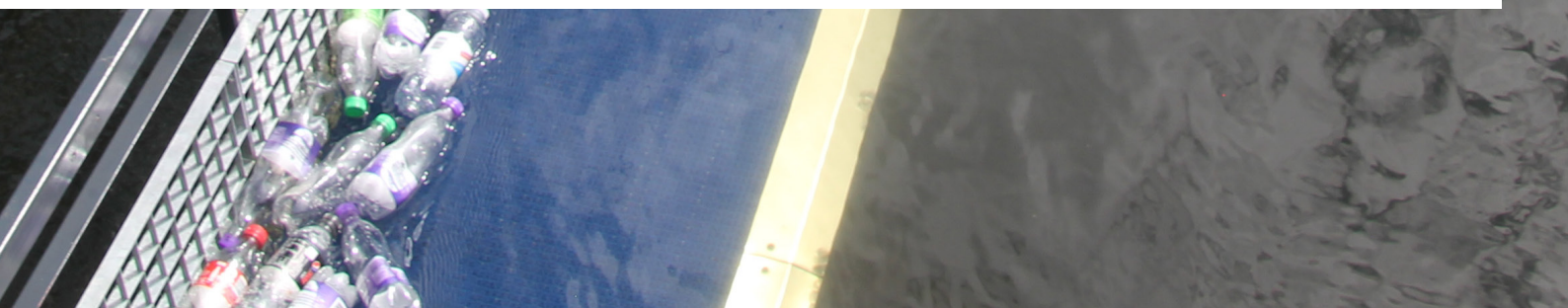
SeaProtectorOne

Removal of plastic garbage from rivers and streams

Findings and conclusions from test of SeaProtectorOne at the Tangevaerket Dam

Date: 20. October 2020

ARTLINCO A/S



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Removal of plastic garbage from rivers and streams

Findings and conclusions from test of SeaProtectorOne at the Tangevaerket Dam

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Test conducted in the period from 29th of april to 9th of july 2020

Report made for:
All in on green ApS

Report made by:
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October 2020
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Content:

Executive summary

SeaProtectorOne (SPO) is a module based plug and play system for collecting macro plastic in rivers and streams before the plastic garbage gets to the oceans and slowly turns into micro plastic.

With just a column installed on the river bank, the SeaProtectorOne can be virtually installed anywhere and automatically adapts to the water level and transports the waste to a container on the edge where it can be easily collected and driven away when the system gives a message that it's full.

With a variety of sensors, it will adapt to different conditions, lifting and going into a security position on the shore or quayside if the weather gets rough or bigger items are on collision course and thereby can act autonomously without the need for an operator.

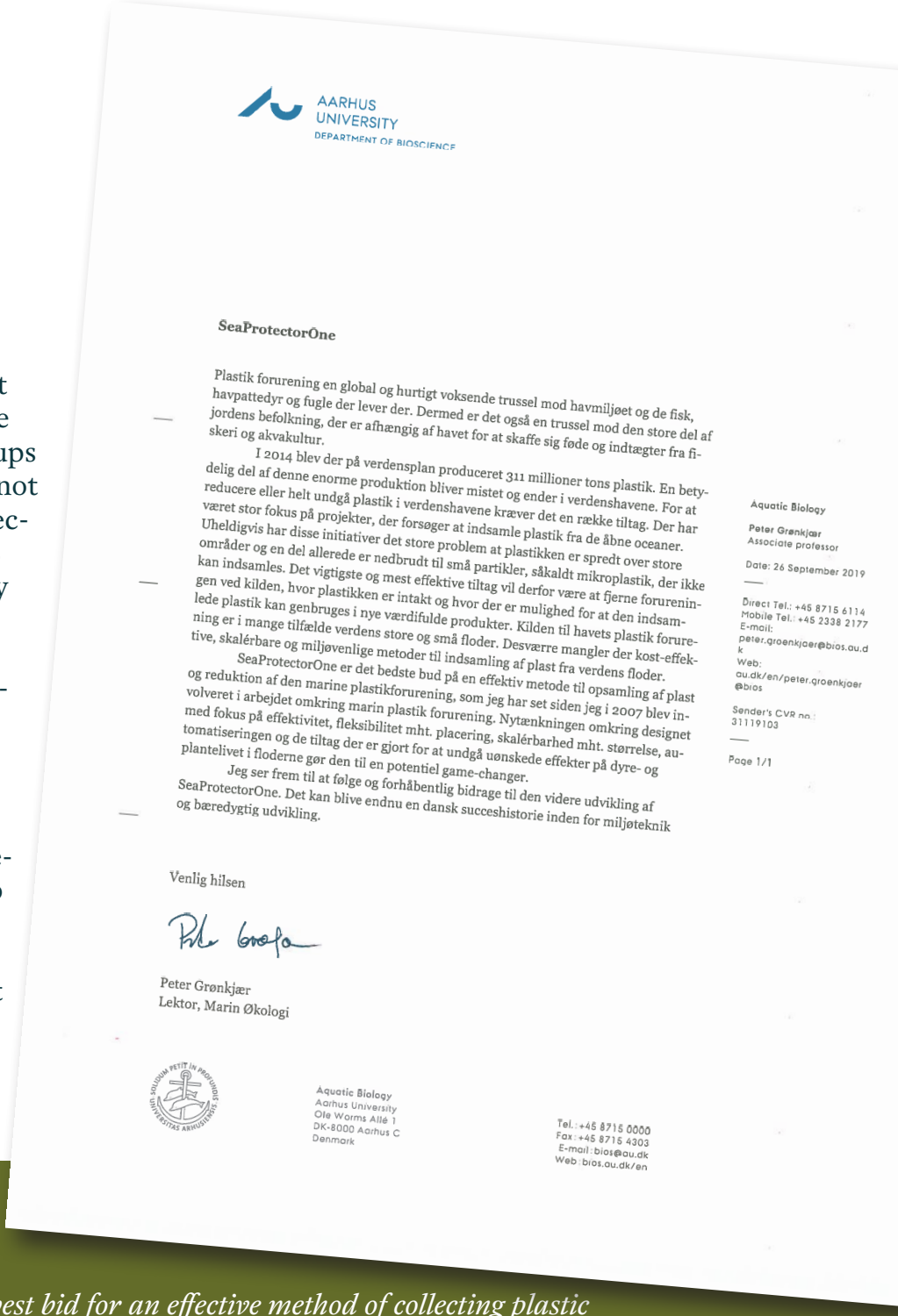
In this test Artlinco, as an impartial consultant, has tested the efficiency of which the SeaProtectorOne can collect different types of garbage.

The test has been conducted with two different setups (rev.a and rev.b) of the SeaProtectorOne but focuses mainly on rev.b that is the biggest and most challenging setup. Rev.b is also with a bigger grid that will affect the performance of the smaller waste types.

I theory the grid size of the SeaProtectorOne can be as small as 14mm and still have no impact on fish fry, thus collecting al macro plastic from 14mm and up to oil barrels (above this size the automatic collision detection system will come into effect).

In our tests we used a grid size at 20x60mm and 42x60mm and we can conclude that from plastic cups and up to big 20 l canisters (but not limited to that size) the SeaProtectorOne collects practically 100% of the garbage that comes its way while in operating mode and 60-75% of candy and candy bar papers. With the smallest grid(20x60mm), it even collects around 75% of the lighters.

Transferred into a real-world scenario it can be expected that two SeaProtectorOne' covering the whole width of a river but still allowing ships to pass can collect 85% of all macro plastic.



AARHUS UNIVERSITY
DEPARTMENT OF BIOSCIENCE

SeaProtectorOne

Plastik forurening en global og hurtigt voksende trussel mod havmiljøet og de fisk, havpattedyr og fugle der lever der. Dermed er det også en trussel mod den store del af jordens befolkning, der er afhængig af havet for at skaffe sig føde og indtægter fra fiskeri og akvakultur.

