Ref. Ares(2020)496831 - 27/01/2020

HAZRUNOFF PROJECT

"Integration of sensing and modelling technologies for early detection and follow-up of hazmat and flood hazards in transitional and coastal waters"

Analysis of available response equipment well suited to transitional waters

Funded by European Union Civil Protection and Humanitarian Aid

WP	4, Task 4.2.3
Action	Report – Analysis of available response equipment well suited to transitional waters
last updated	20 /01/ 2020
version	Final
authors	Cedre
participants	All partners

Disclaimer

"This document covers humanitarian aid activities implemented with the financial assistance of the European Union. The views expressed herein should not be taken, in any way, to reflect the official opinion of the European Union, and the European Commission is not responsible for any use that may be made of the information it contains."

TABLE OF ILLUSTRATIONS

TABLE OF FIGURES

INTRODUCTION

This report details the works undertaken by Centre de Documentation de Recherche et d' Expérimentations (Cedre) to perform an analysis of available response equipment suited to transitional waters under Task 4.2.3 of Work Package 4.

Work Package 4 aims to contribute actively to an efficient preparedness and response to floods and hazmat response in transitional waters, through the clear definition of site-adapted response actions and protocols including know how on the available equipment adapted to the characteristic of estuaries for emergency responders.

Background

Main estuaries associate important rivers and transitional waters (coastal embayment, delta), associated with flood risks and potential for hazmat incident, due to the presence of a wide range of activities, such as energy, chemical or oil facilities (refineries), large storage of various products, shipyards, ship traffic with liquid cargo etc… All these activities are close to urban areas or sensitive activities like fishing or aquaculture potentially exposed to hazmat incidents and associated risks.

Hydrographic conditions in estuaries such as salinity and suspended matter change the behaviour of the pollutants, high velocity of currents, shallow depth along muddy banks and often plant debris and/or waste mixed to the pollutant are challenging conditions for response operation. Indeed some response equipment useful for containment and recovery **of floating pollutants** may become inefficient in these specific conditions.

The question of floating pollutant (oil, vegetable oils and chemicals with high viscosity…) containment and recovery in areas characterised by strong currents is a recurrent issue, particularly in rivers and estuaries where fast-flowing water is often found. There are generally two types of problems raised by such configurations:

- first, the difficulty in deploying containment booms in strong current, given the extremely strong pull forces exerted by such currents,

- second, these booms' very limited capacity to contain oil in such conditions. ***It is considered that leaks of oil are liable to appear under the boom when facing into currents exceeding a theoretical value of around 0.35 m/s (approximately 0.7 knots).*** This is a relatively low current speed, bearing in mind that floating booms tend to naturally form an apex in which the water exerts its maximum perpendicular strain, which can even, in strong currents, lead to complete submersion of the boom, rendering it ineffective.

This critical speed greatly reduces the efficiency of containment and trawling operations using conventional booms in areas of strong current. In an attempt to provide a suitable containment solution for this scenario, various systems have been developed by the spill response industry over recent years.

In addition of booms, the efficiency of recovery devices (skimmers and pump) may be also greatly reduced due to the presence of floating debris which is often observed in estuaries.

The review that will be presented in this report is not exhaustive but based on trials organized by Cedre since 2013 and conducted in 2018 in the frame of the HazRunoff project with the support of manufacturers of such equipment, and partners (Port authorities and crew of support vessel and mooring services of the Loire estuary, France). In fact, in the Loire estuary, past incidents had underlined such need for new protocols and equipment for a better efficiency of the response.

RESPONSE IN ESTUARIES AND TRANSITIONNAL WATERS

Available Response Equipment and Strategies

In case of spill of a floating pollutant at sea surface, manufactured floating booms are used in the aim to prevent or limit oil contamination of banks or sensitive resources and activities.

Booming is used for different purposes:

- protection: to protect sensitive banks, natural resources or amenities such as water intakes, harbour facilities…;
- containment: to contain and concentrate the oil in the aim of facilitating its recovery by using skimmer located within the boom;
- deflection: to divert the oil either off the shore or towards the shore to a collection point on the shore.

Booming is not only used in static configurations (i.e. anchored/moored) but also in dynamic configurations, i.e. towed by one or two vessels, aiming at "hunting" drifting oil slicks threatening to hit the shore.

Booms Deployment

Booms can be used in different configurations either dynamical (towed booms) or static (moored booms).

DYNAMICAL BOOMING: TOWED BOOMS

Boom can be towed by two vessels in U, V or J configuration. For example, a 300m towed boom may allow sweeping a 100 meters wide area. Towing vessels should be able to manoeuver at very slow speed (0,5 knots to 1 knot).

This booming system is then usually transformed into an at-sea oil recovery system by deploying a recovery device (skimmer) within the boom, from one of the towing vessel or from a third one, behind the boom. Some specific dynamic containment system (see below) allowed a higher towing/recovery speed.

Contained oil can also be just towed at a very low speed to be skimmed along a bigger vessel or a quay. If facing currents or winds, the vessel(s) can stay in a stationary position to reduce the relative speed and prevent the oil escaping.

Dynamic booming (as well as recovering) can also be carried out by using a single vessel equipped either with an outrigger or with a specific device called paravane (a device similar to the one used for surface trawl net by fishing vessels) that maintains the opening of the boom only by advancing against the current at speeds of 0.5 to >5 knots (Fig. 1).

Aircraft equipped with suitable air-to-sea communication is usefully to assist dynamical containment and recovery operations by guiding the vessels towards the main oil slicks.

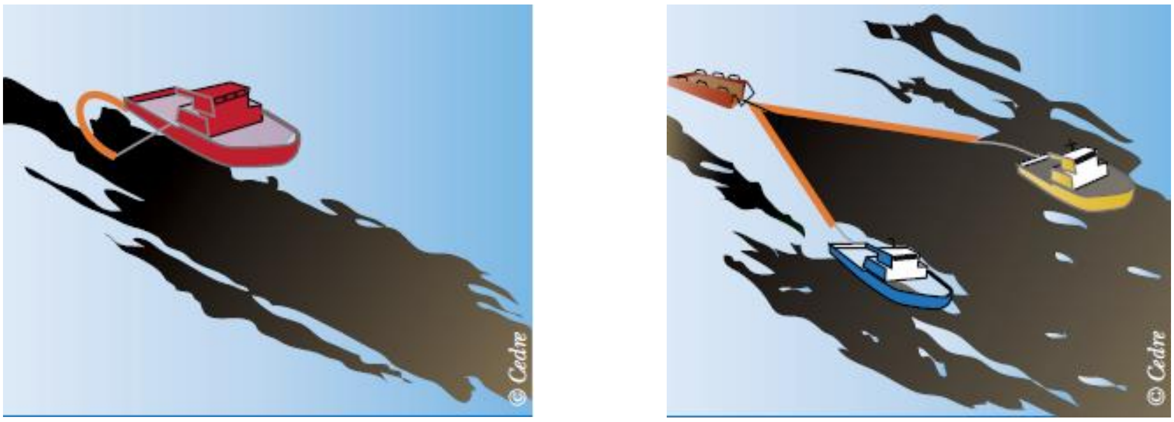


Fig.1 *- Dynamic containment configuration (source Cedre):*

Single vessel using an outrigger | *2 vessels towing a boom in a V configuration with a recovery barge at the apex of the boom*

Photo 1: *Boom and Trawl boom towed by one vessel equipped with a paravane (source Cedre)*

Photo 2: *Examples of dynamical booming configurations (source: Cedre)*

STATIC CONFIGURATION: MOORED BOOMS

Fixed booming is widely used in coastal waters along the shoreline for different purposes: to contain the oil at the source (leakage from a stranded vessel, from a wharf, etc.), to protect sensitive natural habitats or economical resources (aquaculture, water intake, marina, etc.), to contain a stranded slick.

Here after are described some static booming configurations that are likely to be implemented in an estuarine or port environment.

- **To contain oil at the spill source**

It consists in isolating the source by surrounding it, either by encircling it or by containing the floating oil between the vessel and the quay.

  - Leakage scenarios: oil transfer or bunkering operations (at-sea or at berth); stranded or sunken wreck, etc.
  - Prevention scenarios: wreck lightening, oil transfer or bunkering operations (at-sea or at berth) etc.

Note: In many harbours with oil transfer or (un)loading activities, booms are pre-stored at the immediate vicinity of the transfer spot to be immediately deployed in case of emergency - see are systematically deployed during each operations.

