs must

be lifted to the water with crane capacity of at least 1.5 tons. Nearshore work on vehicles is facilitated at a jetty or pier with mooring. Freshwater and workshop access make sure equipment stays in good shape and short-term maintenance and repairs may be carried out on site. The availability is summarized in Table 8.

		Demo locations			Pilot sites		
		Dubrovnik	**Marseille**	**Tarragona**	**Ashdod**	**Hamburg**	**Venice**
Infrastructure	Jetty / quay	tbd	Yes	yes	tbd	Yes	Tbd
	Mooring	Tbd	yes	Yes	Tbd	Yes	Tbd
	Crane	tbd	Yes	yes	tbd	Yes	tbd
	Workshop	tbd	Yes	yes	tbd	Yes	Tbd
	Parking	Tbd	Yes	yes	Tbd	Yes	yes
	Storage	Tbd	Yes	yes	Tbd	Yes	tbd
	H2-filling station	No	Yes, but in 60 km distance	yes, but in 100 km distance	Yes, but in 45 km distance	yes	Tbd

Table 8: Overview on the available infrastructure at the test and demo locations.

The available infrastructure depends on the locations in Dubrovnik, Ashdod, and Venice, which will be chosen during the project. Hydrogen filling stations are available in Tel Aviv (45 km to Ashdod) and Venice Mestre, but not in the vicinity of Dubrovnik.[13]

The closest station for hydrogen filling (200 bars) is at Le Castellet, 60 kms from test area in Marseille. At the Subsea Tech facilities in Marseille storage and deployment facilities for the SeaClear2.0 system, as well as workshops and parking spaces are available.

In Tarragona, the consortium will have access to test sites within the port area offering cranes, jetties, and mooring facilities. Depending on the final site, TECNOSUB portable warehouses/workshops would be installed in the area. Storage of equipment may be arranged in the TECNOSUB facilities. Parking close to the test site will be available, even if it would be advisable to use TECNOSUBs provided transport. The nearest hydrogen filling stations are in Huesca (200 km) and Barcelona (100 km).[14]

Multiple test sites in the port of Hamburg are available including necessary infrastructure for deploying and storing equipment. The exact location depends on the requirements regarding the specific task demonstrated in Hamburg. If needed, hydrogen filling stations can be found in Harburg, south of the city, and within the city center.

[13] https://www.h2stations.org/stations-map/?lat=49.763948&lng=12.582221&zoom=4
[14] https://www.h2stations.org/stations-map/?lat=49.763948&lng=12.582221&zoom=4

2.3.5 Social spaces, office, and meeting rooms

The test and demo operations require social rooms and office space to work at the system software components and gather for meetings. The availability of respective facilities is necessary to allow smooth operations. Table 9 summarizes the circumstances at each demo location except for Ashdod and Dubrovnik. The test locations in Ashdod and Dubrovnik will be specified within the duration of the project and depend on the exact demo requirements. Therefore, information on social spaces and offices will be available upon selection.

		Demo locations			Pilot sites		
		Dubrovnik	**Marseille**	**Tarragona**	**Ashdod**	**Hamburg**	**Venice**
Social space	Social Space	tbd	Yes (18 people max)	yes	tbd	Yes	yes
	Canteen	tbd	Yes (18 people max)	yes	tbd	Yes	yes
	Restrooms	tbd	Yes	yes	tbd	Yes	yes
	Offices	tbd	Yes	yes	tbd	Yes	-
	Local networks	tbd	High speed FO network	tbd	tbd	yes	yes

Table 9: Overview on the available social spaces, offices and meeting facilities at the test sites.

In Marseille most of the requirements are met, unless they are higher than the ones depicted in the table above. In that case, other facilities like a hotel or conference room will have to be looked for in Marseille, but it will not be in the vicinity of Subsea Tech facilities or the test sites.

Tarragona can offer the full amenities, as well as Hamburg. The vicinity to the social and office spaces described depends on the exact test sites, at least in Hamburg, but will be taken care of.