I 2014 blev der på verdensplan produceret 311 millioner tons plastik. En betydelig del af denne enorme produktion bliver mistet og ender i verdenshavene. For at reducere eller helt undgå plastik i verdenshavene kræver det en række tiltag. Der har været stor fokus på projekter, der forsøger at indsamle plastik fra de åbne oceaner. Uheldigvis har disse initiativer det store problem at plastikken er spredt over store områder og en del allerede er nedbrudt til små partikler, såkaldt mikroplastik, der ikke kan indsamles. Det vigtigste og mest effektive tiltag vil derfor være at fjerne forureningen ved kilden, hvor plastikken er intakt og hvor der er mulighed for at den indsamlede plastik kan genbruges i nye værdifulde produkter. Kilden til havets plastik forurening er i mange tilfælde verdens store og små floder. Desværre mangler der kost-effektive, skalérbare og miljøvenlige metoder til indsamling af plast fra verdens floder.

SeaProtectorOne er det bedste bud på en effektiv metode til opsamling af plast og reduktion af den marine plastikforurening, som jeg har set siden jeg i 2007 blev involveret i arbejdet omkring marin plastik forurening. Nytænkningen omkring designet med fokus på effektivitet, fleksibilitet mht. placering, skalérbarhed mht. størrelse, automatiseringen og de tiltag der er gjort for at undgå uønskede effekter på dyre- og plantelivet i floderne gør den til en potentiel game-changer.

Jeg ser frem til at følge og forhåbentlig bidrage til den videre udvikling af SeaProtectorOne. Det kan blive endnu en dansk succeshistorie inden for miljøteknik og bæredygtig udvikling.

Venlig hilsen

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> *"SeaProtectorOne is the best bid for an effective method of collecting plastic and reducing marine plastic pollution, which I have seen since I became involved in the work on marine plastic pollution in 2007. The new thinking around the design with a focus on efficiency, flexibility in terms of location, scalability in terms of size, automation and the measures taken to avoid unwanted effects on the animal and plant life in the rivers make it a potential game-changer."*

Assesment of SeaProtectorOne concept by
Peter Grønkjær
Associate professor
Aquatic Biology
Aarhus University

Technical review

Overall structure

- Consists of tower, sled, boom with filtration unit, control unit for all workflows and waste container
- The strength of the construction is based on Pythagoras
- Modular tower and boom with filtration unit. Can be shipped in a 20 ”container
- Can filter up to 65 meters across a river (one SPO on each side)
- Filtration unit consists of grid and conveyor belt. Mesh size can be adapted to local conditions (eg. fish fry or seasonal conditions)
- Easy to assemble (plug’n’play)
- Easy to mount
- Powered by hydraulic motor with bio-oil and electricity
- Sensors and cameras (including thermal) ensure safe operation and data capture
- Has low energy consumption - can be powered by turbine, wind or solar (add on)

Assembly

- Mounted on existing quay edge or on built-up cast foundation, adapted to requirements, calculations and the surroundings.
- Typically mounted on a day with the help of a crane or similar
- Immediately in operation after installation
- The design of the waste container is adapted to individual, local requirements and needs

Security

- Control unit responds to the following events (and sends SPO to safety position):
  - Approaching ship traffic (thermal cameras)
  - Approaching smaller vessels (dinghy, canoe, kayak etc) (thermal cameras)
  - Wind speed with mean wind above specified strengths (locally determined) (anemometer)
  - Temperature below / above specified degrees (locally determined) (temperature sensor)
  - Can be programmed to respond to other objects (add on)
  - Fully functional even in the dark

Workflow

- Runs 24/7
- Control unit ensures automatic emptying at the desired time interval and/or at filled filtration unit
- Can be controlled manually
- The process of emptying the filtration unit:
  - Filter unit is tilted in the horizontal direction
  - Filter unit is raised vertically to empty position
  - Grid door opens
  - Filtering unit tips back and conveyor belts unload waste in waste container
  - Grid door closes
  - Lower the filter unit vertically to the calibrated filter position
- The process of activated safety signals (safety position):
  - Beacon signal on tower and filter unit
  - Filter unit is raised vertically to empty position
  - Filtering unit rotates 90 degrees around the tower (parallel to the quay edge)
  - Filtering unit re-establishes filtering position when safety signal is terminated (control unit registers “free path”)
- Follows river and ebb - measures water surface and continuously adapts to depth
- For optimal waste management, the windscreen and tipping function are mounted on the filtration unit

Maintenance and cleaning

- Easy to maintain
- SPO consists of sub-elements, which are primarily available worldwide
- During maintenance and/or cleaning, move the filter unit to the safety position
- In the safety position, the entire filter unit can be accessed and inspection, replacement and other necessary maintenance can be performed
- Servicing of hydraulic system takes place on land (bio-oil)

Background

The plastic pollution of the oceans is a global, rapidly growing problem and a threat to both fish, marine mammals and birds, as well as all the people that are dependant on the ocean. Its estimated that between 1.15 to 2.41 million tonnes of plastic enters the oceans via rivers annually, which accounts for about 25% of the total plastic increase in the oceans.

SeaProtectorOne is developed by All In On Green to collect plastic waste from the rivers and streams before it enters the oceans and is spread over a huge area, where its both difficult and expensive to collect.

SeaProtectorOne is developed in corporation with Aarhus University to ensure that it doesn't affect marine life.

SeaProtectorOne is a fully automated system that can collect garbage from the rivers without interference from people - it only needs to be emptied when it tells that the container is full.

SeaProtectorOne adapts to the water level and can detect excessive wind and large objects and move into a security position on the shore or quayside if necessary.

SeaProtectorOne delivers the collected waste to a container at the base when full or at a predefined time interval.

SeaProtectorOne is modular, so it is easy to transport, easy to assemble and can be varied in length.

SeaProtectorOne can be placed on the edge of the river or stream, on a quay or a riverbank. Alternatively, it can be placed surrounded by water on a pile foundation. Naturally it can be placed staggered on both sides of the river to cover the full width (up to 62meters) of the river and still allowing for pasing of river traffic.