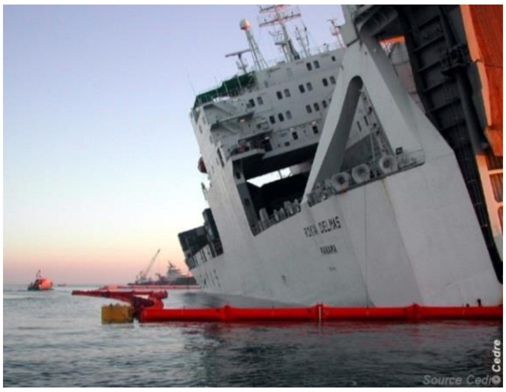


***Photo 3, Photo 4** : Corralling a vessel (source Cedre)*


Photo 5, Photo 6 : *Containing oil against a structure (source Cedre)*

- **To exclude oil from sensitive resources**

Booms are deployed at a slightly oblique angle to deflect the oil towards as easy-access recovery site. To allow vessel traffic, a gate (removable boom section) can be set up between two moorings points.

Photo 7 *: Protecting a natural sensitive site (source: Cedre)*

Photo 8 *: Protecting a fishing port (source: Cedre)*

- **To deflect oil toward a collection area**

In some conditions booms can be used to deflect oil in the aim (i) to recover it quieter waters or less sensitive areas or (ii) to simply divert the oil off a sensitive sites (Fig. 2).

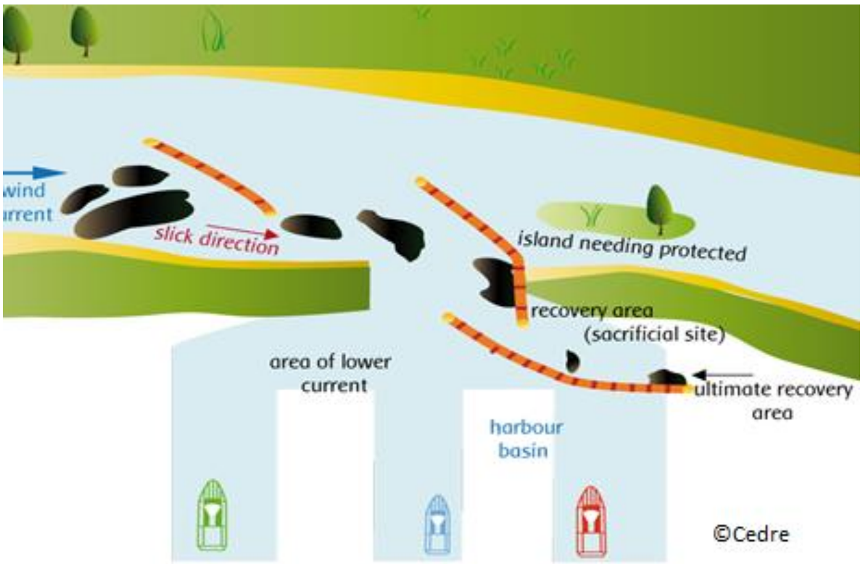


Fig. 2 *- Deflecting oil toward less sensitive areas, like harbours facilities (source Cedre)*

Operational Limits and Constraints of Booming

The limitation on the use of booms is related to wind, waves and currents (and water depth).

BOOMS LIMITATIONS

- When deployed perpendicular to the current, booms fail in containing oil when current velocities are over 0,35 m/s (0,7 knots). Beyond this limit, even if the boom stays in place, the oil escapes. To avoid it, the boom has to be installed in an oblique configuration: its opening being then inversely proportional to the current velocity. It is possible to deflect floating oil even in a 1,5m/s (3knots) current velocity (Fig. 3), but this requires a far greater linear of booms to implement.

Current strength		Maximum angle
knots	m/s	degrees
0,7	0,35	90
1,0	0,5	45
1,5	0,75	30
2,0	1,0	20
2,5	1,25	15
3,0	1,5	13

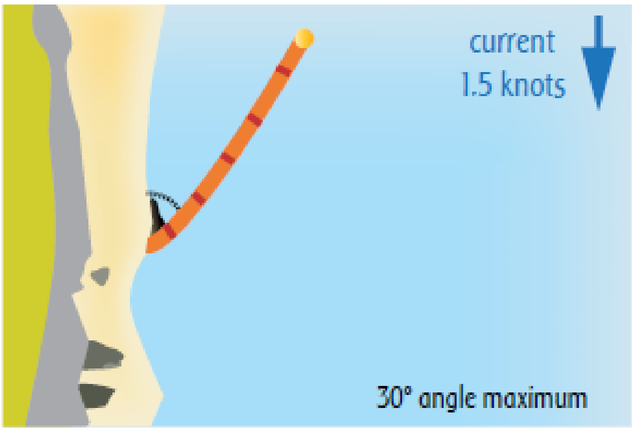


Fig. 3 *– oblique configuration to afford current strength (source Cedre)*

- Wind and waves in excess can cause *splash-over* of contained oil (Fig. 4), very high current may cause the boom to suffer *submersion* particularly in case of low buoyancy or when anchored in fast current or towed at too fast speed, (Fig.5). This means that the limit of use of the equipment is reached; flat permanent booms are more subject to submersion than inflatable booms. Low viscosity oil escapes at lower velocity than viscous one. The turbulence shears droplets from the underside of the oil slick that then escape under the boom. This process is call *entrainment* (Fig. 6). In too fast currents or towage speed, vortex is being created behind the booms allowing some oil to escape under the boom (Fig.7).

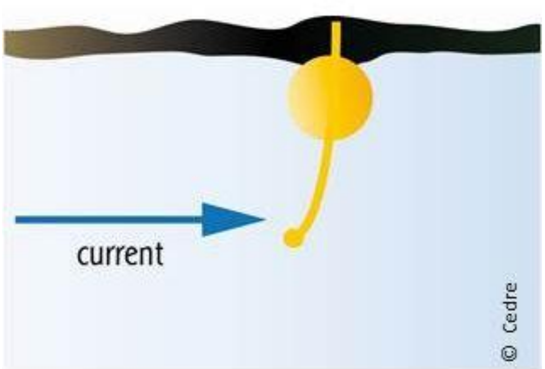


Fig. 4 *- Splash over (source Cedre)*

Fig. 5 *– Submersion (source Cedre)*

Fig. 6 - Entrainment (source Cedre)

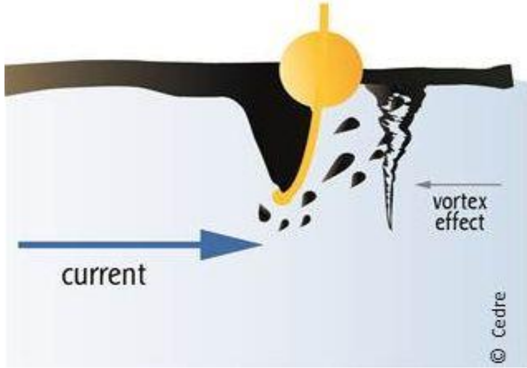


Fig. 7 - Leakage due to vortex effect (source Cedre)

- A boom has a limited retention capacity; the leak threshold is quite rapidly reached. Beyond a certain quantity of accumulated oil, a boom alone is not sufficient to allow the containment of an oil slick: a skimming/pumping system has to be associated for avoiding the oil escape under or over the boom.

BOOMING LIMITATION

- Booming is not practicable everywhere: its feasibility depends on many characteristics of the sites, both geomorphological (type of substrate, no presence of sharp rocks or objects, water depth, for example) and hydro dynamical (currents, wind, wave exposure, tidal ranges, etc...).

- The booming of a wide area is not efficient, see useless beyond 600 m: such an operation, that is time and resources consuming, is most of the time not at all compatible with allotted time and available resources. Moreover, the efforts applied on such long booms are likely to be very strong and to lead to displacements of some anchoring elements, and then to subsequent retention failures all along the linear of the booming system.

- Booming is most of the time not easy to carry out. It generally requires dedicated oil spill response equipment (booms, anchoring lines, skimmers, etc.) as well as more or less specialized logistics both on the water and on land. Booming also supposes a considerable availability of time for implementation – and in situ maintenance - and numerous skilled personnel.

- Booming is not always systematically appropriate: for example, a containment of light volatile oils at a source not only may create a risky situation - for the crew first but also for the concerned facilities (explosive or ignition atmosphere) - but maybe useful because such products generally evaporate and dissipate very rapidly.

- For all these reasons above mentioned, it is commonly recognized that the protection by booming of sensitive sites is better achieved when a set of procedures have been prior developed in a *Boom Implementation Plan.*

Booms Characteristics and Types

BOOMS CHARACTERISTICS

There are different types of manufactured booms: floating, shore sealing and sorbent booms. The most frequently used are the floating boom. Floating booms are manufactured in a wide variety of designs, sizes and materials for different applications.