VLPF will provide the consortium partners and their teams involved in the demo with all the facilities offered by its new office premises on the island of Tronchetto in Venice, the only island directly reachable by car. The premises will be equipped with social space for meetings of up to 70 people, restrooms, internet access and printing facilities, reserved parking space and an exclusive waterfront office of about 50 square meters.

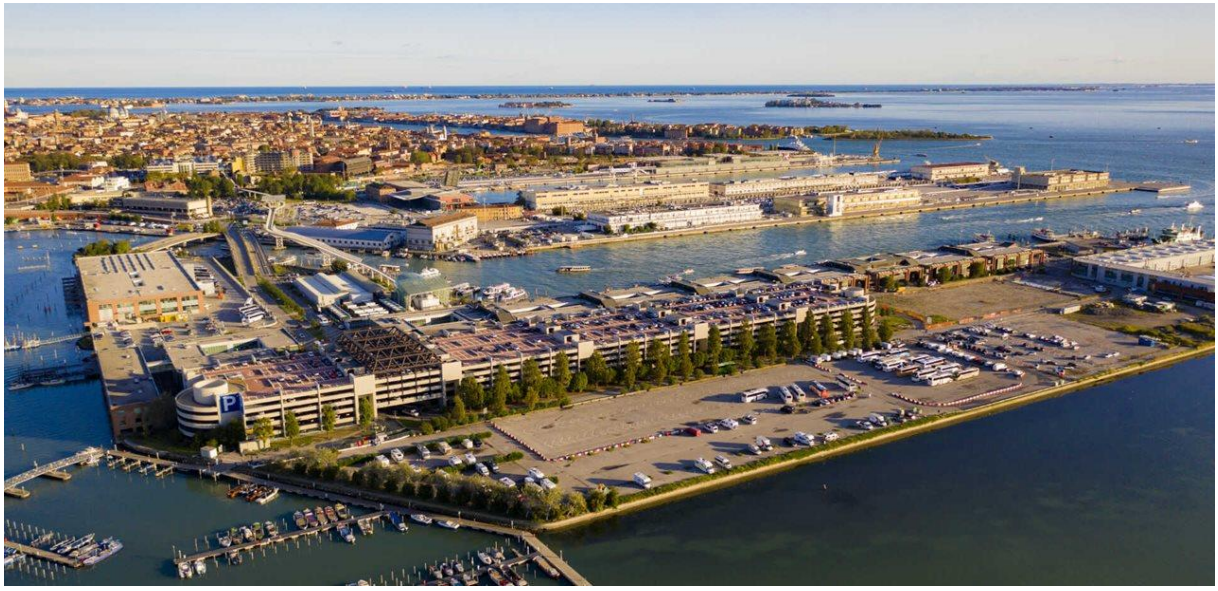

Figure 12: Office and Social Space in Venice available to the SeaClear2.0 consortium during the planned demo campaign.

2.3.6 Stakeholder Options

In all the demo and pilot sites, the stakeholders interested and concerned with the SeaClea2.0 system are clustered in five major groups representing industry, authorities, science, non-governmental institutions (NGO) and legislative bodies. Their key concerns and expectations towards the SeaClear2.0 System are summarized in table 10 below. Most stakeholders don't have concerns but the authorities, that wish for safe operations and reliability of the technology in use. Expectations on the other hand involve the innovative potential to facilitate and optimize operations and increase safety standards in the future. No information exists on the stakeholder opinion of legislative bodies yet, but the authorities expect the increasing use to lead to the introduction of relevant standards. A broader acceptance of autonomous systems within the workforce is desired and the SeaClear2.0 system is considered a tangible door-opener. Cooperation, collaboration and participation from research and innovations is a key prospect anticipated by authorities as well as the scientific community.

