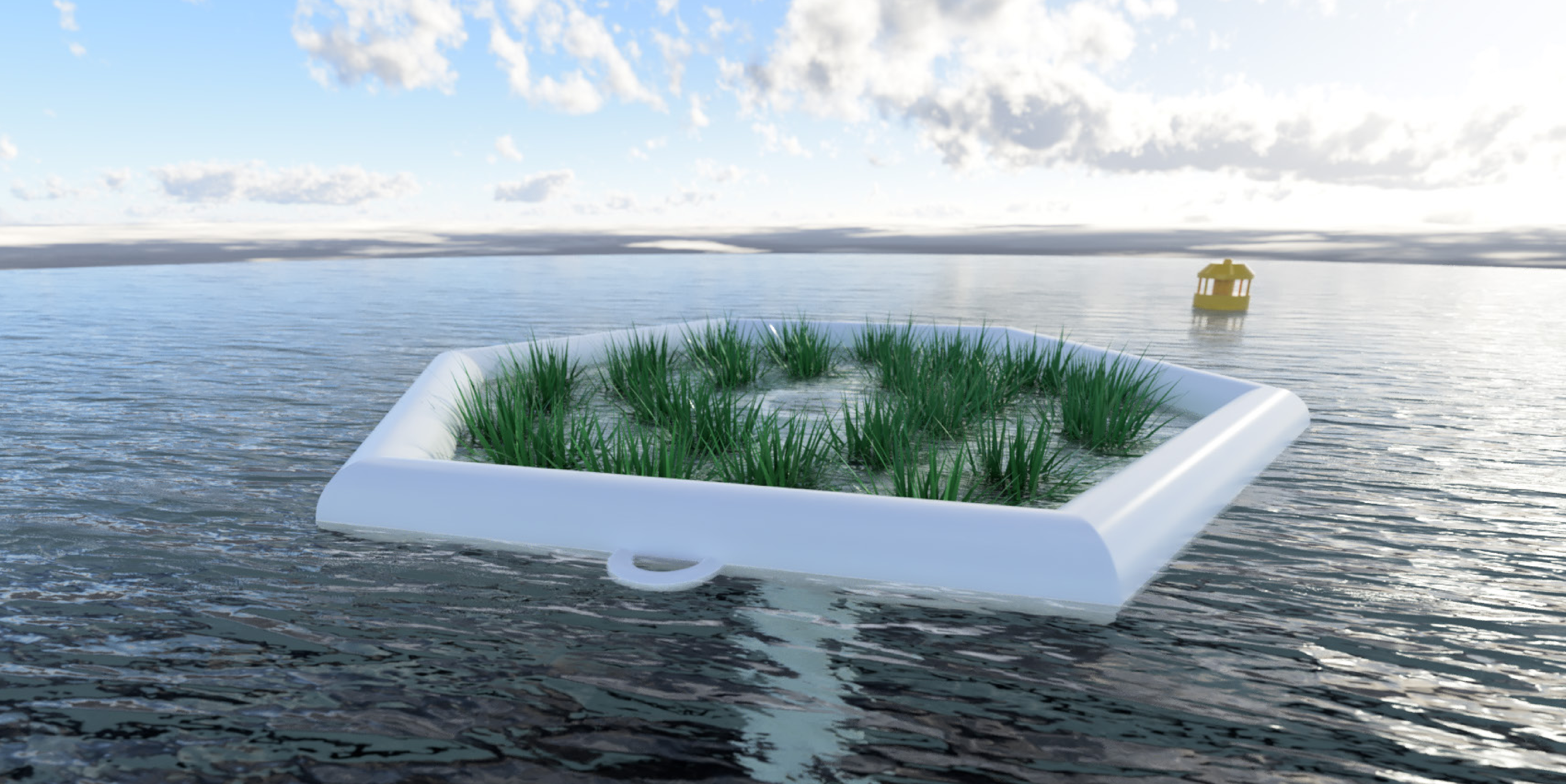

C-FILTER

10 PAGE SUMMARY

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THE GLASGOW SCHOOL OF ART
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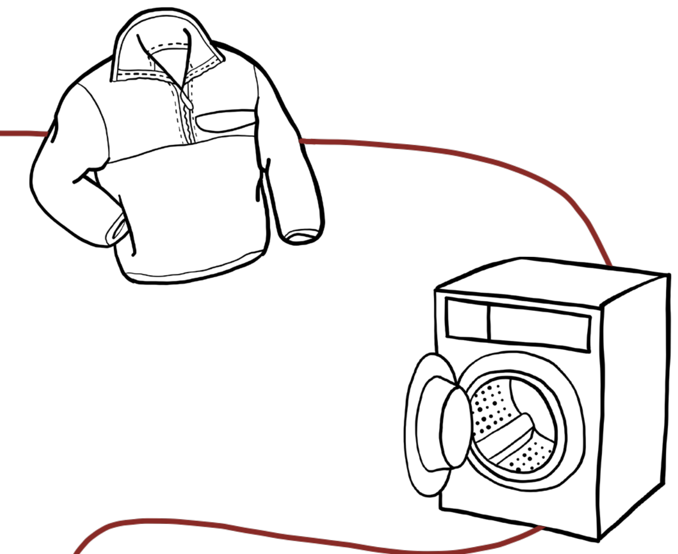
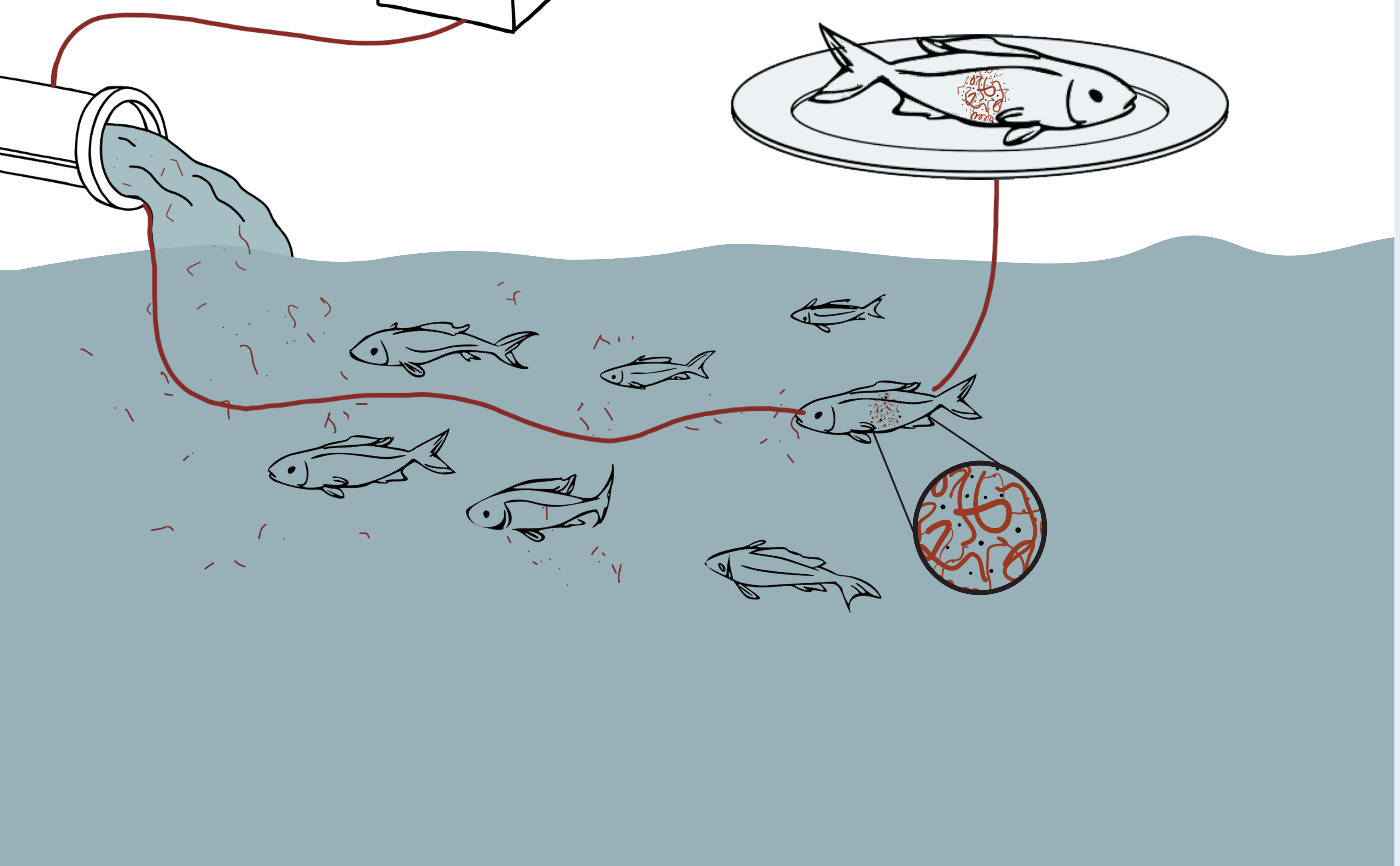
PDE 2021

the problem

The rise of the fast fashion phenomenon has resulted in an increased wear and disposal of clothing, often made from synthetic materials – polyester, nylon, acrylic and others. When these synthetic textiles are washed, the plastic fibres which have been woven into the fabric are subject to mechanical and chemical stresses which cause breakages. Tiny thread-like particles called microfibres are released into wastewater streams and travel into oceans. Upon reaching the ocean, they act like sponges, absorbing other toxic pollutants like pesticides. Ingested by sea life, they travel up the food chain and are ingested by humans.



Consumption of microfibres has been proven to impact a marine animal's ability to feed and reproduce. Studies have shown hormonal, reproductive and genetic issues in marine life. The impact on humans has not yet been confirmed but scientists have hypothesized that it could lead to health effects including reproductive problems, cancer, and DNA damage.



the solution

WHAT

c-filter is a fully submersible ocean microfibre filtration system.

WHO

c-filter targets ocean clean up companies and schemes. User interaction with the system would be conducted by the stakeholders or by companies hired by the stakeholders.

WHY

c-filter is designed to reduce the number of microfibres in the ocean and therefore reduce the environmental and health hazards that they pose.

WHERE

c-filter is designed to be adaptable to various oceans and various depths however, this project looks closely at the Arctic as a target zone.

HOW