They are generally composed of 4 main components (Fig. 8):

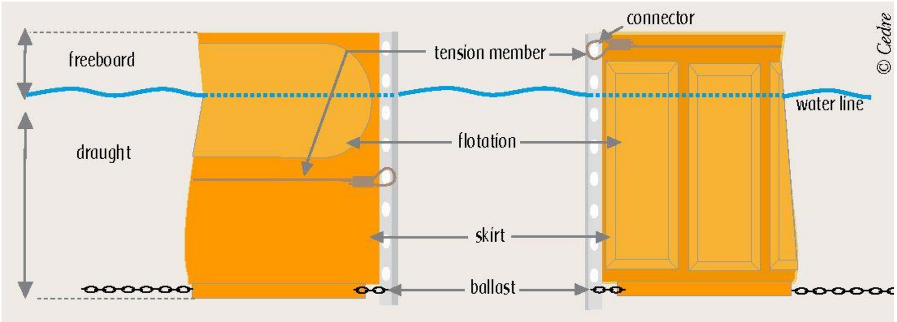


Fig. 8 *- The main components of a floating boom (source Cedre)*

- the flotation chamber or floater contains air (inflatable booms and some self-inflating booms) or foam (permanent booms and some self-inflating booms), provides buoyancy and prevent splash-over (heavier boom used in rough offshore conditions requires more flotation than lighter boom used in calm water);
- the skirt acts as a screen below the waterline and prevent oil from escaping below the boom. Forces from currents acting on a boom increase with skirt depth and can cause skirt failure;
- the tension element bears the forces imposed by the wind, the waves and the currents or by towing. It consists usually in chain, wire cable, fabric webbing;
- the weight or ballast enables the skirt to stay vertical in water. It may consist in individual weights but usually the tension element (chain, wire cable…) serves as ballast.

Freeboard and draft

When deploy at sea, the part of the flotation chamber above the sea surface defines the freeboard that prevents the oil to splash-over the boom. Wind forces on a boom increase with freeboard surface area.

The draft (defined by the part of the flotation chamber under sea surface plus the skirt) prevents oil from escaping under a boom in low to moderate current conditions. Shallow draft skirts reduce the tension on a boom.

<u>Height of booms</u>

The total height of a boom usually refers to the type and location of its use according its tolerance to sea states. On the market, one can find overall heights between 0,20 m up to more than 3 m for heavy offshore purposes. Generally, the draught represents around 60% of the overall height.

Three categories of boom size can be identified, the sea condition and currents are key determinant to choose appropriate one:

Total height (freebord+ draught)	Categorie	Conditions
<0,5 m	Lightweight boom	calm waters wave height <0,3 m
0,5 to 1m	Medium weight boom	protected waters wave height from 0,3 to 1 m
> 1m	Heavy duty boom	offshore wave height > 1m

TYPES OF BOOMS

A lot of manufactured booms are proposed on the market, and their designs and sizes should be evaluated depending environmental conditions to optimize: tensile strength resistance, roll stiffness (resistance to turn over in high currents and wind), ability to conform waves (minimizing oil losses due to splash-over or oil escaping under the skirt). Ease and rapidity of deployment (from land or boat), ease of storage are other important elements to consider.

Floating booms can be classified according their size, their behaviour at sea (curtain booms Vs fence booms), and their design (float types).

Fence boom are flat-shaped permanent type boom. Floaters usually consist of foam moulded within boom (Fig. 9). They can be deployed quickly but have lower buoyancy and be liable to plane under the effect of current or wind. Some models are suitable for routine deployment, protection of terminal facilities and marina in calm conditions. This type of boom is designed to respond in calm to slight conditions (inland waters, harbours), in low currents <0,5 knots).

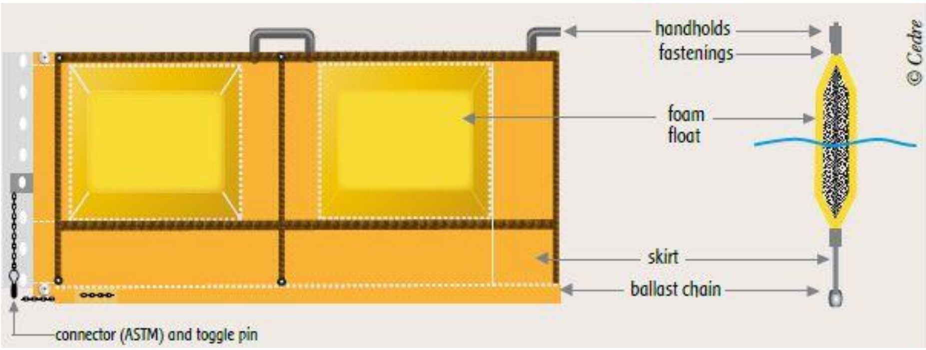


Fig.9 - *Fence-type floating boom (source Cedre)*

Curtain booms have more flexible skirt and move more independently from the floats allowing better wave response. There are different types of curtain booms:

- Permanent booms (with foam floaters) are rapid to deploy, can be used in area where currents are > 0,5 knots.
- Self-inflating booms (with an air flotation automatically ensured, when deployed, through openings or one-way valves, the chamber being maintained in configuration either by pieces of foam (Fig.10), or thanks to a (ring- or diamond-shaped) shaping internal structure) (Fig. 11) are rapid to deploy, have a good buoyancy due to solid flotation plus air trapped in the pocket, a good behaviour to swell and winds. Boom with foams are complicate to repack; those with internal deploying structure are easier to store and repack because on reel.

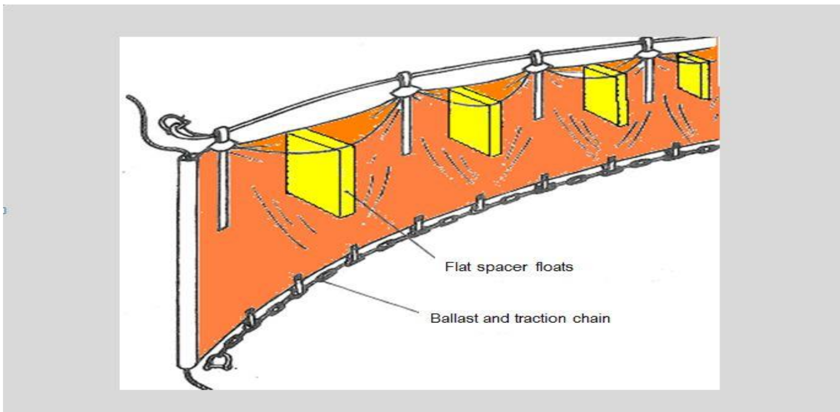


Fig.10 - *Self-inflating booms* with foam floaters *(source Cedre)*

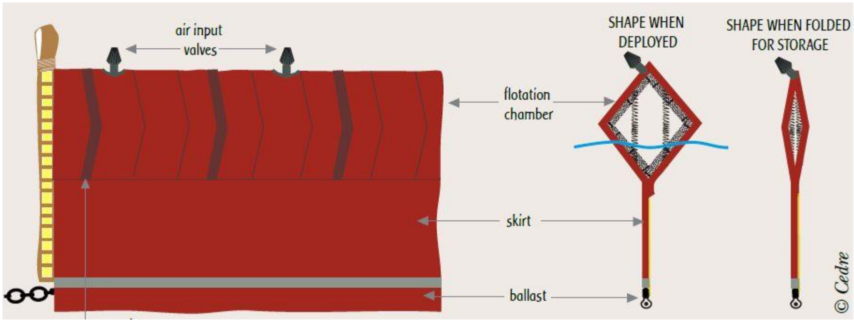


Fig. 11 **-** *Self-inflating booms* with internal shaping structure *(source Cedre)*

- <u>Inflatable booms</u> (with a cylindrical air-filled flotation chamber) (Fig. 12) allow compact storage and have high buoyancy. The Inflation time and the space for deployment have to be taken in account and they require particular emphasis on maintenance (valves…). They are the most usual type of boom used offshore from spill response vessel; they are also widely used in estuaries to protect sensitive sites.

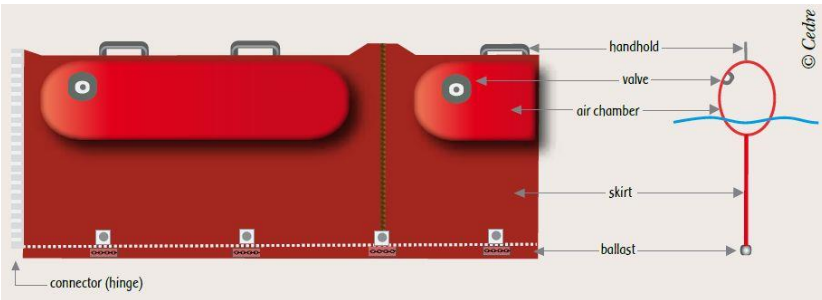


Fig.12 *- Inflatable boom (source Cedre)*

Sorbent booms

Sorbent booms are products in which the loose sorbent material is contained in a very oil-permeable netting envelope. Certain models have a "skirt", a flexible ballasted screen which improves their ability to contain a floating pollutant. Sorbent skirted boom are used to retain, contain and absorb oil (depending on oil viscosity) on calm waters.