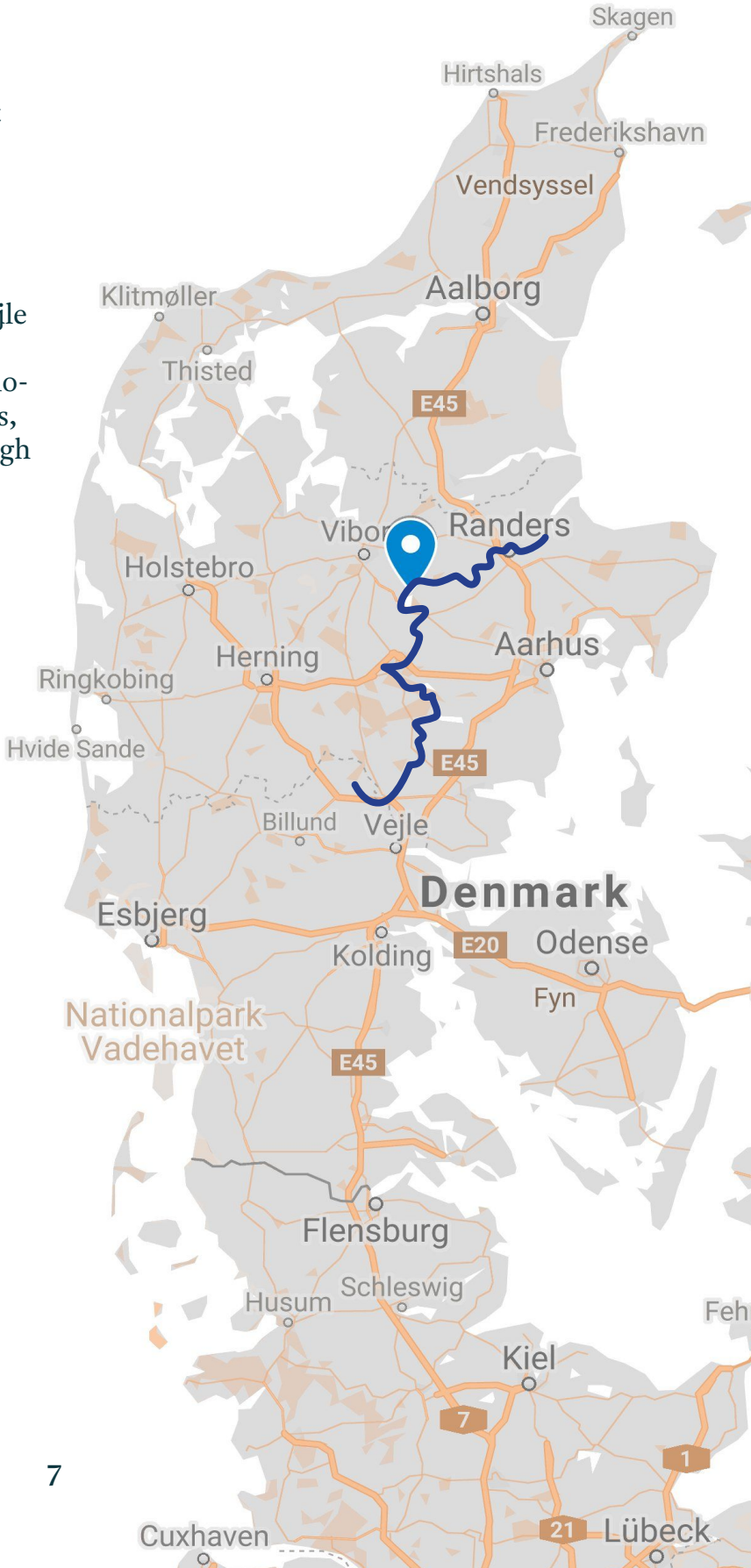
Test setup

Test Area

Gudenå or Gudenåen is Denmark's longest river and runs through the central parts of the Jutlandic peninsula. An anglicized version of the name often seen is 'The River Guden'.

Gudenåen has its spring in Tinnet Krat, Vejle Municipality (between Nørre Snede and Tørring-Uldum) and flows a total of 149 kilometres (93 mi) to Randers Fjord in Randers, on a northward course which takes it through the central parts of Jutland.

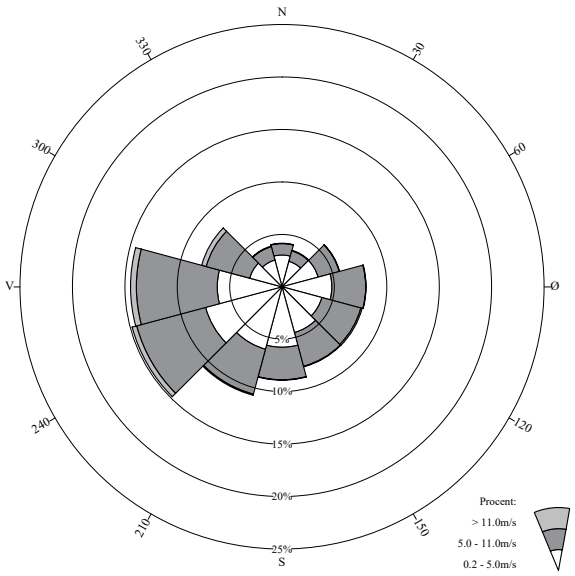
Source	
location	Tinnet Krat
Elevation	72 m
Mouth	
Location	Randers Fjord
Elevation	0 m
Length	149 km
Basin size	3,300 km2
Discharge	
Average	32.4 m3/s



Areal view

The test site is located right after the Hydroelectric dam, (Gudenåcentralen A.M.B.A.) and thus the water is already filteret and free from debris and garbage, making it a clean and consistent base for tests.

Weather conditions



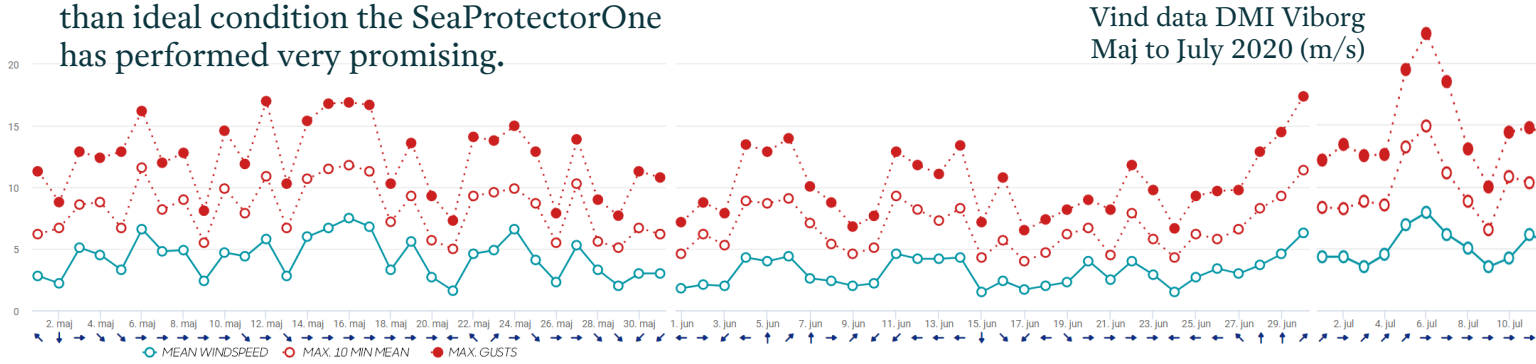
Windrose from Foulum weather station,
16km from test site
Based on winddata from 01-01-89 - 31-12-98