	Expectations	Concerns
Industry	● access to new approaches in sustainability, safety, transport, environmental protection ● facilitate/ enable operations with technical solutions ● increase operational safety	
Authorities	● cooperation & collaboration in port community involving innovative technology ● implementing autonomous vehicles in port operations / standardization ● create acceptance for autonomous vehicles fulfilling regular operations ● technical solution for the marine litter challenge	● safe operations ● reliability of technology
Science	● define the role of legislation to reduce ocean plastic ● participate from research and technology developments in project	
NGO	● join forces in solving marine litter issues ● raise awareness	
Legislation	-	

Table 10: Summary of the stakeholder opinions and expectations in the demo and pilot locations by interest groups.

In each demo and pilot site, the immediate involved stakeholders in the SeaClear2.0 project are and will be the local and regional authorities as well as a varying set of ministries. In the first place they are the institutions granting permissions to the planned campaigns. At the same time, they are also most likely the ones mandated to detect and remove marine litter as all the regions are concerned with or heavily impacted by its occurrence and therefore seek for solutions, especially technology-based ones, to meet the challenges arising from it.

2.4 Conclusion

The previous sections gathered comprehensive information on the preconditions potentially impacting the demo planning in each of the involved sites. Full demos of the SeaClear2.0 system will be organized in Dubrovnik, Marseille, and Tarragona. In the pilot locations Ashdod, Hamburg, and Venice only parts or specific components of the full system will be deployed. A decision on which needs to be taken within the upcoming planning process.

The best timing to plan and implement a demo campaign according to local weather and climate conditions will be from spring to fall to avoid weather phenomenon like strong winds, storm surges, and heavy rain. Only in Tarragona mid-summer might be strenuous due to the expected heat, recommending scheduling SeaClear2.0 operations in spring or fall.

Considering the general nature of the test areas at the Mediterranean Sea will, it is likely to encounter a seafloor with sandy mud, and silt. Beside rocky bottoms, precious and protected seagrass meadows are common. With a good chance, litter is trapped or entangled in both cases, careful removing to prevent damage on the marine environment and avoid further degradation of marine litter is necessary. In the only non-Mediterranean pilot site, Hamburg, sludge on the seafloor may cause litter to sink into the ground posing a challenge to detection and collection. Additionally, visibility is limited due to the high turbidity of the Elbe River. Low visibility should be expected also in the Mediterranean, as ship traffic and currents will stir up sediments and particles that obscure the underwater view. The known currents occurring in all the sites range between 0-4 knots at maximum. The operational water depth is limited to 25 m, at least in Tarragona, Hamburg, Venice and presumably also in Ashdod. This is true also for Marseille. Only Dubrovnik may be offering an environment with up to 50 m operational depth.

The litter fractions have been extensively discussed in D2.1 Marine litter report. Most of the test sites suffer equally from smaller litter findings sourcing from touristic activity in the vicinity or inflows from currents. Therefore, in terms of collection, a variety of samples is available for demo purposes. The largest fractions exceeding 1 m^2 may be found in Dubrovnik, Hamburg, and Marseille, most of it connected to fishing and port operations.

The use case domains established in the project proposal determine the assignment to the demo and pilot sites. Full demos will be carried out in Dubrovnik, with emphases on the fishing industry and aquaculture. Marseille serves the Nature Reserve category with the Calanques National Park, and Tarragona possibly as a port location or touristic zone. As there are six sites but only five domains, one will be focused twice. Depending on the development in Israel, the port use case may be the fit for Ashdod pilot hosting a partial system demo. The same applies for Hamburg and Venice, where the urban channels and respectively touristic sites will be highlighted in a partial system demonstration.

There are predefined areas with potential to be a final pilot and demo site in each of the participating countries to host such an event. This will be further refined once the actual planning begins. In terms of dissemination many opportunities for different events and actions have been outlined in all sites, ensuring that a wide variety of stakeholders gets involved and a broad audience is reached.