Photo 9 : ***Sorbent boom*** *(source Cedre)*

Photo 10 ***: Sorbent skirted boom*** *(source Cedre)*

Shore sealing booms

These booms are composed of one or two chamber(s) filled with water acting both as skirt and ballast and one upper air-filled chamber providing buoyancy (Fig.13). They are used in shallow tidal waters: the boom will settle on the ground as the tide ebb and will form an oil-tight seal between the sediment and the high water mark.

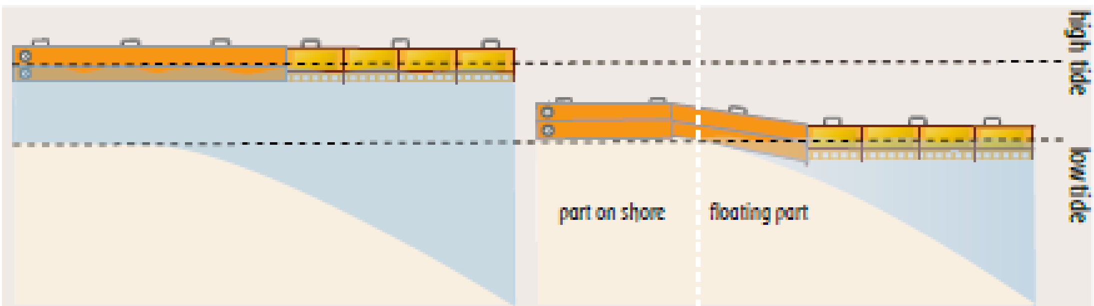


Fig. 13 *- Shore sealing booms (source Cedre)*

CONTAINMENT SYSTEMS DESIGNED FOR CURRENT CONDITIONS

Some types of containment/recovery systems have been specifically developed by manufacturers in recent years, especially for fast current ***to collect oil at speeds of up to 2,5 knots even 5 knots for some models***. The technologies adopted vary, but the basic principle is the same*: **reduce the speed of the fluids between the boom inlet and the bottom of the pocket where the pollutant is collected***.

Some of these systems are presented in the following paragraphs, especially those tested by Cedre in the Loire estuary.

NOFI Current Buster and Elastec (ORC AB) BoomVane paravane

DESCRIPTION AND PRINCIPLE OF THE EQUIPMENT

The *NOFI Current Buster* is designed to collect and concentrate oil floating at the water surface in current speeds from 3 knots for the smallest model (*Current Buster 2*) to 5 knots for the *Current Buster 6 and 8* designed for offshore response (Fig. 14). This speed can represent either the movement of the water mass in relation to the stationary system, for instance moored in a river perpendicular to the current (static mode), or the relative current speed when towed behind or beside a vessel (dynamic mode).

In addition to its improved behaviour in current, the system also includes a water and oil separation device, whereby the oil is concentrated and stored in the temporary storage unit at the rear of the *Current Buster*.

It is composed of two air-filled chambers, similar to those of an inflatable boom, which form a funnel shape to collect the oil at the water surface (Fig. 15). These two chambers join together to form a tapered channel which accelerates the flow. A skimming device is placed at the end of this channel to remove the surplus water in the incoming flow, thus concentrating the oil. This concentrated oil then flows into a wider separator and storage tank with a flexible base. This calm area combines the roles of both separation (evacuation of water, after settling, via the drainage valves, located on the bottom of the tank) and temporary oil storage. A skimmer or submersible pump can be deployed in this temporary storage area to remove the collected oil.

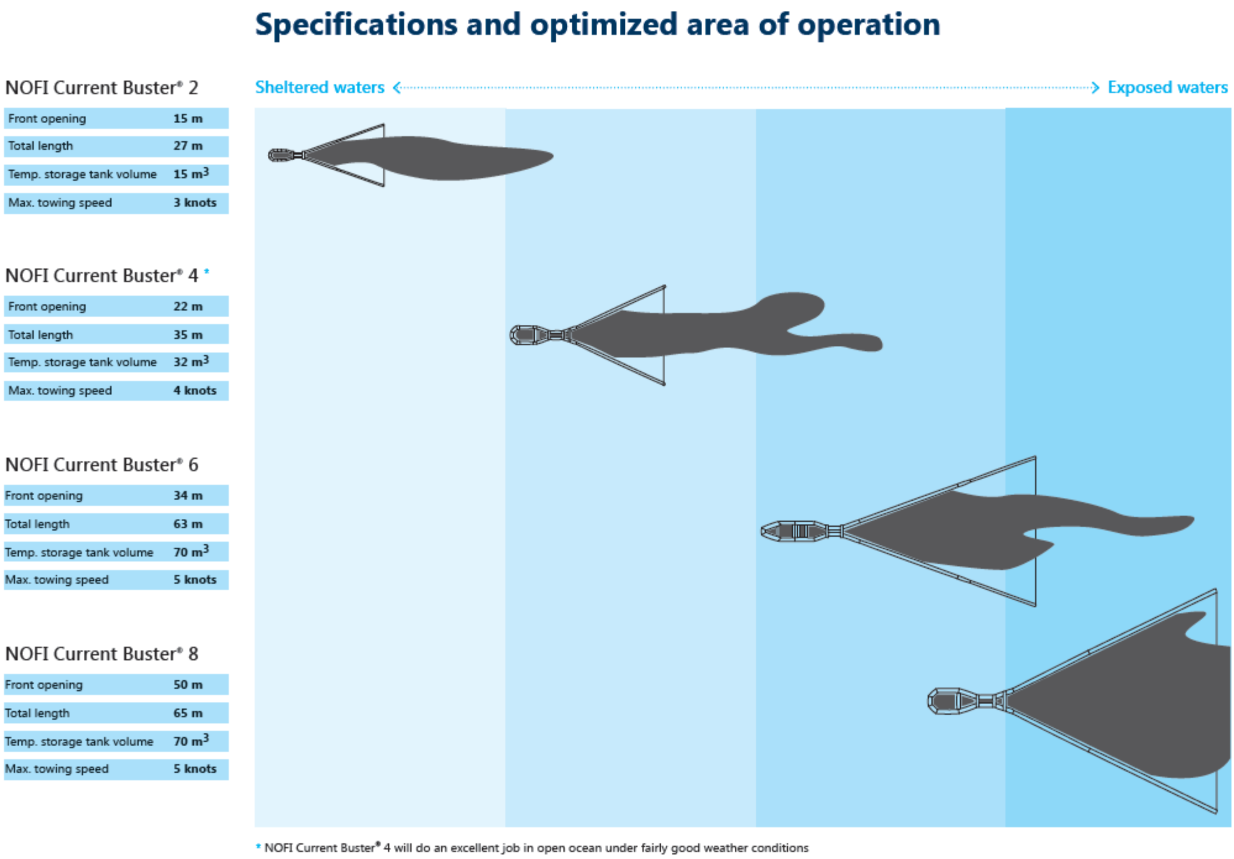


Fig.14 *– The range of 4 Current Busters and their optimal area of operation*

(source: NOFI)

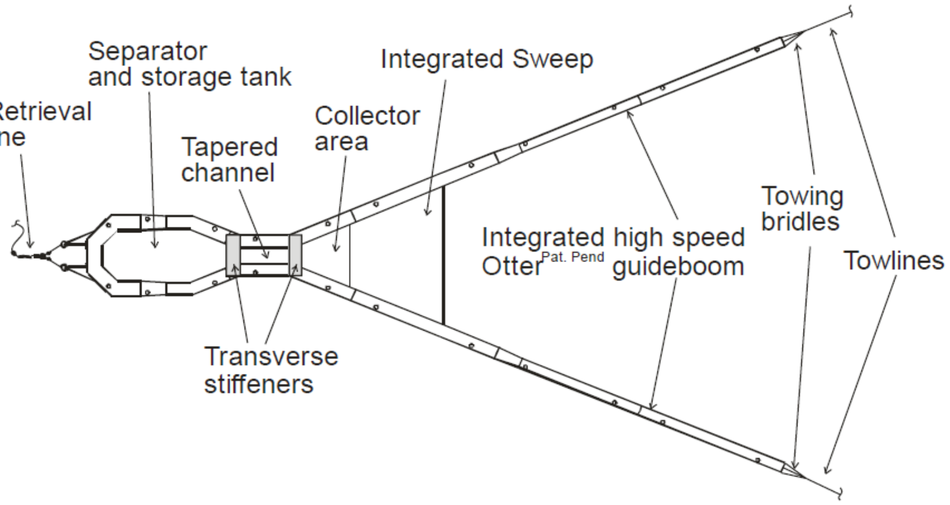


***Fig.15** – Diagram of the Current Buster 2 (source: NOFI)*

For more details: https://www.nofi.no/en/oilspill/nofi-current-buster-teknologi/nofi-current-buster-2

RESULTS OF TRIALS IN THE LOIRE ESTUARY

The *Current Buster 4* was tested by Cedre and the tests confirmed the efficiency of the concept for areas of strong current but also highlighted the need for a vessel with at least

350 hp and a V-shaped hull to deploy and tow the *Current Buster 4.*

In the event of a real spill, mobilising such a vessel can take several hours, which raises the issue of the availability and mobilisation of support vessels.