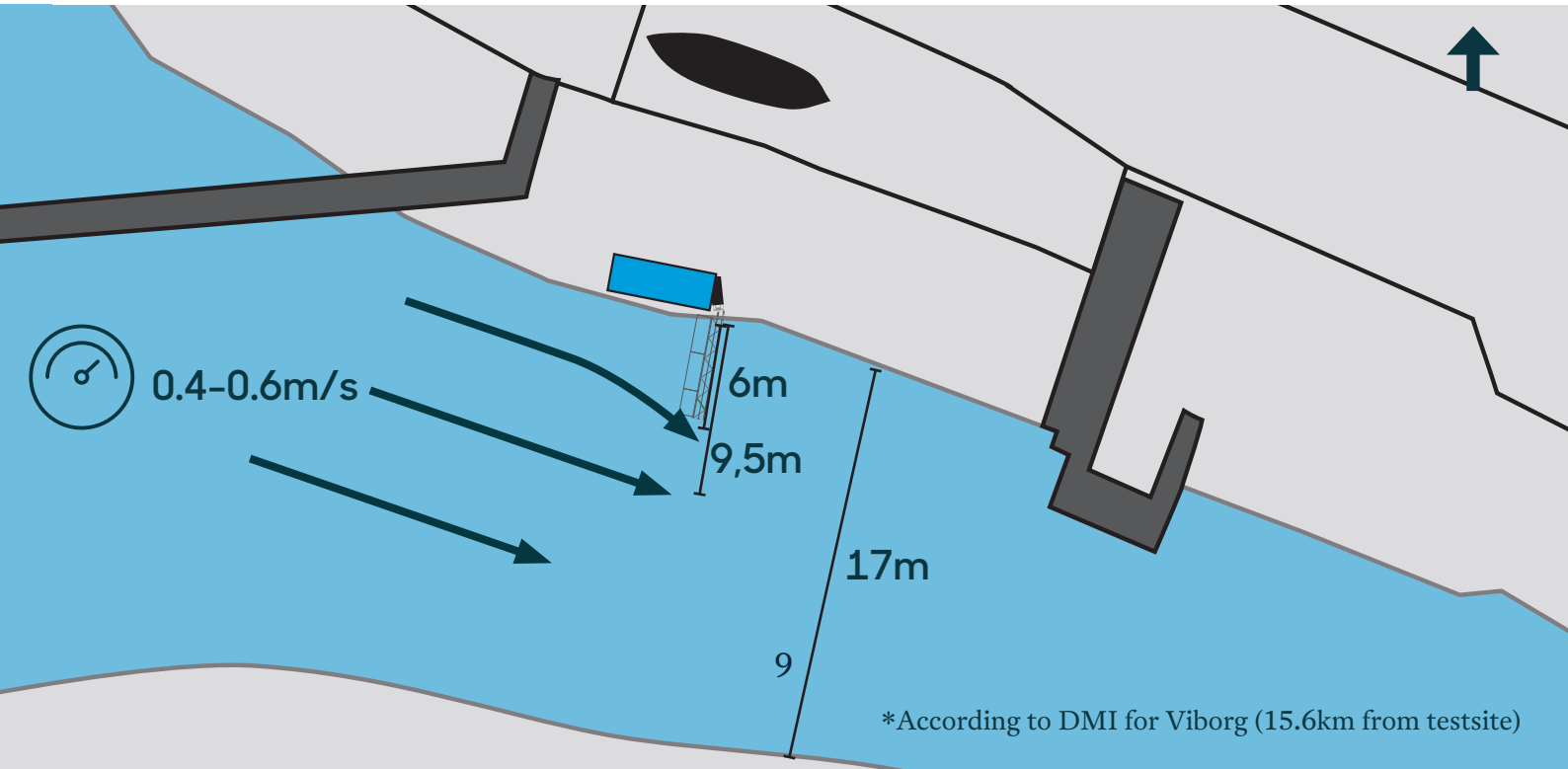
The site is characterized by relatively low current (0,4-0,6 m/s) and a wind (dominantly from west and west southwest) that is mostly in the same general direction as the current. But due to the topography, many gusts come from different directions.

Due to the shape of the river bed, the current is turning a little outwards at the SeaProtectorOne. This makes the current hit the SeaProtectorOne in an angled that isn't 90 degrees. Together with the low current and the gusts, this makes this place more challenging for the SeaProtectorOne. Despite these less than ideal condition the SeaProtectorOne has performed very promising.

The weather in the days of testing was with a mean wind speed at 5.7m/s and maximum gusts at 9,8m/3.*

Vind data DMI Viborg
Maj to July 2020 (m/s)





*According to DMI for Viborg (15.6km from testsite)

SeaProtectorOne RevA

The first test setup was with a 6 meter beam with a 60x20mm grid, that moved the collected waste to a container at the shore by:

33sek **1** lifting the beam free of the water and in height with the container or containers

22sek **2** turning the beam with the waste parallel to the shore

5sek **3** tipping the content into the container

22sek **4** turning back into position

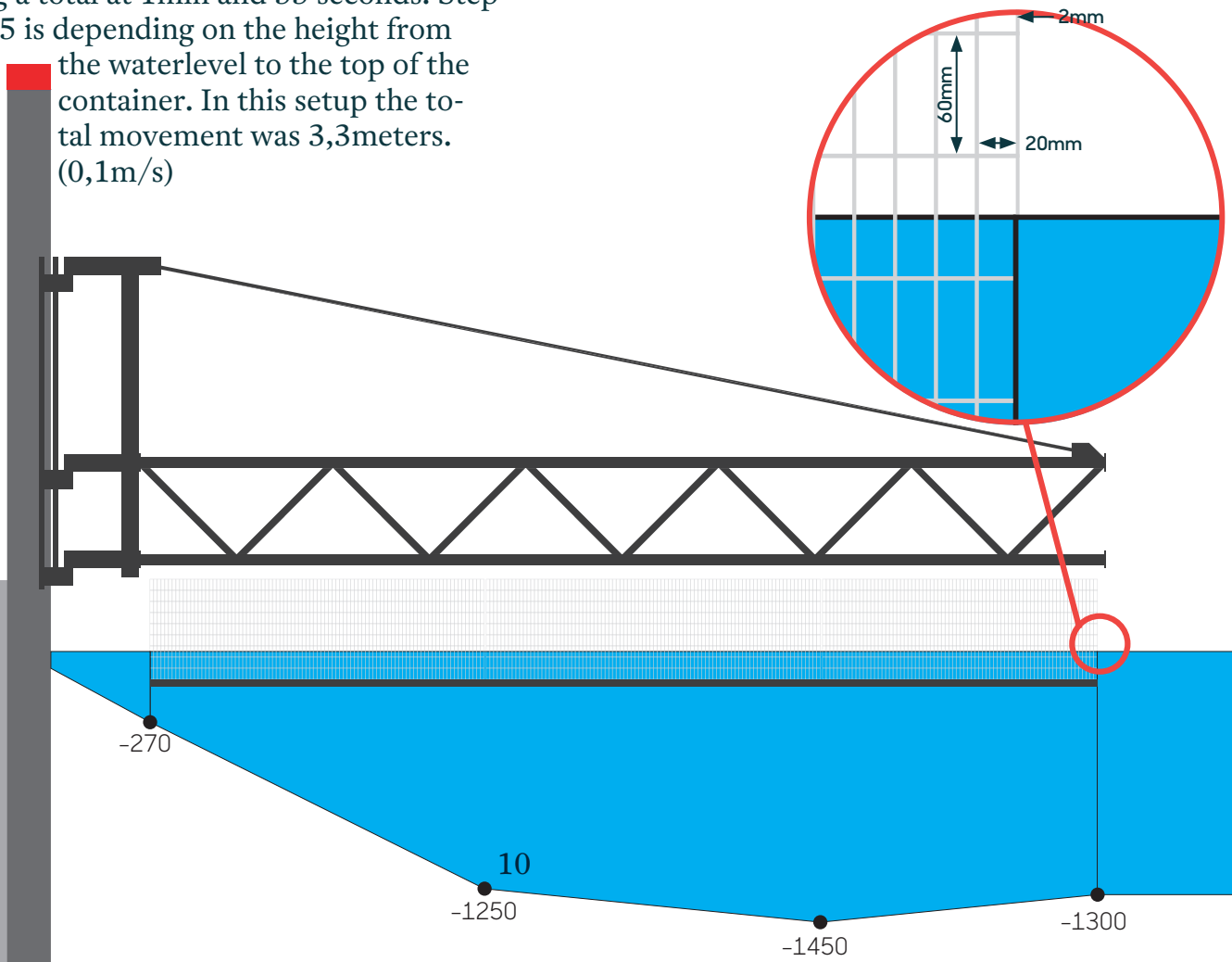
33sek **5** lowering down to the water.