c-filter catches microfibres by directing water in a spiralling motion, inducing a centrifugal force which directs the water through the filtration medium.

research

current solutions

Solutions which exist for collection of plastic debris are typically designed for macroplastics. Such systems often use a pump which draws water through a container or netting. However, microfibre collection in the marine environment is limited due to the small size and wide dispersal of these particles. Currently, no solution exists for the collection of microfibres from the marine environment.

SYSTEM 001/B

The current market leader in macroplastic collection is System 001/B by The Ocean Clean Up - a passive system which follows the natural ocean currents. The large HDPE pipe suspends a net below it to catch the plastic. The sea anchor creates drag to allow the plastic to catch up and be caught in the net.

science of filtration

Filtration has 4 main requirements:

1. Filter medium
2. Fluid suspended with solid particles
3. Driving force
4. Mechanical Device

stakeholder network

"This is a **deeply complex and difficult problem to solve**. Generally speaking, microplastics and microfibres pose a unique challenge because of how difficult they are to clean up. Any solution implemented would need to ensure that it did not cause a new problem for the ecosystem."

*- **Truett Sparkman,** Program assistant, Trash Free Seas, Ocean Conservancy*

"With regard to microfibres in the open Marine environment, the only technologies being used for capturing microfibres have been developed for collecting things for **data analysis rather than for reducing pollution."**

*- **Mark Spalding**, President, The Ocean Foundation*

"There are not many filters available - most focus on more macro because of the issue of filters, damage to marine organisms, ensuring that it can work effectively at sea."