To reduce mobilisation times, a strategic approach could be to deploy a containment and concentration system based on a similar concept but on a smaller scale, meaning that it could be deployed and operated by lighter vessels such as pilot boats, which can be made available and operational very quickly in ports and harbours.

Trials were implemented with the *Current Buster 2* (CB2) which will be far lighter to tow and therefore likely be able to be deployed using smaller and less powerful vessels (dimensions 27 m long, compared to 35 m for the *Current Buster 4*, and a far smaller storage tank of 15 m^3 compared to 32 m^3).

For the test, both vessels, Bonne Anse provided by the St-Nazaire Subdivision of "Phares et Balises" (18.7 m long with two 175-hp engines and a bow thruster) and a smaller boat (7.5 m aluminium hull with a 225-hp Volvo Penta engine) were efficient.

Two configurations were tested, with two vessels or one vessel and a paravane.

A paravane is a towed aquatic device, sort of wing functioning as an hydrofoil that use the current strength generating an oblique traction to tow a system (boom, fishing gear, etc.) away from the current flow or the ship axis (Fig.16).

The paravane chosen, the *BoomVane* is composed of a series of vertical vanes within a rectangular aluminum frame fitted with a foam float made of fiberglass and resin to keep the device at the surface. A stabilizer arm helps to provide the device with balance. The model used for the *Current Buster* 2 trials had a shallow draught of 0.5 m and weighed 51 kg.

Photo 11, Photo 12 : *View of the BoomVane on the dockside prior to deployment and on the water (Source: Cedre).*

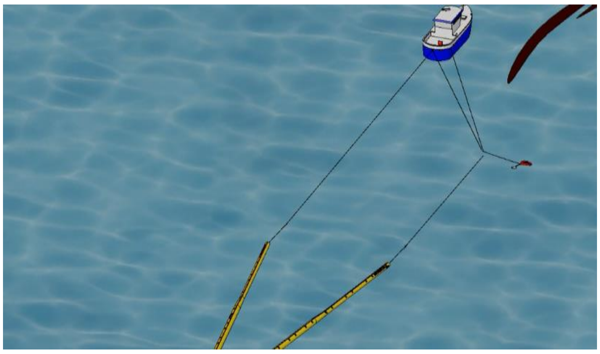


Fig. 16 *– Diagram of the BoomVane travelling backwards along the starboard towline of the Current Buster (Source: All Maritim/NOFI).*

The trial combined dynamic collection and pumping using a floating storage tank on the water. The floating storage, an *Aristock* tank (*Aerazur brand*) with a capacity of 10 m^3, was inflated on the dockside. Its capacity is consistent with the capacity of the CB2's temporary storage and settling tank (capacity of 15 m^3 including at least 5 m^3 of oil).

Two pumping configurations were tested and compared: first, the floating storage tank was moored to the rear of the Current Buster 2, then secondly alongside a vessel over to the Current Buster 2, to remove the pollutant. Following this operation, the vessel return to dock and emptying of the floating tank were also investigated.

These pumping operations were carried out while the towing of the *Current Buster* continued slowly (speed of over 1 knot to ensure sufficient sideways pull by the *BoomVane*). 500 liters of pollutant simulator (popcorn), forming a 20 m^2 slick were successfully collected

Once the floating storage tank was half full, it remained alongside the boat to return to dock to be discharge.

***Photo 13** : An Aristock floating storage tank alongside the the operating support boat (source: Cedre).*

Photo 14 *: The support boat and Aristock alongside the CB2 in preparation for pumping while towing continues at reduce speed (source: Cedre)*

Photo 15 *: Recovering the simulated spill (popcorn) by using a skimmer in the settling storage pool of the Current Buster 2 for transfer to the floating Aristock tank. (source: Cedre)*

During this trials, the *Current Buster 2*, a smaller vessel of 225 hp and 7.5 m long (similar caliber to a pilot boat) was shown to be able to operate the Current Buster 2 satisfactorily (deployment, towing and oil pumping phases) up to a speed of travel of 2.8 knots, at which the popcorn remained contained within the temporary storage unit. This approach could result in a very short vessel mobilisation time for use near to port areas, by using pilot boats.

In the context of the trial (<50 cm waves), the maximum speed for collection operations appears variable, from 2.8 knots to 3.6 knots (when travelling against or in the same direction than the waves).

Photo 16 *: View of the current buster 2 towed by a vessel an Boom Vane paravane (source: Cedre)*

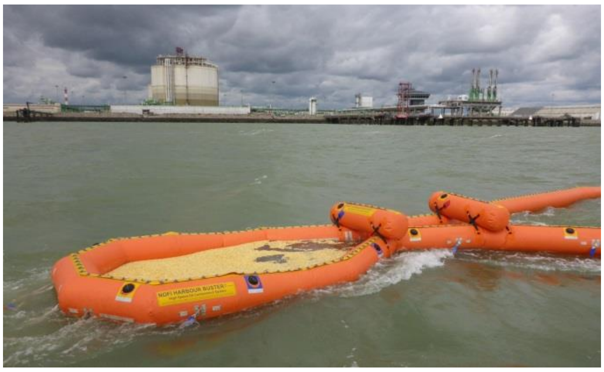


***Photo 17** : Waves coming from behind, surface speed of 3.6 knots, satisfactory containment (source: Cedre)*

***Photo 18** : Waves coming from behind, surface speed of 4.1 knots, leakage (source: Cedre)*

The trials in dynamic mode show that it is far easier to tow the system using a single vessel together with a *BoomVane* paravane, than with two vessels to free the difficulties in coordinating manoeuvers between the two vessels.

The trials in static mode validated the viability of deployment from a dockside using the *BoomVane* to open the two arms of the *Current Buster2*, facing into the current.

Desmi Speed Sweep and Ro-kite paravane

DESCRIPTION AND PRINCIPLE OF THE EQUIPMENT

The Speed Sweep is developed by the Danish company *DESMI*. The concept of porous barriers between the two legs of a v shape boom to slow down the current was developed in the eighties in Norway and taken over in 1993 by EXXON and tested, in 1998 at *Ohmsett* facility (New Jersey, USA). The test showed that the system allow to double the critical speed. The system was also evaluated in Norway in 2010 during the annual exercise implemented by NOFO and the Norvegian Coastal Administration.

The principle consists in adding several openwork net curtains to conventional booms, gradually dissipating the current from the opening towards the bottom of the containment bag (Fig. 17). This device aims to allow trawling speeds and a high rate of encounter with slicks, without compromising containment performance. The device does not have integrated storage capacity and therefore the collection of the pollutant must be carried out continuously. A pump integrated in the bag or a floating skimmer can complete the device in order to discharge the pollutant to the towing vessel.

It can also be towed by a single ship with the help of the Ro Kite inflatable paravane specifically designed by *DESMI (Fig. 18)*.

For more details: https://www.desmi.com/advanced-sweep-systems/speed-sweep.aspx

***Fig.17** – Diagram of the Desmi Speed Sweep (source: DESMI).*

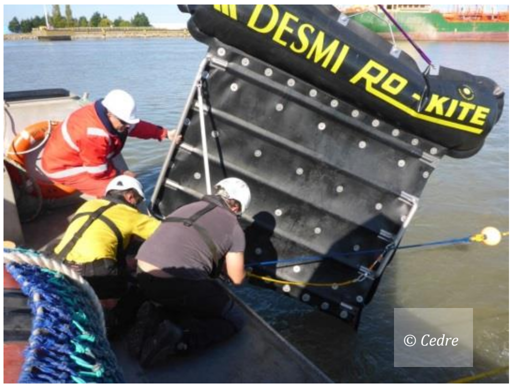


***Photo 19** : View of the Ro-Kite paravane (source: Cedre)*

***Photo 20** : Skimmer for oil recovery at the apex of the system (source: Desmi)*

Fig. 18 *– Schematic diagram of the device towed by 2 boats and by a single boat with a paravane (source: Cedre)*

RESULTS OF TRIALS IN THE LOIRE ESTUARY

Some trials (manoeuvrability and collection capabilities in current) were conducted in the Loire estuary, with popcorn and oranges as pollutant slick simulators.