From a regulatory perspective it is recommended to start the planning at least 2-3 months ahead of time to apply for necessary permissions to deploy and operate aerial and waterborne vehicles in accordance with environmental laws. By that time, the authorities granting permission will generally require insurance for the involved vehicles to be in place. The campaign missions including risk assessment and mitigation measures must be clearly described. Data sheets to vehicles in operation shall be made available. Lastly, information on the institution / facility applying as well as specifying on the operators maneuvering the equipment and holding the respective license needs to be supplied to complete the application. Hamburg and Tarragona are the strictest about wearing safety equipment like safety shoes, helmet and life vests when working nearshore.

3. Boundary conditions

In this section the focus is set on defining constraints that go beyond the physical infrastructure and that are more closely related to the actual robotic system limitations in the envisioned maritime operation. This includes technical, environmental, operational, regulatory, and safety constraints that may impact the overall functionality and operation of the robotic system. The purpose is to establish the boundaries within which the system must operate, considering various external factors that might affect its performance.

While there might be some overlap with Section 2, it's beneficial to distinguish between the two sections to provide a more comprehensive understanding of the project's challenges and limitations. Section 2 focuses on the limitations and requirements of test site while this section is about the conditions and limitations under which the technology will operate from the end-user's perspective.

3.1 Technical Constraints

The technical constraints are related to the hardware capabilities and software/technology limitations for each individual component of the robotic system.

Communication Range

- Constraint: Limited communication range between land and robotic system.
- Design objective: Achieve a communication range of at least 1000 meters to ensure seamless control and data transmission between the operators on land and the robotic system.

Battery life

- Constraint: Limited battery life of the ROVs or UAV.
- Design objective: Use generator onboard the USV as power source for both the ROV and for the UAV in order to have a minimum of 8 hours operation time at maximum propeller thrust.

Payload

- Constraint: Identified litter in the test areas are ranging between 1 and 105 kg (source: Deliverable 2.1 Marine litter occurrence domains report)
- Design objective: Enable payload capacity up to 105kg +100%

Litter sizes

- Constraint: Identified litter in the test areas are ranging between 5x5cm to over 100x100cm in cross-section, with the following percentages:

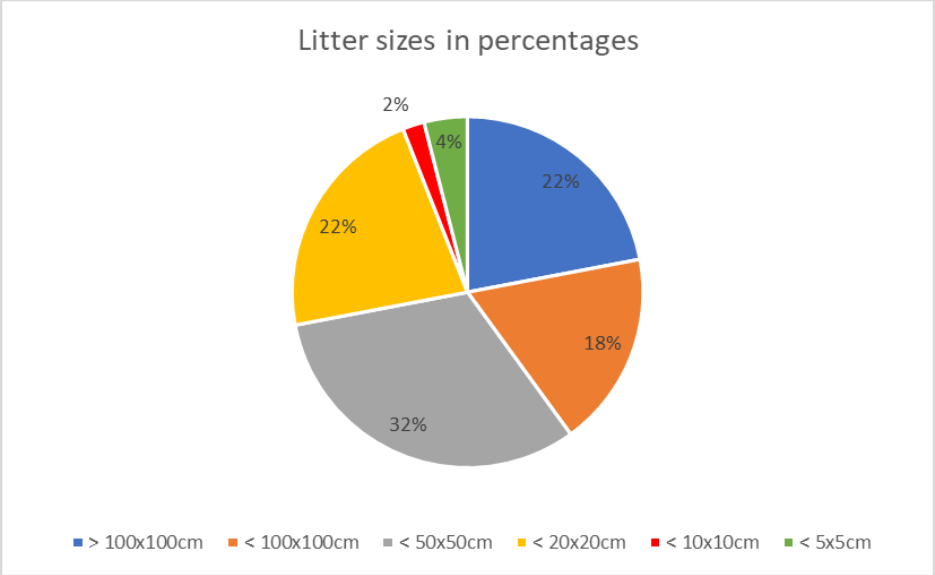

Figure 13: Overview of the litter sizes and their percentage breakdown (source: [15])

- Design objective: Enabled grasping capacity up to be able to address up to 78% of the identified litter sizes by enabling grasping of objects up to 100cm by 100cm in size.