*- **Dr. Laura Foster,** Head of Clean Seas, Marine Conservation Society*

THE OCEAN FOUNDATION

PROJECT SEAGRASS

Ocean Conservancy

PLASTIC OCEANS

marine conservation society

insights

filtration

- There are currently **no marine solutions** which collect microfibres. The filtration techniques being implemented cannot filter microfibres.
- Research showed that centrifugal filtration is the most effective at removing microfibres from water.
- Seagrass naturally filters plastic.

dispersal

- Microfibres are very **widely dispersed**.
- Zones with high microfibre densities include the Arctic, the Mediterranean and Hudson Bay.
- Microfibres sink, partly due to ocean currents.
- Depths with the highest densities in the Arctic were found between 20.8-63.7m and 1003-1015m below the surface.

environment

- The ocean, and Arctic especially, are very harsh conditions to work in.
- The marine environment can be very expensive.

market

- Typical market products use a pump which draws water through a container or netting.
- These products are often made from some type of high strength plastic, like HDPE.

concept generation

Brief

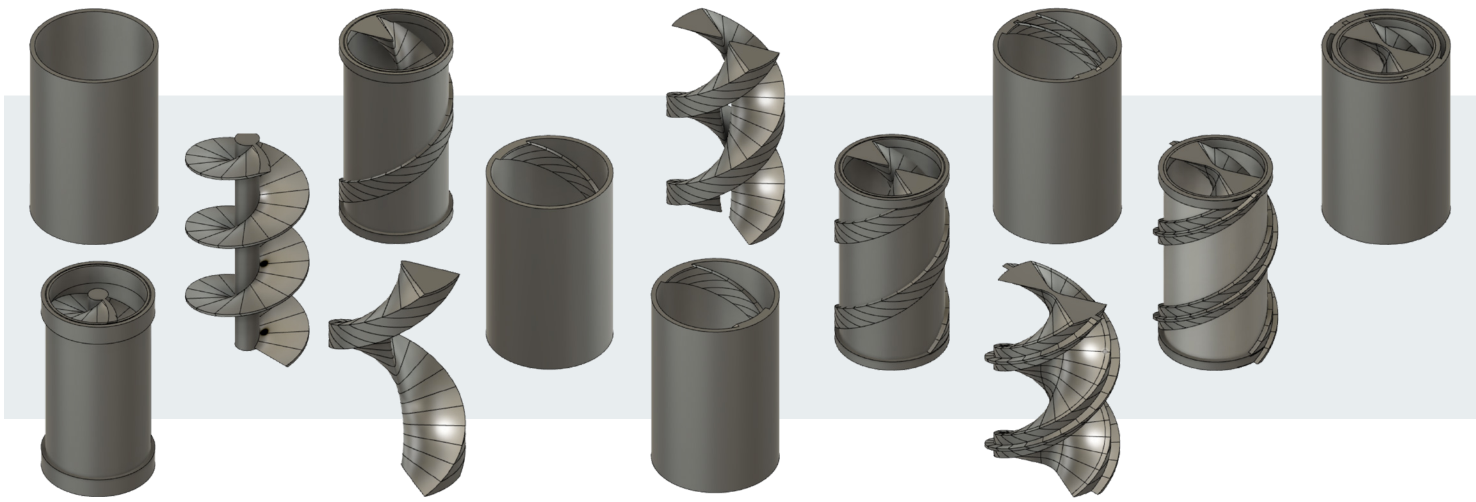
Design a system which effectively collects microfibres from the World's oceans whilst remaining innocuous to it's environment, creating no further pollution. The system should be adaptable to different environments so that it can be used across the various locations.

2D ideation

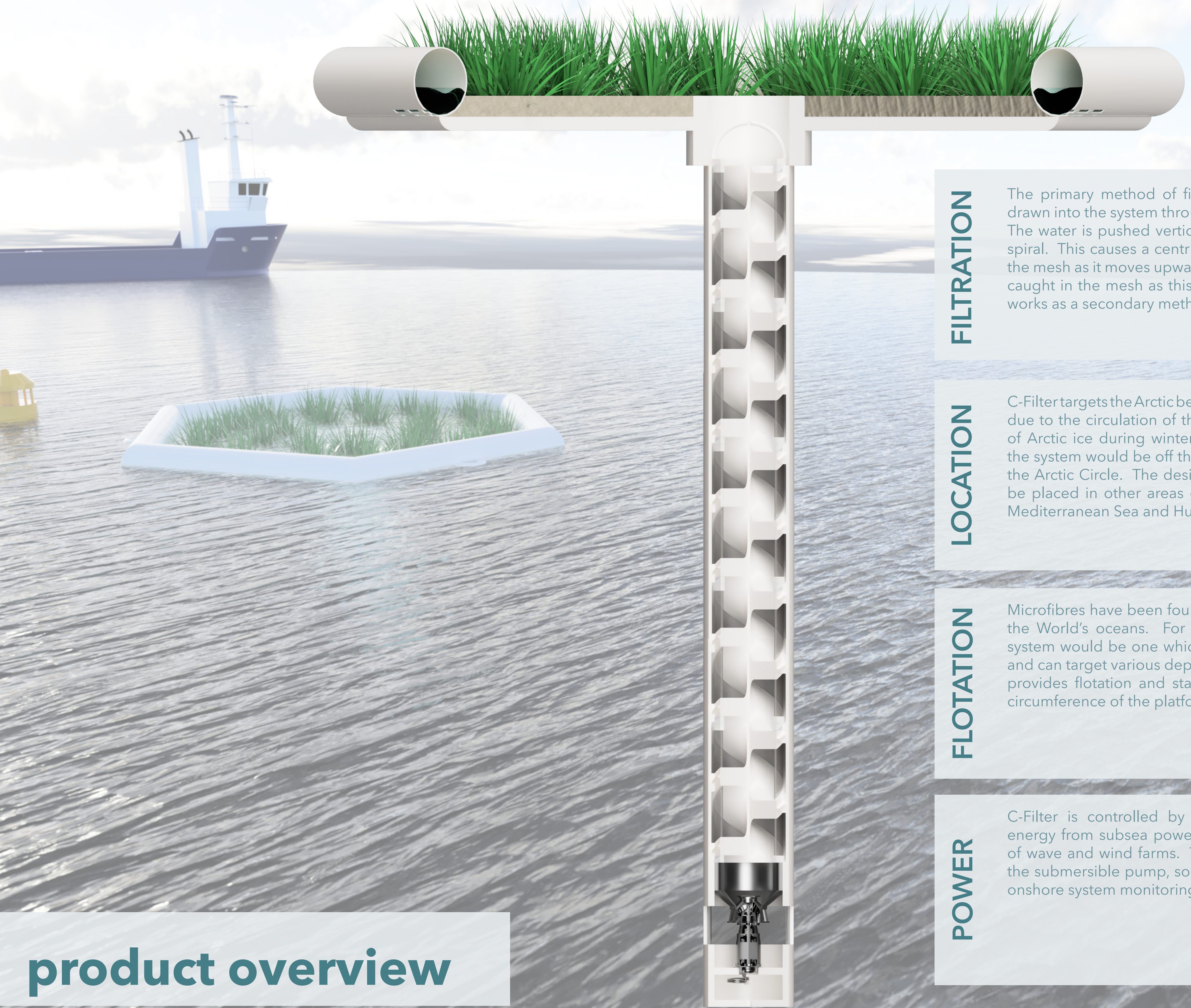
Networking with experts in the field of fluid mechanics, provided valuable feedback for each concept. Following these interviews, an evaluation of the feasibility and effectiveness of each concept was made and one concept was chosen to develop.