The tests were conducted with the device towed by the *Bonne Anse* (18.7 m long with two 175-hp engines and a bow thruster) and a smaller boat (7.5 m hull with a 225-hp Volvo Penta engine) the other with the *Bonne Anse* alone being connected to the Ro-Kite 2000 paravane.

During these trials, the *DESMI Speed Sweep* equipment remained effective in the order of 3.1 knots under the best conditions for the *Speed Sweep*. For example, for a surface speed of 2.5 knots of the device, the speed measured at the bottom of the pocket was 0.4 knots, which represents a significant and decisive reduction.

The deployment of the equipment requires a certain degree of technicality, in terms of knowledge and implementation of the equipment, but also marine skills. Extensive initial training combined with regular training seems imperative to keep this equipment operational. The effectiveness of such equipment in the event of real pollution will depend on the integration of this competence within the team in charge of implementation, as well as on a good knowledge of its deployment and operation by the teams involved (initial training). Once acquired, this knowledge should be maintained and developed through regular training.

This system makes it possible to extend the traditional limits of containment from 0.7 knots to around 3 knots.

Photo 21 *: Surface current attenuation within the Speed Sweep during test in the Loire estuary (Source: Cedre)*

LMOS 15 Lamor/Egersund

DESCRIPTION AND PRINCIPLE OF THE EQUIPMENT

Developed jointly by the Norwegian company *Egersund* and the Finnish company *Lamor*, the *LMOS Sweeper* system is a floating hydrocarbon collection system composed of a deflector structure that combines several successive levels of deflector booms that creates hydrodynamic currents that concentrate oil into the recovery channel and guide the contained oil to a skimmer and pump in the apex of the sweeper. The water flow is also reduced by a bottom net, increasing the concentration of recovered oil before reaching the skimmer inlet. In fact, the floating pollutant is guided towards the end of this structure where is located a floating tunnel that reduces the speed of the current, and leads to a collection pool. The design is given to allow operation in waves up to 3 m and at towing speeds up to 4.5 knots.

The device does not have integrated storage capacity and therefore the collection of the pollutant must be carried out continuously. A pump integrated in the bag or a floating skimmer can complete the device to discharge the pollutant to the towing vessel. It is towed by a single vessel with the help of pole(s) or *Sea-Foil* paravane.

For more details: https://www.lamor.com/sweep-skimmer-mos-15

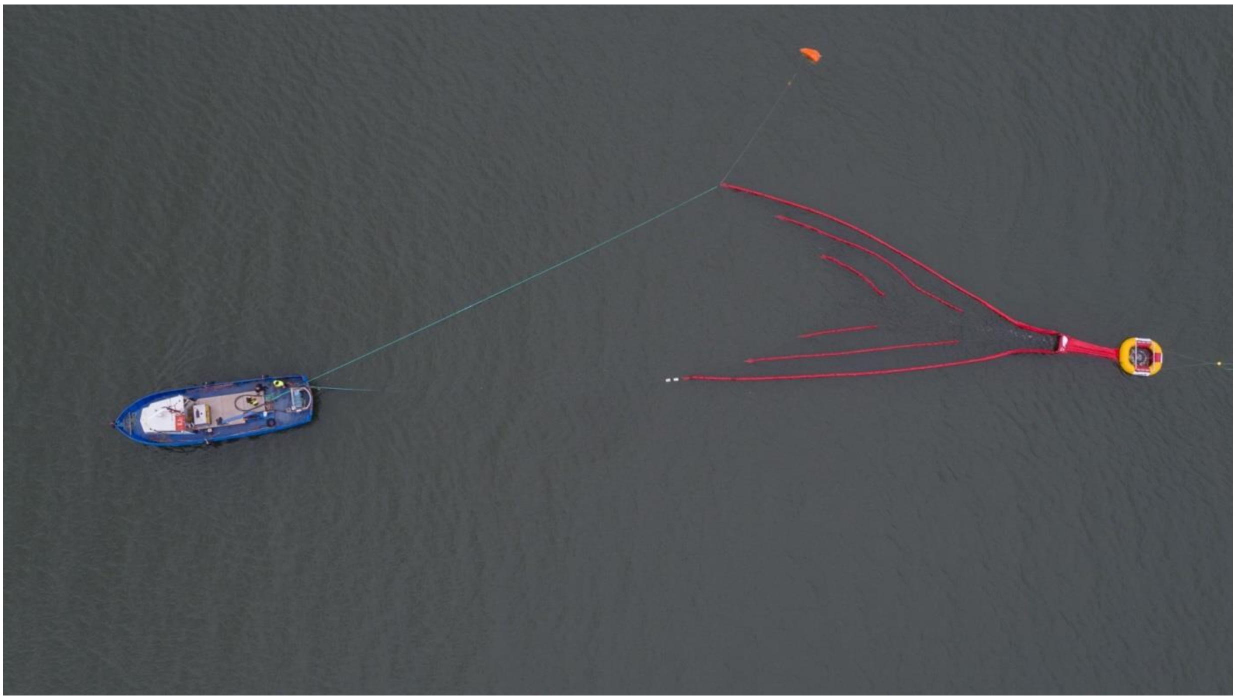


Photo 22 *: LAMOR LMOS 15 system towed by a single boat and paravane (source: Lamor) view of the successive deflector booms*

Photo 23 : *Deflector booms, tunnel and pool (source: Cedre)*

Photo 24 : *The Sea Foil - Egersund paravane (source: Cedre)*

Funded by European Union Civil Protection and Humanitarian Aid

Photo 25 *: Detail of the tunnel and the pool of the LMOS 15 (source: Cedre)*

Photo 26 *: Bottom net visible during the deployment (Source: Lamor)*

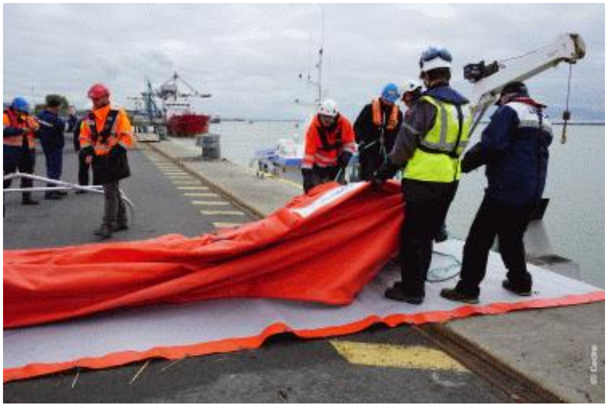


Photo 27, Photo 28 *: Deployment using a boom reel on a dock in Saint-Nazaire (Source: Cedre)*

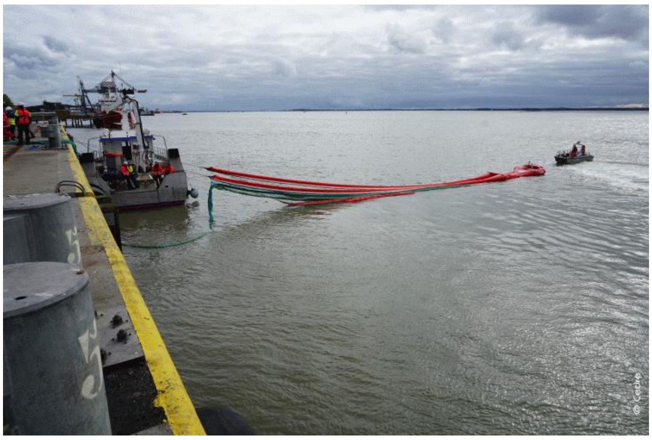


Photo 29, Photo 30: *Deployment of LMOS 15 from a dock using the hydraulic crane of the work vessel provided by the Lighthouses and Beacons subdivision of Saint-Nazaire (Source: Cedre)*

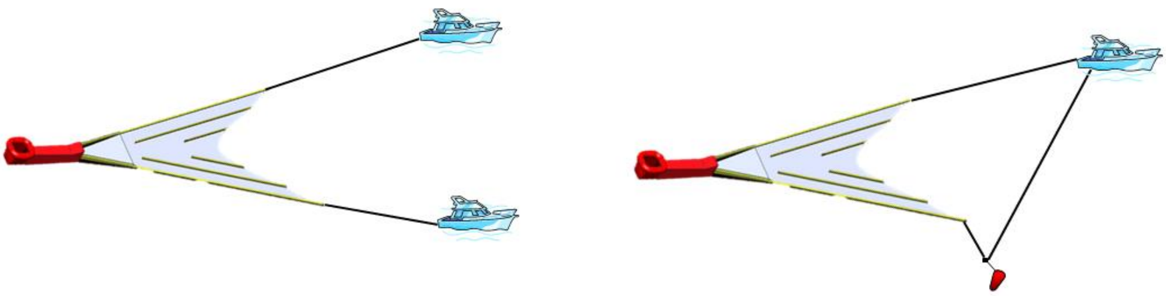


Fig. 19 *– Schematic diagram of the device towed by 2 boats and by a single boat with a paravane (Source: Cedre)*

RESULTS OF TRIALS IN THE LOIRE ESTUARY

The tests focused on the use of the devices in dynamic mode (towed by two vessels and then by one) to make trails of manoeuvrability and collection capabilities as well as in static mode (deployment from a dock) in association with a paravane. On static mode, the trial included the feasibility of turning the entire device over when the tide reverses and the validation of the nautical means necessary.