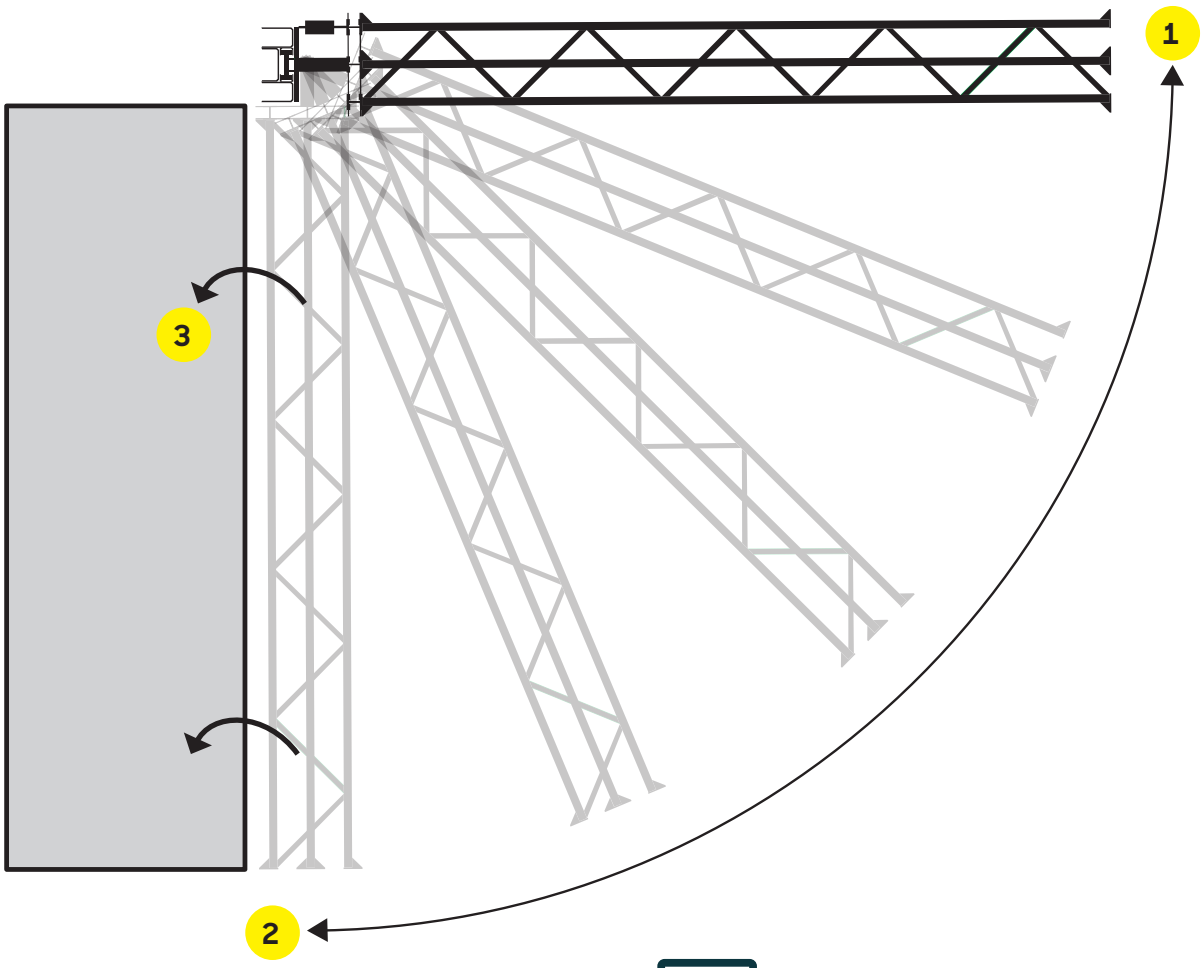
Giving a total at 1min and 55 seconds. Step 1 and 5 is depending on the height from the waterlevel to the top of the container. In this setup the total movement was 3,3meters. (0,1m/s)

The movement into security position (because of excessive winds or big objects) is done in a similar manner:

1 lifting the beam free of the water and in height with the container or containers

2 turning the beam with the waste parallel to the shore





1min 55sek

SeaProtectorOne RevB

In RevB a bigger grid is tested that seems more fitting for the leafs found in Aarhus Å. This could affect the collecting performance of the smaller waste types.
The beam is prolonged to 9.5 m and the waste is trasnported to the container by a conveyer instead of the swing mechanism:

33sek **1** lifting the beam free of the water and in height with the container

7sek **2** Open the gate

13sek **3** moving the collected waste to the container by the conveyer

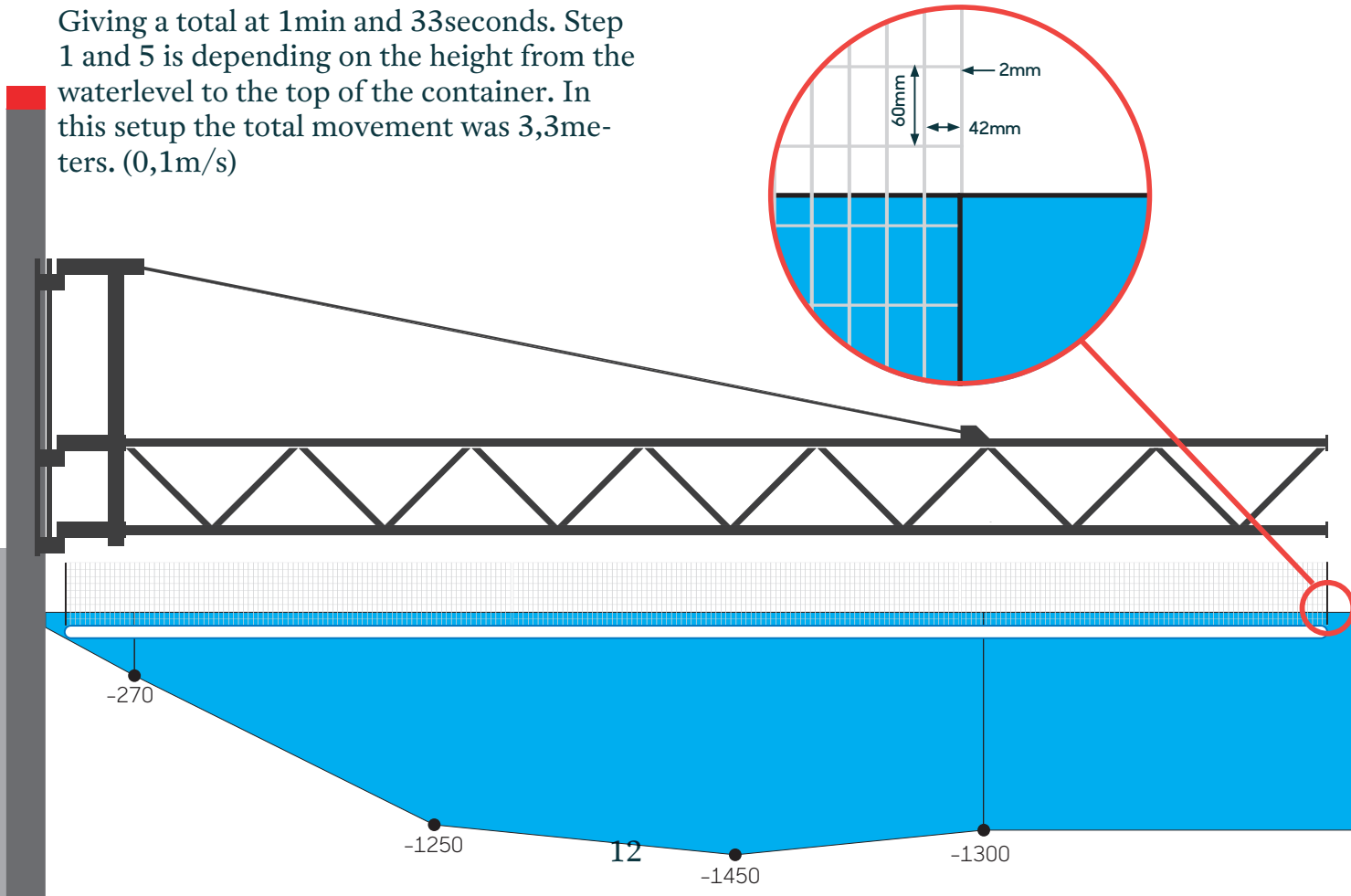
7sek **4** Close the gate

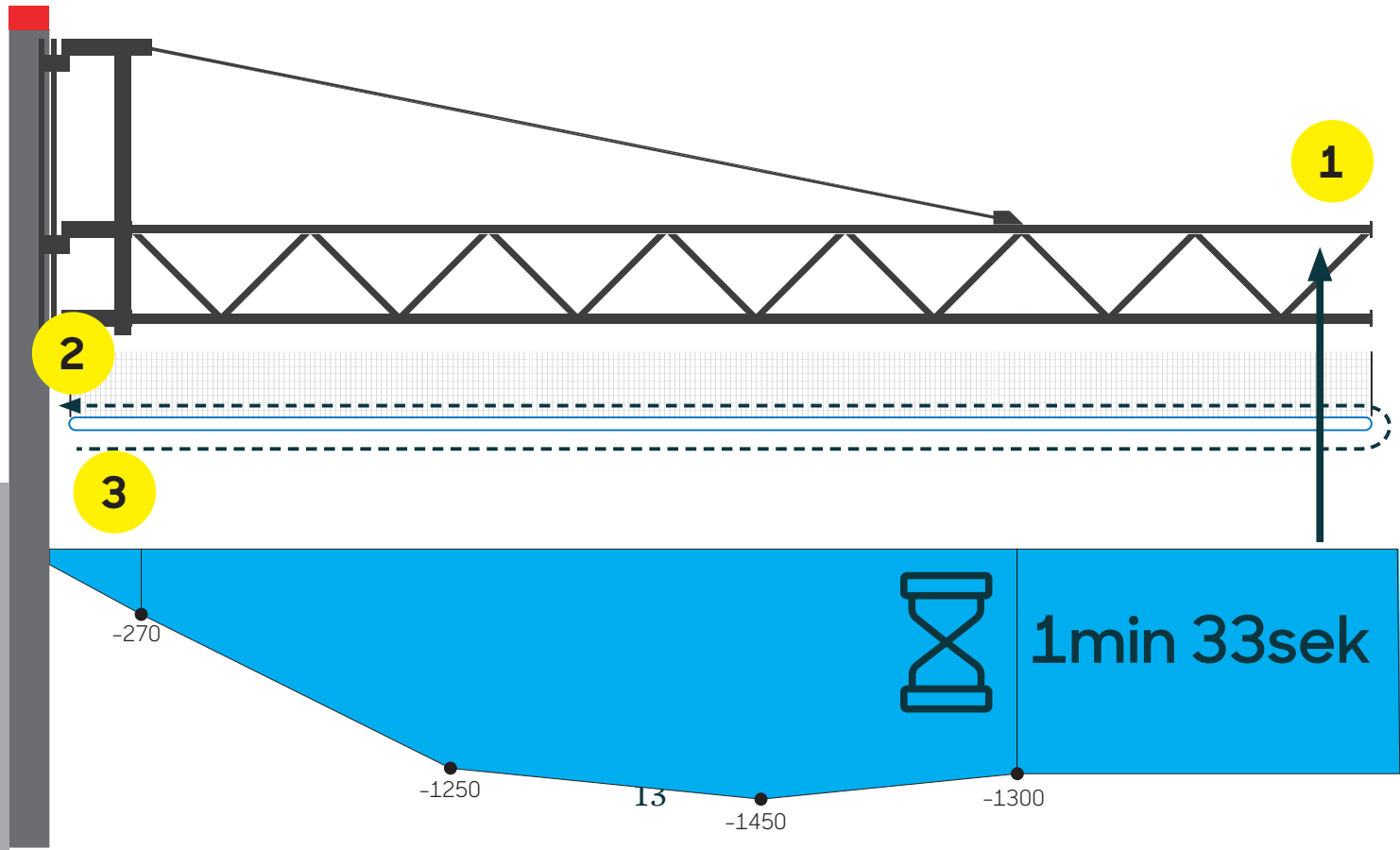
33sek **5** lowering down to the water

Giving a total at 1min and 33seconds. Step 1 and 5 is depending on the height from the waterlevel to the top of the container. In this setup the total movement was 3,3meters. (0,1m/s)

The movement into security position (because of excessive winds or big objects) is still done with the swing function like in RevA

Grid size:
Different grid sizes can be fitted to ensure optimal performance in different conditions. According to Aarhus University the grid size could be as small as 14mm and still have no impact on fish fry.




1
2
3
-270
-1250
-1450
-1300
1min 33sek

Garbage types

Based on the most prevalent macroplastics from “Plastic Rivers” as well as items that could prove a challenge for SeaProtectorOne; 8 different garbage types was chosen for the test, where both lighter and candybar paper was knowingly to small to be catched in the more coarse grid fittet on the SeaProtectorOne RevB.

Test was also conducted with pipe insulation, Styrofoam, pizza trays, construction waste, tarpaulin and large 100 liter cannisters, without making further studies in this regard.

The highest quantity of testing was focused on the bottles which constituted the largest part of plastic litter items in the freshwater environment.