3D Generation

Digital 3D modelling was an easy way to experiment with various forms and provided quick 3D visuals. The 3D models could easily be transferred into CFD software for analysis of fluid flow.



3D printing of parts validated the structure of the chosen concept, allowed for physical interaction with the mechanisms and provided clearer representation of the aesthetics.



product overview

FILTRATION

The primary method of filtration is centrifugal filtration. Water is drawn into the system through the submersible pump at the bottom. The water is pushed vertically upwards and spun around the inner spiral. This causes a centripetal force that forces the water through the mesh as it moves upwards through the pipe. The microfibres get caught in the mesh as this happens. The seagrass on the platform works as a secondary method for filtration.

LOCATION

C-Filter targets the Arctic because it is a 'dead end zone' for microfibres due to the circulation of the ocean currents. Due to the expansion of Arctic ice during winter months, the most northern location for the system would be off the north coast of Norway remaining within the Arctic Circle. The design is not limited to this location and can be placed in other areas of high microfibre pollution, such as the Mediterranean Sea and Hudson Bay in North-Eastern Canada.

FLOTATION

Microfibres have been found in various locations and depths across the World's oceans. For this reason, the more effective filtration system would be one which is adaptable to different environments and can target various depths. The platform at the top of the system provides flotation and stability. The ballast pipes, which line the circumference of the platform allow for control of buoyancy.

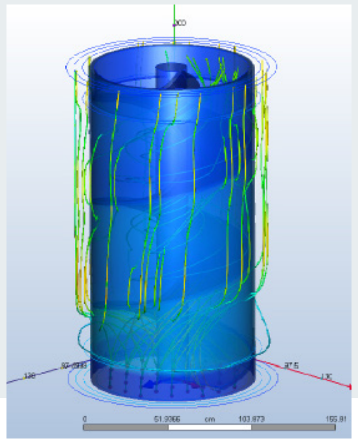
POWER

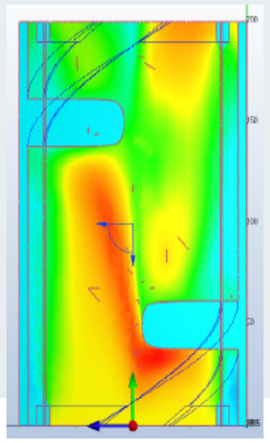
C-Filter is controlled by a smart buoy. This device harnesses energy from subsea power hubs, typically found within the vicinity of wave and wind farms. The buoy controls power transmission to the submersible pump, solenoid valve and air pump and allows for onshore system monitoring.

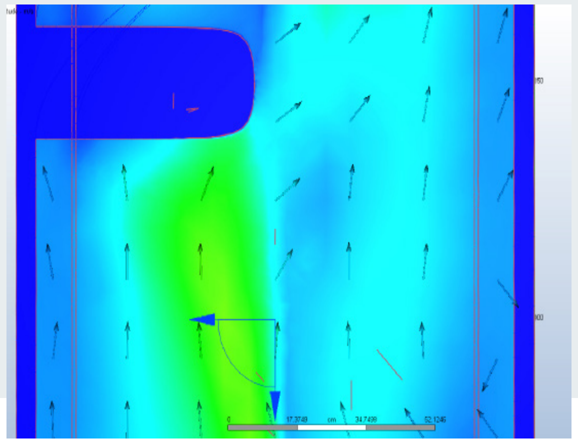
development

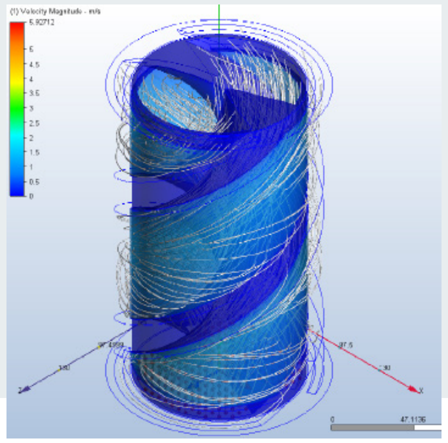
pipe

The design for the pipe followed many iterations. Fluid flow analysis, conducted using Autodesk CFD, helped to evaluate each iteration. Evaluations were made based on flow direction, velocity and centripetal force magnitudes. The scale was determined based on manoeuvrability for cleaning giving each individual mesh section dimensions of 2m in height by 1m in diameter. The external pipe is 12m in height by 1.4m in diameter.









pump

Contact with hydraulic engineering companies provided information about the type of pump that such a system would require.