The *LMOS 15* is supplied with a metal hoop that can be easily installed in the collection pool. On this arch is fixed a *Lamor* weir skimmer equipped with a positive displacement pump. As this pump is integrated into the skimmer, it operates in discharge mode, which makes it possible to transfer the collected liquid to the dock without any problem and continuously. It should be noted that the discharge sleeves are integrated in one of the arms of the *LMOS 15* (optional asymmetrical assembly carried out in the factory).

The launch time, which includes a short inflation time (less than 5 minutes) and deployment, is approximately 15 minutes. Only the rear storage pocket called "pool" requires inflation because the arms are cylindrical foam floats.

During the trials, it was noted that the device perfectly follows the deformations of the water surface (30 to 40 cm lapping).

This equipment is much more demanding than traditional booms of comparable size. It is necessary to use significant nautical means, qualities incompatible with small boat.

The *Lamor LMOS 15* equipment demonstrated good performances in terms of speed attenuation into the collection pool, allowing it to remain effective well beyond what conventional booms allow (0,7 knot), in the order of 3.5 knots under the best conditions.

Tests highlighted the difficult and very specific conditions encountered in the Loire estuary (important forces due to the current), the need for the team involved during a real spill, to get a good knowledge of its deployment and operation and the maintenance of this knowledge through regular training.

ELASTEC Rapid River Response System (R3S) and FilterBelt Skimmer

DESCRIPTION AND PRINCIPLE OF THE EQUIPMENT

The *R3S* is an oil spill recovery solution for wide, fast, shallow and remote rivers. It is designed to operate in rivers with fast current but on relatively calm water bodies.

Initially the *R3S* equipment is comprised of a *Kvichak MARCO Filterbelt Rapid Response Skimmer (RRS) vessel*, two paravanes (shallow water 0.5m *BoomVanes*™), two 150 ft legs of fast-water solid-core *Elastec Optimax* boom. A work boat is required for the system. The *FilterBelt Skimmer* is an oil-absorbing conveyance belt system that filters oil and debris from the water. The system does not have an integrated storage capacity and must therefore be used with a skimmer capable of quickly recovering the incoming flow of oil. The manufacturer recommends using a towable bladder to allow the work boat with the skimmer to transfer the oil to this storage capacity while continuing to collect oil.

The *Marco FilterBelt Skimmer* concept has existed since 1973 and was initially designed to be integrated onboard of oil recovery vessels. *ELASTEC* recently introduced a portable version intended to be adapted to any work boats or vessels of opportunity.

For more details: https://www.elastec.com/products/r3s-rapid-river-response-system/

RESULTS OF TRIALS IN THE LOIRE ESTUARY

For the trials in the Loire estuary the system was composed of 2 sections of the solid-core boom lightweight fence boom *Optimax*, 40 m long each as standard, arranged in a V-shape to funnel the oil. The system is held open, facing into the current, by two paravanes (1 m *BoomVane™* were used) (Fig.20), and can be towed by a work boat.

At the apex of the system, the booms arranged in a V-shape feed into a narrower channel which corrals the concentrated oil towards a belt skimmer (*Marco Portable FilterBelt Skimmer*) installed at the bow of a second work boat connected to the boom.

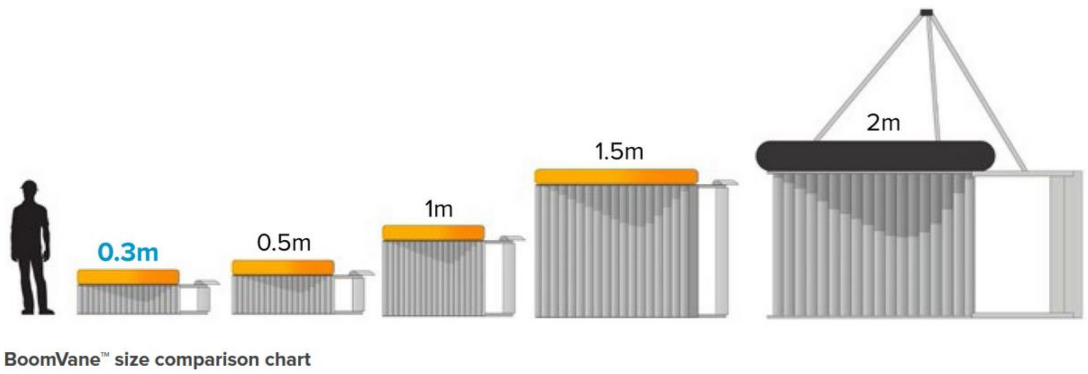


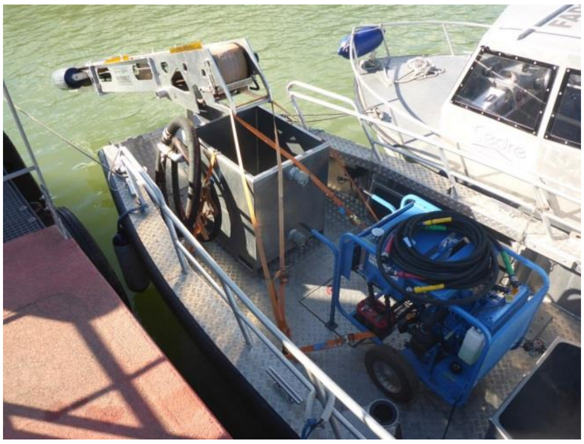
***Fig.20** – The 5 models of BoomVane™ and their draught, (source: ELASTEC)*

***Photo 31** : Trials on the Loire of the R3S (V-shaped boom and skimmer on a support boat) connected at the apex of the booms. The system is towed by a single boat assisted by two paravanes (Source: Cedre – Altiview)*

The *FilterBelt* system is composed of a sump hopper which also serves as a mounting to which the filter belt is attached. The rotating belt is powered by a hydraulic motor while an induction pump pulls oily water through the belt. A power pack is required to run the pump and motor.

This recovery system appears to be well designed and features a screen for debris separation (which is an important issue in estuaries and rivers) and a small storage tank (capacity of approximately 700 litres) for gravity separation of the oil and water.

However, it is important to note, the need for a derrick onboard on the workboat to be able to raise the *FilterBelt Skimmer* during navigation transit to unload the oil collected if a towable bladder is not used.



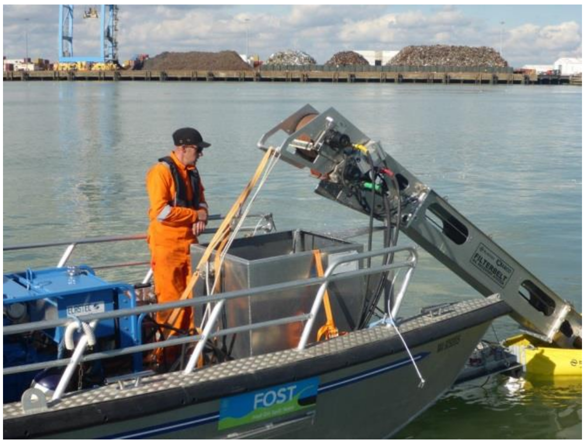


***Photo 32** : Overview of the on-board set-up: hydraulic power pack, mounting tank and Marco FilterBelt Skimmer (source Cedre).*

***Photo 33 :** The Marco FilterBelt Skimmer in operation (source Cedre).*

During the trials, due to the light weight of the *Optimax boom*, the boom could be deployed manually from the deck of the towing vessel. Deployment and retrieval were fast and easy.

Under the trial conditions (wind < 5 knots, no waves), the system proved readily maneuverable.