Plastic Rivers, from earthwatch institute

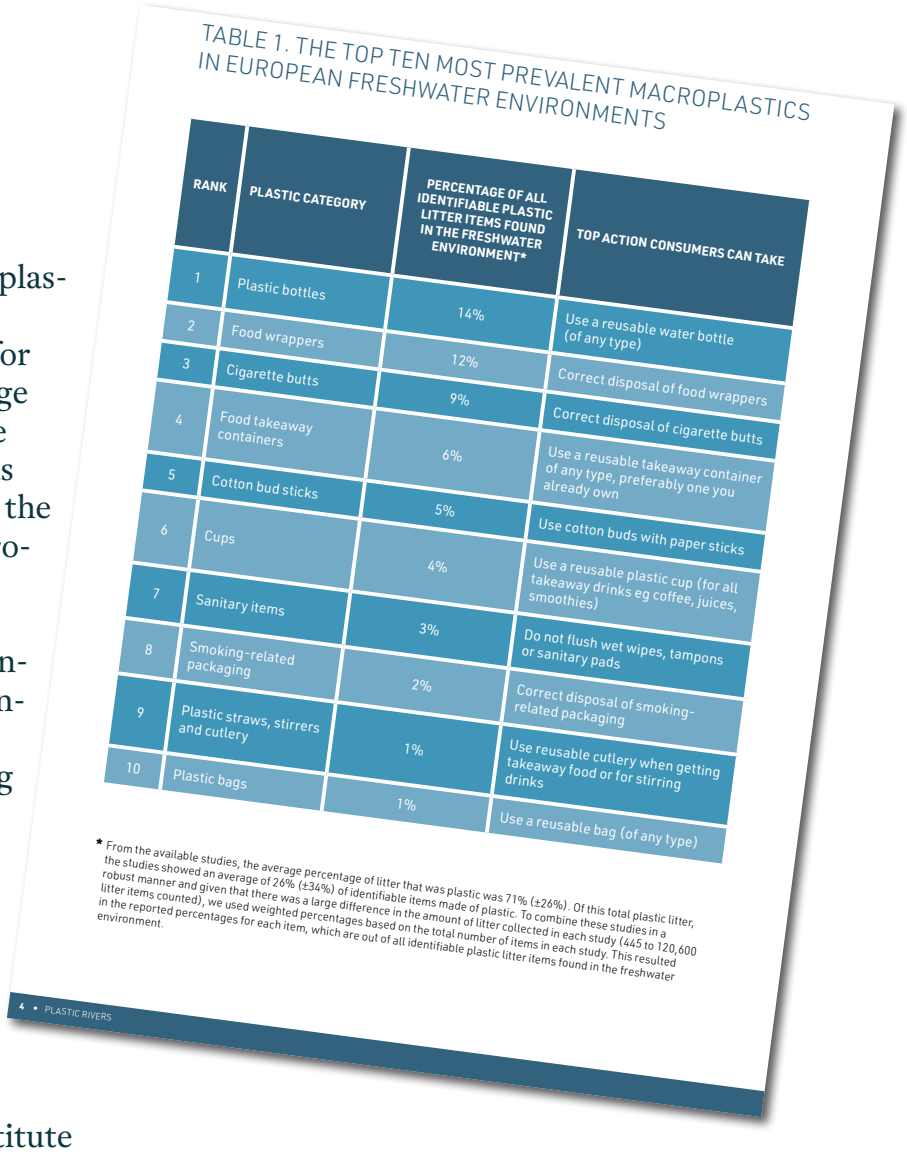


TABLE 1. THE TOP TEN MOST PREVALENT MACROPLASTICS IN EUROPEAN FRESHWATER ENVIRONMENTS

RANK	PLASTIC CATEGORY	PERCENTAGE OF ALL IDENTIFIABLE PLASTIC LITTER ITEMS FOUND IN THE FRESHWATER ENVIRONMENT*	TOP ACTION CONSUMERS CAN TAKE
1	Plastic bottles	14%	Use a reusable water bottle (of any type)
2	Food wrappers	12%	Correct disposal of food wrappers
3	Cigarette butts	9%	Correct disposal of cigarette butts
4	Food takeaway containers	6%	Use a reusable takeaway container of any type, preferably one you already own
5	Cotton bud sticks	5%	Use cotton buds with paper sticks
6	Cups	4%	Use a reusable plastic cup (for all takeaway drinks eg coffee, juices, smoothies)
7	Sanitary items	3%	Do not flush wet wipes, tampons or sanitary pads
8	Smoking-related packaging	2%	Correct disposal of smoking-related packaging
9	Plastic straws, stirrers and cutlery	1%	Use reusable cutlery when getting takeaway food or for stirring drinks
10	Plastic bags	1%	Use a reusable bag (of any type)

* From the available studies, the average percentage of litter that was plastic was 71% (±26%). Of this total plastic litter, the studies showed an average of 26% (±34%) of identifiable items made of plastic. To combine these studies in a robust manner and given that there was a large difference in the amount of litter collected in each study (445 to 120,600 litter items counted), we used weighted percentages based on the total number of items in each study. This resulted in the reported percentages for each item, which are out of all identifiable plastic litter items found in the freshwater environment.

4 • PLASTIC RIVERS

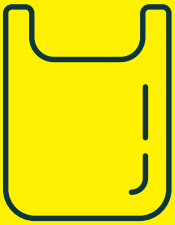
Lighter

1/2 litre bottle

1 1/2 litre bottle

20 litre canister

To go cup



Plastic bag

Candy bag

Candybar paper

Test method

All tests were performed by dropping the test subjects in the water approximately 10 meters from the SeaProtectorOne.

The test was focused on the garbage that was within the reach of the SeaProtectorOne only. In a real world situation garbage will be spread across the entire river, and only the part covered by the SeaProtectorOne can be collected.

The collecting performance will be very dependant on the actual weather and current situation. with a low current as on the test site, a wind from the opposite direction is expected to easily move the waste floating on the surface.

Because of the relatively big grid size, the smaller items as candybar paper and lighters is expected to be a big challenge to collect.

With the smallest possible gridsize (14mm) both lighters and candybar paper will be collected, because its impossible for these to penetrate the grid.

Apart from the waste collection tests, operational tests of the SeaProtectorOne were also made - including 10 days of continuous operation. These operational tests were without any problems.

All efforts was made to ensure that items not catched by the SeaProtectorOne was otherwise collected, to ensure at test with no pollution of the Gudenå.

Test results

mean wind speed = 5.7m/s
maximum gusts = 9,8m/3*

The bottles distributed quite evenly at the grate, and the wind did not seem to have much effetc on the bottles. The movement made by the SeaProtectorOne before lifting up from the water, made the bottles distribute even more, securing no bottles were lost.

Collected/Total RevB

170/170 ½l

70/70 1½l

= 100%

The big plasic containers were easily collected - but because of the big area above water on completely empty containers, they were more sensitive to wind. A big gust from the opposite direction made one cannister move out of the SeaProtectorOne and passed on by.

RevB

13/14 20l

= 93%

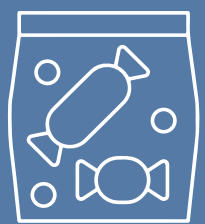
The paper cups were no problem - even filled with water they were still close enough to the surface to be caught in the grate.

RevB

65/65 cups

= 100%

One candy bag was torn and slipped through the grate. As long as the candy bags are relatively whole 100% would be collected. There was no need for further testing.



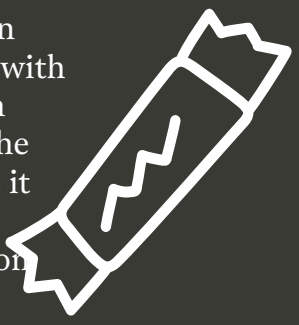
RevB

11/12 bags

= 92%

*According to DMI for Viborg (15.6km from testsite)

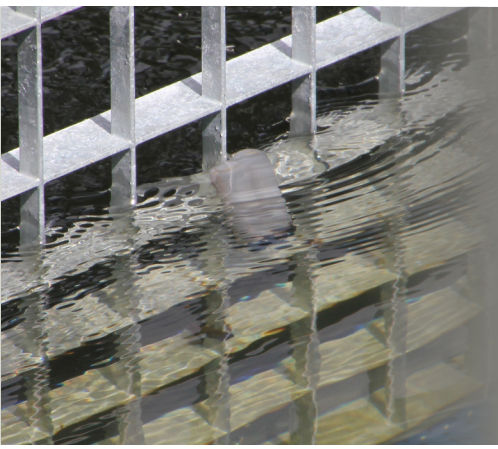
The candybar paper was clearly on the limit of what can be collected with the big grid. If the paper had been crumpled it would pass through the holes - or get stuck in the holes so it wouldn't be collected.
With the smaller grid the collection rate is expected to be 100%



RevB

7/11 bags

= 64%



As expected the lighters are too small to get caught in the grid in RevB- even if they are caught for a start because of their vertical position in the water - when the SeaProtectorOne moves to collect the waste, it passes through. This test was therefore conducted with RevA.

RevA

6/8 lighters

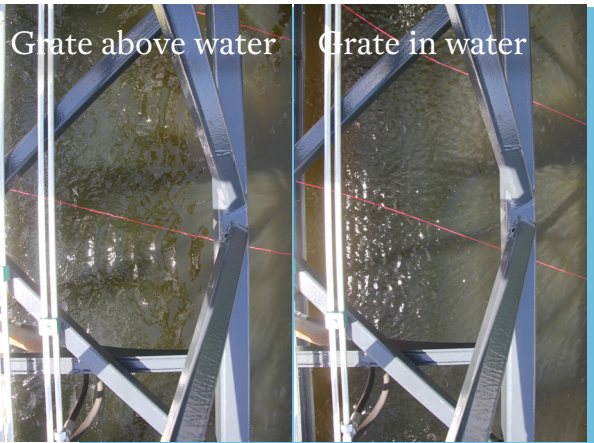
= 75%

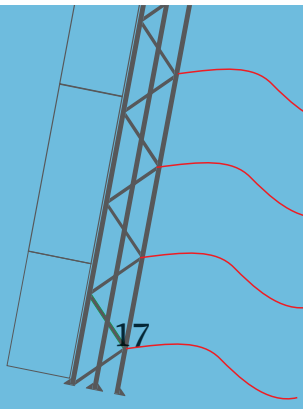
The plastic bags proved no problem, as long as they float with the water they will be caught- and even a large tarpaulin was no problem - but did affect the flow.

RevB

10/10 bags

= 100%





The flow in the river is not in a 90 degree angle to the SeaProtectorOne as preferred. This makes the collected waste tend to move to the end of the belt instead of distributing evently. When the grate is submerged in the water it has a very little effect on the flow direction.

Data transferred into real-world figures.

Based on the data collected, we have calculated what our findings transfer to in a real-world situation.