Malcolm Harris from Hytec Hydraulics specified that the system needed

" a high flow, relatively low output pressure device."

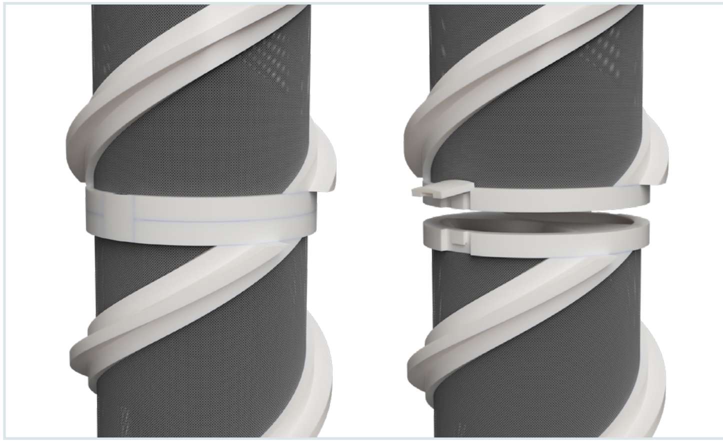
The pump was further specified by calculating the volume flow rate using a velocity between 1-1.5m/s and the cross sectional area of the pipe.

The chosen device is an axial-flow propeller pump by Grundfos with an input power of 37kW, flow rate of 4000m^3 and discharge diameter of 800mm.

IP Rating : IP68

Insulation Class : F

Model : KPL.800.37.8.T.50.9.L.38



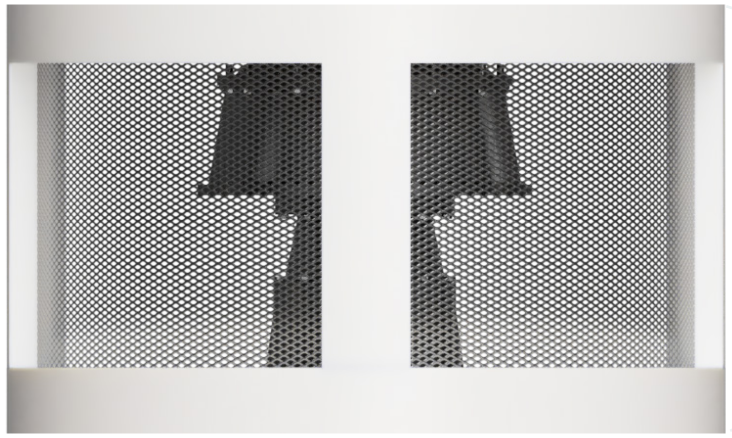
seamless connection

The connection rings on either end of the mesh sections required a non-permanent joining mechanism, so that they could be easily disconnected for cleaning. The designed clip mechanism locks the sections together seamlessly to minimise disruption of fluid flow.

protection

To protect the pump and prevent entrainment and impingement, the external pipe was extended downwards, encasing the pump within the system. This design provided impact reduction potential for impingement and entrainment in two ways:

- Physical barrier - Fine mesh screen
- Behaviour Deterrent Device - Velocity Cap - *changes the main direction of water withdrawal from vertical to horizontal which eliminates vertical vortices and creates a horizontal velocity pattern which gives juvenile and adult fish an indication for danger.*



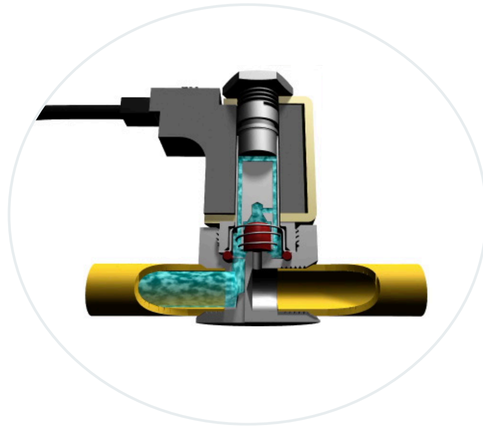
development

platform

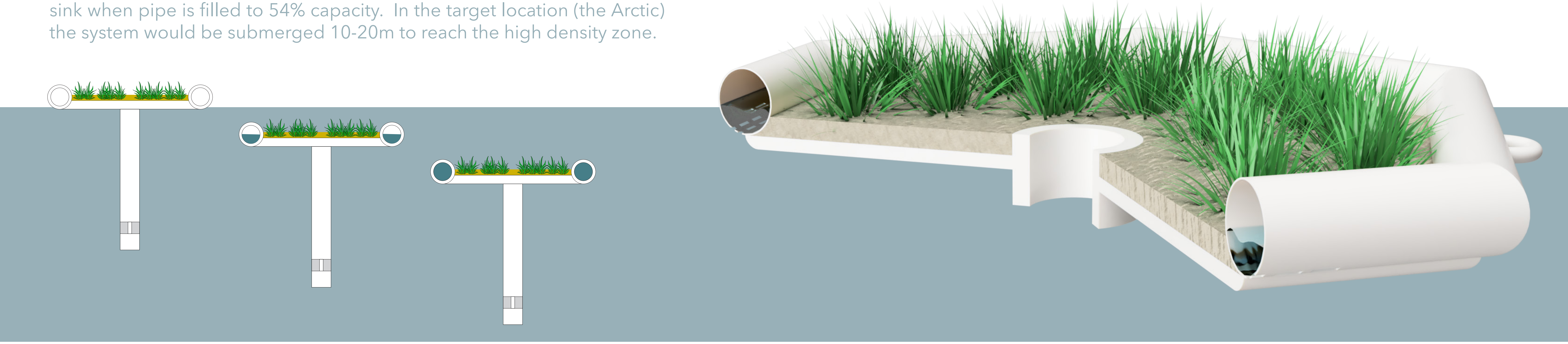
Taking inspiration from submarine ballast tanks, the platform was designed to control buoyancy. Flood grating on the bottom of the pipe, a 2-way normally closed solenoid valve and pressurised air hose control the ratio of water to air in the pipe. For submergence, the solenoid valve is energized, allowing air to flow out of the pipe and water to flow in. To make the system rise, high pressure, compressed air is fed into the pipe, forcing the water out. The volume of the pipe is 19.4m^3 and the system will begin to sink when pipe is filled to 54% capacity. In the target location (the Arctic) the system would be submerged 10-20m to reach the high density zone.