Object recognition accuracy

- Constraint: Inaccurate identification of underwater litter objects.
- Design objective: Improve object recognition algorithms to achieve 90% accuracy in identifying and classifying litter items.

User Interface and Human-Robot Interactions

- Constraint: Limited user-friendliness in the control interface.
- Design objective: Develop an intuitive and user-friendly control interface for operators overseeing the cleaning process, that provide reliable information about the status of the ongoing operation and permit intuitive user interaction also on low-power devices (e.g. tablets). In addition, enable access of the general public to public information via a dedicated mobile application.

Adaptability to different types of litter

- Constraint: Inability to effectively handle various types of underwater litter.
- Design objective: Enhance the system's adaptability to different shapes and sizes of underwater litter objects, including the following types of litter: e-scooters, bikes, wheels, and ghost nets.

[15] Deliverable 2.1 Marine litter occurrence domains report

3.2 Environmental constraints

Depth limitations

- Constraint: Limited operational depth for the robotic system.
- Design objective: Enhance the system's structural integrity to operate effectively at depths up to 100 meters.

Current and wave considerations

- Constraint: High currents and turbulent waves in certain cleaning areas.
- Design objective: Improve the stability and navigation capabilities of the USV and ROVs to handle the operation normally at sea state 2 or river currents up to 2 kn.

3.3 Operational Constraints

Operational Range

- Constraint: Limited coverage area for a single deployment.
- Design objective: Optimize the litter depositing mechanism to increase the efficiency of collecting and storing underwater litter, without the need to stop the operation and retrieve to land after each successfully collected litter item. Enable deposition and transportation to shore via a shuttle tender USV cable of transporting a total payload of litter of up to 350kg, with volumes up to 100x100x100cm for each collected litter element.

3.4 Regulatory and compliance constraints

Navigation Regulations

- Constraint: Adherence to maritime navigation regulations and restrictions.
- Design objective: Equip the USVs with collision avoidance modules or ensure emergency takeover maneuvers by the operators regardless of the operation state, in order to comply with international maritime regulations. Collaborate with maritime authorities to obtain necessary permits for the robotic system's operation.

Data Privacy and Security

- Constraint: Stakeholders/End-users impose regulations regarding the handling and storage of data collected during underwater cleaning operations.
- Design objective: Develop protocols/data management plans for secure data transmission and storage in accordance with data protection regulations.

3.5 Safety and security constraints

Emergency Situations

- Constraint: Risk mitigation procedures needed for emergency situations such as system malfunctions or adverse weather conditions.
- Design objective: Develop an emergency response protocol outlining procedures for system shutdown, retrieval, or recovery in case of malfunctions. Monitor weather conditions in real-time and establish automated protocols for returning the system to a safe state during adverse weather events.

Underwater Obstacles

- Constraint: Safety concerns related to potential collisions with underwater obstacles, especially in low-visibility/high-turbidity test sites
- Design objective: Integrate sonar imaging technologies for obstacle detection and avoidance. Implement machine learning algorithms to enhance the system's ability to recognise and navigate around underwater obstacles or objects that do not need to be picked up.

3.6 Conclusion

In this section, the boundary conditions were classified based on the type of constraints enforced on the SeaClear2.0 robotic system. All in all, the identification and careful consideration of boundary conditions are paramount in shaping the framework for the successful deployment and operation of our underwater litter cleaning robotic system. This section delves into constraints spanning technical, environmental, operational, regulatory, and safety aspects, all crucial in defining the limitations within which the robotic system must function. By acknowledging these constraints, or risks, the appropriate design objectives are formulated. The latter lay the groundwork for designing a robust and adaptive robotic system that can navigate the complexities of maritime operations in all the envisioned demo and pilot sites.