Plastic type:	% of total identified plastics*	weighted %	Collected by SeaProtectorOne		weighted %
Bottles	14%	44%	 100% 93%	97%	42%
Food wrap-pers	12%	38%	 92% 64%	78%	29%
Cups	4%	13%	 100%	100%	13%
Plastic bags	1%	3%	 100%	100%	3%
Lighters	1%	3%	 75%	75%	2%
total	32%		**Calculated total collection %:**		**89%**

* Plastic Rivers, from earthwatch institute

By applying the weighted percentages of the identified plastic types to our test results, we can calculate that SeaProtectorOne collects 89% of the plastics passing by (87% if using the big grid that can't collect lighters) when submerged into the water.

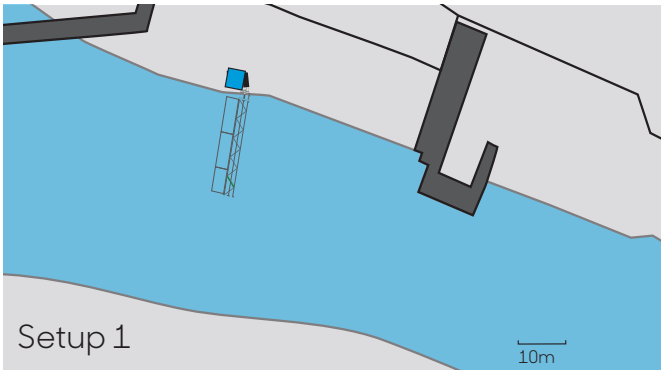
SeaProtectorOne starts an emptying cycle in a predefined interval (depending on the amount of plastic in the water) and/or when the sensors tell that its full. In most cases, we would expect 1 emptying cycle every 2 or 3 hours, but for calculation, we have used 1 cycle of 1min33sek per hour.

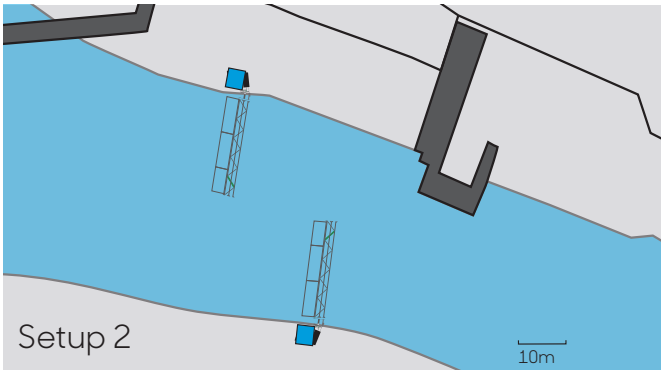
The security position is used when the wind is too strong and can give movements in the structure or make the already collected waste move off the SeaProtectorOne. Winds in that strength weren't observed in the test period (even single gusts at one occasion made a canister float away) but for our calculation, we have set the trigger at a mean wind at 11m/s. According to wind data from Foulum weather station, 16km from the test site, the wind was above 11m/s in 1.9% of the time in the period 01-01-89 - 31-12-98.

This threshold could probably be higher but is dependant on the local conditions such as the current and topography. And in many conditions it would also be possible and

preferable to have a more intelligent trigger for the security position.: ie. when the wind is coming in the same direction as the current, the allowed wind speed is 15m/s. When it coming from the opposite direction it's 11m/s.

Finally, the SeaProtectorOne doesn't cover the whole river, but by working in pairs (or with 3 or 4) it can cover the whole with of the river and still allowing traffic to pass.





% in emtying position (emptying cycle (1,33m) every hour)	3%	
% in security position (wind above 11m/s)	1,90%	
Calculated operating %	95,52%	
Setup	1	2
% of river covered	50%	100%
Efficiency	89%	
Calculated amount of waste collected	**42,71%**	**85,43%**

So based on our data and observations 1 SeaprotectorOne covering 50% of the river or stream should be able to collect 42.71% of all plastic garbage passing by. And by positioning two making the whole width of the river covered, it would collect 85,43%.

In rivers with a very big amount of floating plastic (so that the emptying cycle gets more frequent) an extra set could be placed that collects the plastics when the first one is emptying.

Conclusions and findings

Optimal placement

The optimal placement of SeaProtectorOne based on our observations, is with a flow of around 0.3-1 m/s coming in a 90degree angel to the grid with the dominating wind direction coming from the same side. Preferably placed so it is protected from strong gusts from the opposite direction.

Waves

SeaProtectorOne will be operating in various weather conditions and with ships/boats etc passing by. This will most likely present waves lapping against the boom creating quick and local increase in water head.

Big waves passing in the opposite or across the direction of the flow can push the outer pieces of waste away from the SeaProtectorOne.

The optimal location is therefore protected from large waves.

Wind

SeaProtectorOne will be operating in days with moderate to strong wind force. Especially winds opposite to water flow direction or cross wind away from the base could present a challenge in retaining the waste.

We saw that gusts (above 10m/s according to DMI)in the opposite direction of the flow could move light pieces of waste free from the SeaProtectorOne.

A windscreen will be added to the design to counteract this phenomenon.

If the wind reaches speeds above 12m/s* the SeaProtectorOne will start emtying cycle and go into security position.

The optimal location is with the wind coming dominantly from the flow direction.

*Due to weather in the test period, SeaProtectorOne hasen't yet been tested at wind speeds above 12m/s. Its possbile that this trigger can be set at a higher wind speed after testing.

Observations

Waterhead

One of the features of SeaProtectorOne is its ability to follow the water head up and down. At the same time the strainer must be submerged at an appropriate level to ensure collection of waste.

This functioned perfectly with the automatic regulation.

The optimal depth is around 30cm.

Flow

SeaProtectorOne relies on a continous flow to collect. Flow speed will not be constant and a difference between velocity of different rivers is to be expected.

We define the flow velocity as a span from 0,4* to 2 m/s (*Amazon river is one of the fastest running rivers).

It is clear that the flow of the Gudenå (0,4-0,6m/3) was enough to secure the waste even from rather strong gusts. But the SeaProtectorOne would probably perform better with a higher flow.

At a lower flow the collected waste would be more sensitive for wind and waves.

Fish

SeaProtectorOne is designed to allow fish to pass, and we did not observe any fish caught in the grate.

However one can not avoid that in certain conditions small fish can be trapped in the garbage, or accidentally be over the conveyer belt when lifting and thus being collected by the SeaProtectorOne.

Large object

SeaProtectorOne will not only collect macroplastics but also experience various larger object both organic and inorganic. Collecting such object will presumably affect the collection of other smaller waste types.

The sturdy build didnt seem to be affected by large objects - and 3 persons could easily walk on the construction without any problems and movements in the construction.

the construction is calculated to be able to handle a minimum of 40 kg per meter. After 6 months of use / testing, there are no signs of weakness, wear or other effects.

Leaves

SeaProtectorOne is tested with 250 liters of leaves (large beech leaves), thrown into the water with an even distribution over 2 minutes.

80% flows through directly through the grid. Those who are stuck, gradually disappear with each emptying cycle.

The grid size can be adjusted to local condition, eg. leaves, to avoid the grid to be filled to fast.

About Artlinco

Artlinco is a full service innovation house with experience from more than 350 local as well as international projects. We don't like guesses or 'stomach feelings'. We build products and services on facts, and ensure that 'everything look and feel for a reason'.

An important common denominator for our more than 350 successful projects is that we work in interdisciplinary teams. Here we create scenarios and solutions that are based on a perfect combination of customer insight, analysis, data, creativity, technical competence, and experience.

With our team of engineers and designers, we analyze conditions and document solutions to ensure a solid foundation on which to base decisions.

We have made use of our experience and contacts to objectively assess SeaProtectorOne during testing in the Gudenåen and assess that SeaProtectorOne is a solid and effective part of a solution to one of our planet's major problems.

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