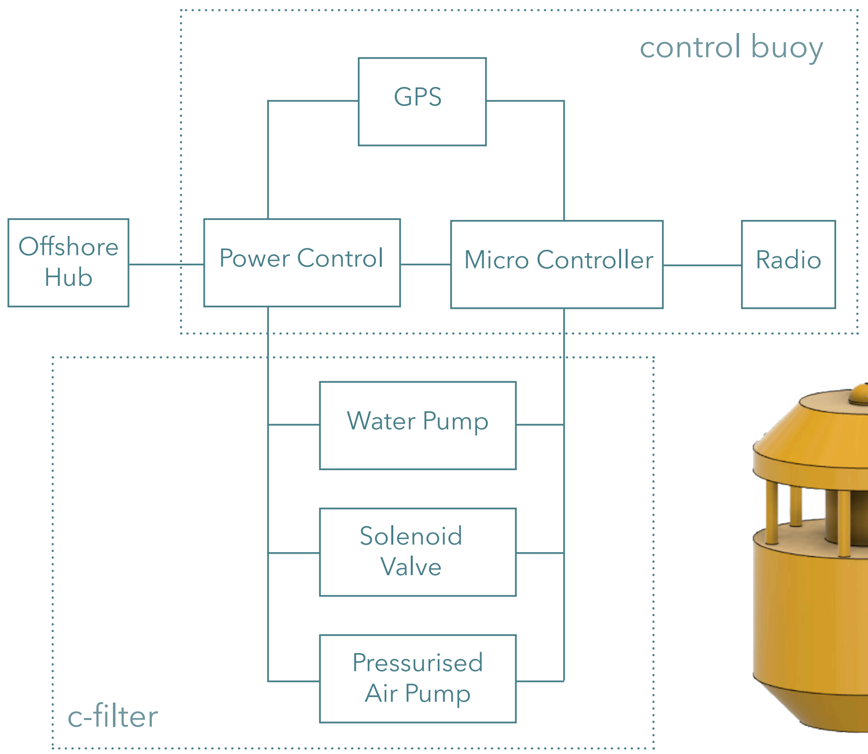
Flood Grating

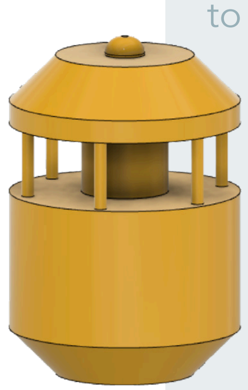
2-Way Solenoid Valve



Handles for Manoeuvring







control buoy

The diagram shows a schematic of the control buoy's instrumentation, inspired by automatic feeder buoys for fish farming and smart buoys for data gathering.

The micro controller is able to control the power inputs to each feature in the system and collect data which can be directly monitored onshore through the radio.

Power sources were evaluated with the help of Scott Roy (University of Glasgow, Electronics). It was decided that because of the pump power requirements, the most feasible solution would be to directly tap into offshore hubs/stations.

seagrass

The seagrass provides a secondary source of filtration due to its ability to naturally capture plastic in its fronds. In addition, it is a considerable carbon sink. Each square metre of seagrass meadow can absorb 83 grams of CO_2 per year.

The seagrass platform in this system has a surface area of 70m^2 and therefore is able to absorb 5827.3g (5.83kg) of CO_2 per year.

materials and manufacturing

material requirements

- Corrosion resistance - Salt water
- Corrosion resistance - UV
- Lightweight (Low density)
- High Strength
- High Formability
- Low environmental impact

main structure

High Density Polyethylene (HDPE) was chosen for the main structural components in the system due to its low density to high strength ratio, corrosion resistance, recyclability and relatively low cost. This material is common across market products. The filtration pipe, ballast pipe and spiral will be extruded. For the connection rings, a long pipe with the profile of the rings will be extruded and then cut into individual sections. The clips will be compression moulded. The screws and hinges are standard components which will be specified as marine grade stainless steel.

mesh

The most common mesh materials used for microfibre filtration were found to be nylon and polypropylene. Polypropylene was chosen for this application due to its better resistance to salt water corrosion. The micromesh has an aperture of 10μm. Non-woven micromesh manufacturing involves extrusion of plastic fibres by various mechanical, thermal and/or chemical processes.

aesthetics

Aesthetics are important for securing interest from stakeholders but can also provide functionality and information about the system.

external parts

For UV resistance, it is required that carbon be added to the material prior to processing, making the system **black** in colour. The inner parts are protected from UV rays so do not require this feature.

control buoy

Buoys are colour coded to direct ships and alert them of hazards. Cautionary buoys are **yellow** in colour and mark dangers such as **underwater structures.**

standards and regulations

ISO 161-1:2018

Specifies the nominal outside diameters for metric thermoplastics pipes for the conveyance of fluids in pressure and non-pressure applications.

- The outside diameter of the filtration pipe is 1400mm.
- The outside diameter of the ballast pipe is 1000mm.

ISO 4427-2:2018

Specifies the nominal wall thickness for polyethylene pipes based on a standard dimension ratio. For both the filtration pipe and ballast pipe, the wall thickness was maximised to increase strength.

SDR = (Outside Diameter/Wall thickness) * 10

- The SDR for the filtration pipe is 13.6, giving a wall thickness of 102.9mm.
- The SDR for the ballast pipe is 11, giving a wall thickness of 90.9mm

ISO 6964:2019 & ISO 18553:2002

Specifies the carbon black content and dispersion in polyethylene pipes.

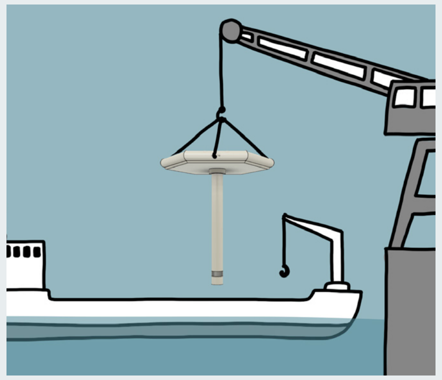
In practice, carbon black will be added to the external HDPE parts for UV resistance. The values for content and dispersion are 2-2.5% and ≤3, respectively. The carbon content would give the system a black colour, however, for presentation purposes it has been shown in white as it is easier to see.

ISO

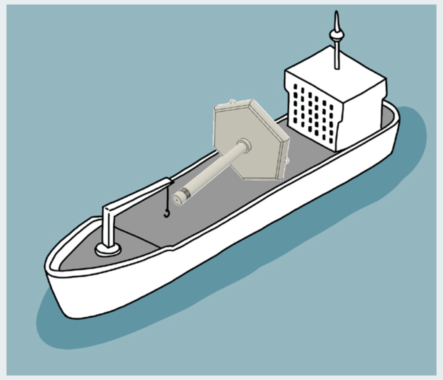
maintenance

installation

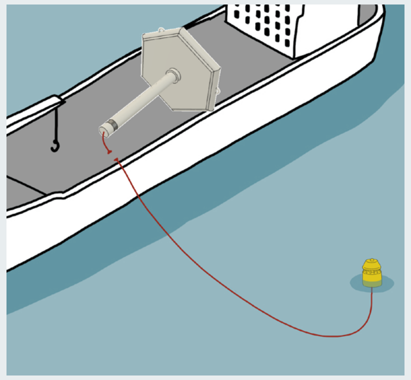
Assembled onshore.



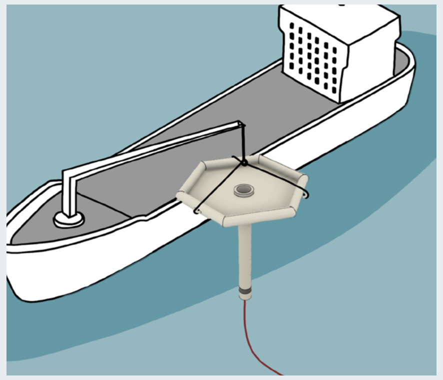
Loading.



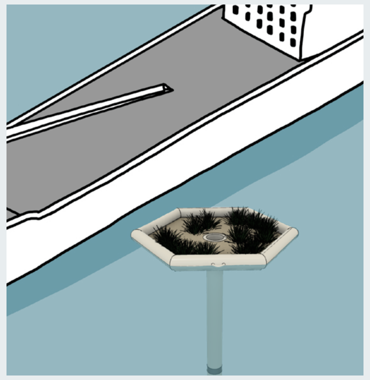
Transportation to site.



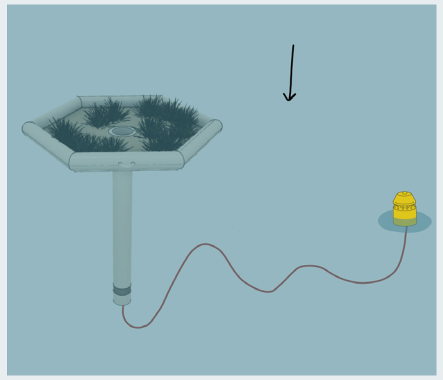
Connection to control buoy.



Unloading.

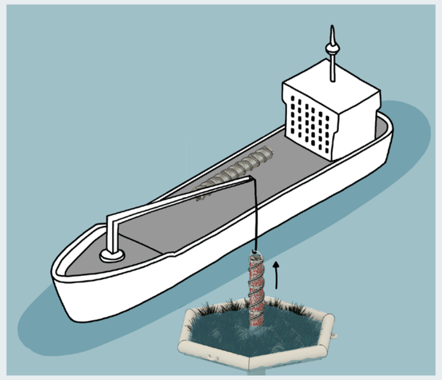


Sand/sediment and seagrass added.

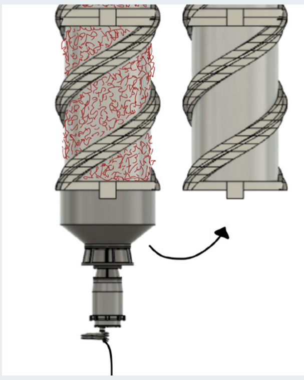


System submersed.

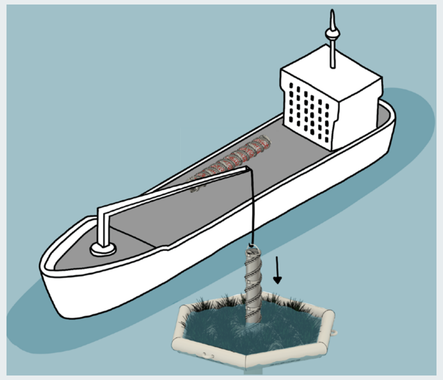
cleaning process



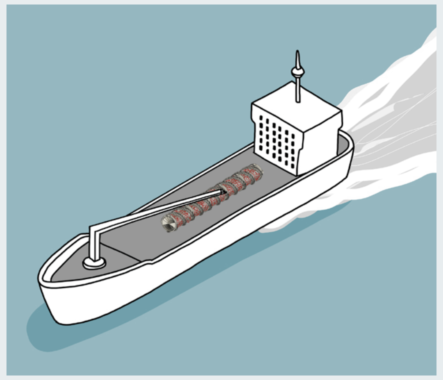
Saturated mesh cylinder removed from system.



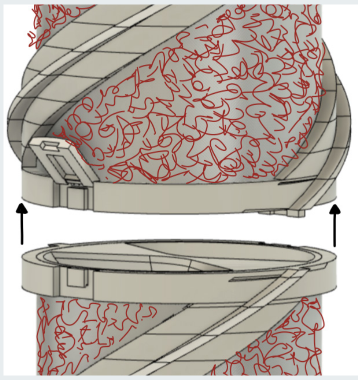
Pump attached to replacement mesh pipe.



Replacement mesh pipe inserted into system.



Saturated mesh pipe transported to cleaning facility.



Mesh sections separated.

Mesh sections cleaned using pressurized air in a controlled environment.

Clean mesh sections stored for future use.

how often does it need to be cleaned? *

once every year

how many microfibres does it collect? *

2.21 billion

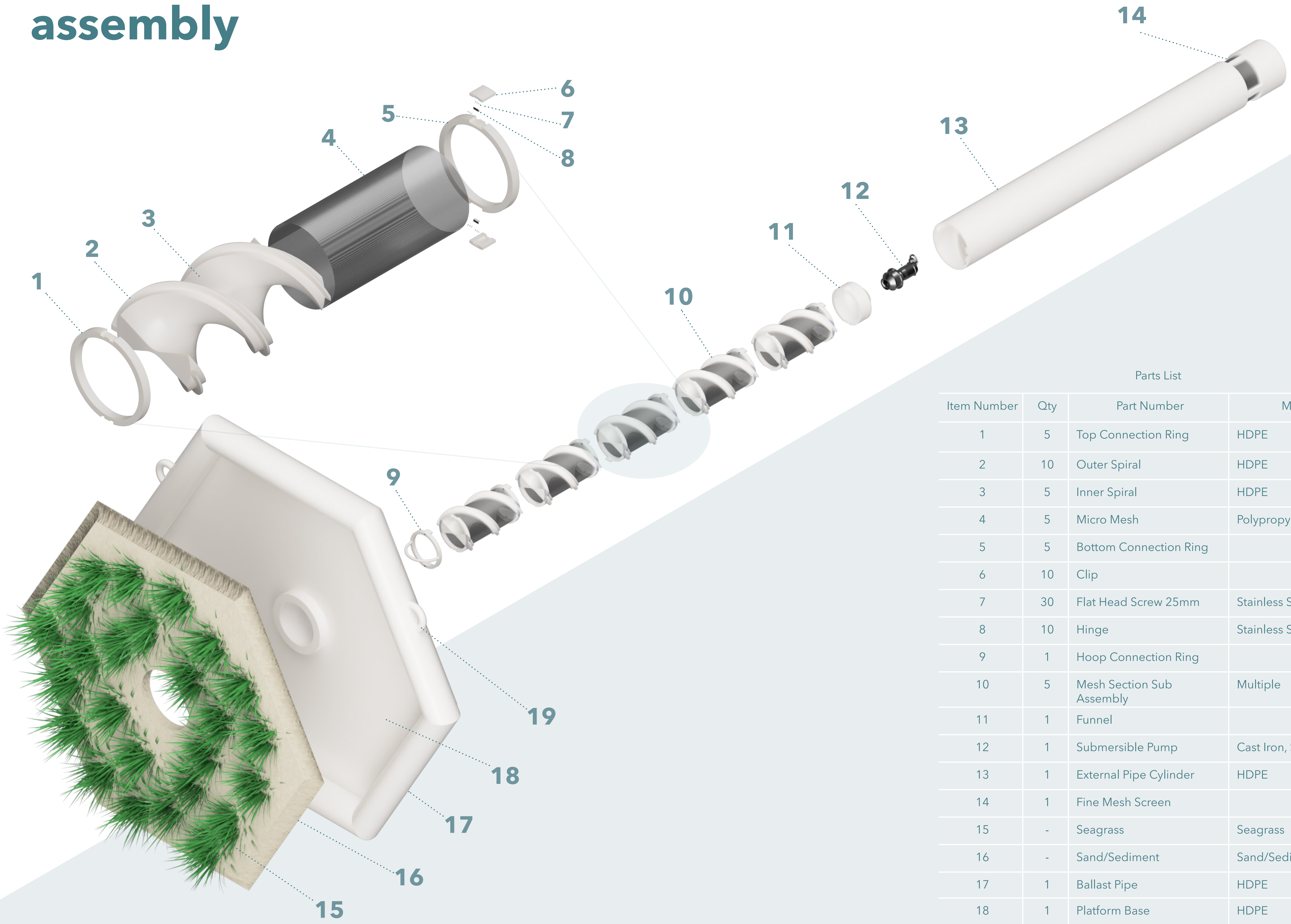
*Calculations were made based on the frequency of cleaning required for a domestic microfibre filter. XFiltra is a domestic microfibre filter which uses centrifugal filtration so assumptions were based on this device.

what happens to the microfibres?

enzyme recycling

Industry feedback revealed that this was the most promising method for recycling microfibres. The enzymes break down the plastic polymer structure into the individual monomers. The individual monomers can then be used to make something new. Similarly to The Ocean Clean Up recycling scheme which turns captured plastic into merchandise, the recycled fibres could be used to generate profit which could be reinvested into c-filter, closing the loop for the system.

assembly



Parts List

Item Number	Qty	Part Number	Material
1	5	Top Connection Ring	HDPE
2	10	Outer Spiral	HDPE
3	5	Inner Spiral	HDPE
4	5	Micro Mesh	Polypropylene
5	5	Bottom Connection Ring	
6	10	Clip	
7	30	Flat Head Screw 25mm	Stainless Steel 316
8	10	Hinge	Stainless Steel 316
9	1	Hoop Connection Ring	
10	5	Mesh Section Sub Assembly	Multiple
11	1	Funnel	
12	1	Submersible Pump	Cast Iron, Stainless steel
13	1	External Pipe Cylinder	HDPE
14	1	Fine Mesh Screen	
15	-	Seagrass	Seagrass
16	-	Sand/Sediment	Sand/Sediment
17	1	Ballast Pipe	HDPE
18	1	Platform Base	HDPE
19	1	Handle	HDPE