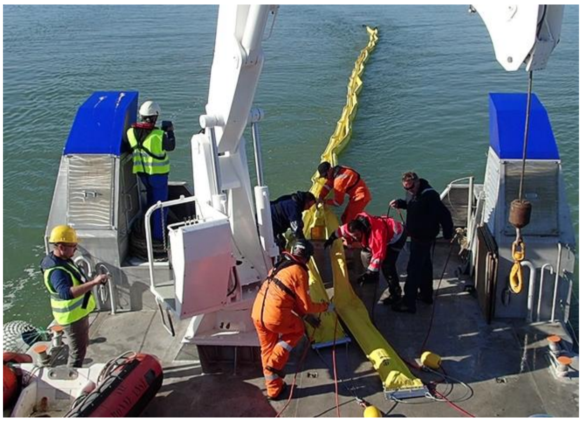


***Photo 34 :** Deploying the Optimax boom from the deck of the Bonne Anse vessel (source Cedre)*

***Photo 35** : Deploying the BoomVane™ using the crane onboard the towing vessel (source Cedre)*

The boom does not include a system to dissipate the current and therefore simply acts as a deflection boom with two legs in a V-shape which increases the critical speed of the system. By gradually increasing the surface speed, the system's efficiency limit was visually determined at 2.1 knots (tested with popcorn). Beyond this speed, vortexes could be seen on the upstream side of the boom, indicating a risk of leakage. The boom nevertheless continued to deflect the spill towards the apex of the system as no part of it was perpendicular to the current.

A quantity of 0.5 m^3 of popcorn was released around 300 meters upstream of the *R3S*.

This simulated slick was intercepted satisfactorily. The system allowed the towing vessel to make the necessary realignments to adjust the system's trajectory according to the slick's drift in the strong current. Even although the bow wave tended to push the slick aside, the *BoomVanes™* opened the system sufficiently wide enough behind the vessel to prevent this from being an issue.

The towing vessel had sufficient engine power (2 x 175 hp) and maneuverability (hull with sufficient drift resistance) to tow the *R3S* and support boat with the *Marco FilterBelt*. It is important however to ensure that the size of the tow boat is compatible with the mass and drag of the support boat.

NORLENSE, Oil Trawl NO-T-600

DESCRIPTION AND PRINCIPLE OF THE EQUIPMENT

The *NORLENSE Oil Trawl NO-T-600* is designed to contain and recover oil at an optimal trawling speed of 2.5 knots, in inshore or port areas (up to 4 knots under some conditions). It can operate in wave heights of up to 1 m. A larger version of the system also exists for offshore use. It can be towed by two vessels or a single vessel with a paravane *Trawldoor*, manufactured by *NORLENSE*.

The equipment is composed of three elements: two deflecting booms (self-inflating boom of diameter 600 mm and skirt with a height of 150 to 300 mm), a concentrator at the apex of the V, made of a narrow channel fitted with a skimming weir which separates the upper layer where the floating slick is located from the rest of the water, and a floating storage and settling bag (10 m^3 capacity) connected to the trawl system (the bag can be replaced when full, thanks to the drop coupling, however the bag cannot be lifted when full). The oil remains in the bag while the water is drained out through an opening at the bottom.

The two legs of the boom are held in a V-shape with good spread by a subsurface net.

For more details: https://www.norlense.no/en/high-speed-sweep-system-oil-trawl

Photo 36 *: Overall view of the Oil Trawl system towed by a single vessel using the Trawldoor paravane, (source: NorLense)*

RESULTS OF TRIALS IN THE LOIRE ESTUARY

In total, 3 configurations were tested: dynamic trials with two boats, then with a single boat assisted by paravane(s) and finally a static trial alongside the quay.

The *Oil Trawl* is fitted with an automatic inflation system which avoids time-consuming manual inflation operations. Deployment resulted very fast.

The operation of the *Oil Trawl* by a single vessel with support from the *Trawldoor* paravane resolved the existing coordination and communication constraints when a pair is trawling. The paravane ensured an optimal configuration. In this configuration, the behaviour of the equipment, in a straight line but also during wide turns, was highly satisfactory.

Thanks to the inflatable coil inside the boom, the system sat firmly on the water surface perfectly following its movements (50 cm high waves).

The maximum speed at which no popcorn (pollutant simulator used during the trial) was seen to start to be lost was approximately 3.5 knots (measured using a surface current meter).

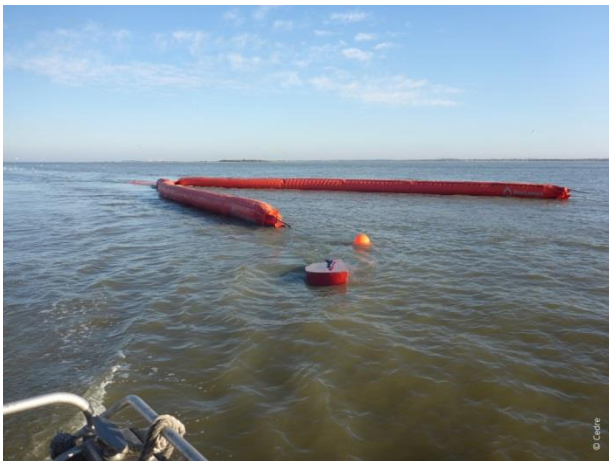


***Photo 37 :** Overview of the Oil Trawl towed by a vessel (Trawldoor paravane seen in the foreground (Source Cedre)*

***Photo 38** : Close-up of the apex of the system and the floating bag(Source Cedre)*

Vikoma, Fasflo

DESCRIPTION AND PRINCIPLE OF THE EQUIPMENT

In 2018, the English manufacturer *Vikoma* produced a new version of it's *Fasflo* skimmer (*mini and maxi Fasflo*) specially designed to collect floating pollutant on waters relatively opened and fast flow rate as estuaries and rivers. The system is given for spill recovery at speeds up to 4knots. Previous models were tested at *Ohmset*t facility (USA) in 2000. The *Fasflo* was not yet tested by Cedre in the Loire estuary, but this skimmer adapted to fast current has proven it's efficiency and seem interesting to include in this review.

The *Fasflo* is an advancing weir-type skimmer designed with floating pontoons on each side to provide buoyancy. Connections allow to fixe two deflection booms to channel the oil into a narrow opening. The next section opens, allowing a decrease in velocity, which provides a quiet zone, and allowing gravity separation. Water escapes through the bottom of the device while oil is collected past a self-adjusting weir and pumped away by an integrated volumetric pump. The *Fasflo Mini* skimming system has a remote positive displacement pump connected to the oil collection sump in the skimmer, to discharge collected oils to storage on a boat or on land.

The system may be used as part of a sweep system alongside an oil response vessel, or in static mode in rivers and streams where the flow can be channeled through the skimmer (Fig.21).

For more details: https://www.vikoma.com/Oil_Spill_Solutions/Skimmers/Fasflo.htm
https://www.vikoma.com/res/Fasflo%20Mini%20Brochure

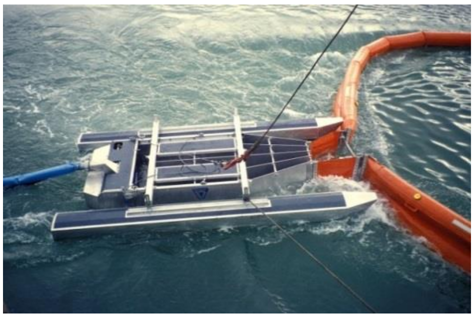


Photo 39 *: Fasflo skimmer (source: Cedre)*

Photo 40 : *View of the ross lines between the two booms (source: Vikoma)*

Photo 41 : *Fasflo use in dynamic mode as a sweep system alongside an oil response vessel (Source: Vikoma)*

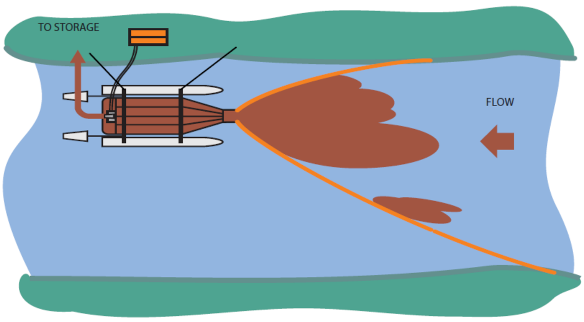


Fig.21 *– Fasflo containment and recovery system used in static mode in river (source: Vikoma)*

Conclusion

In fast current conditions as encountered in many estuaries and rivers and in flood conditions, when the velocity of a perpendicular current is beyond 0,7 knots, the booming arrangement maybe adapted. The reduction of angle between the current and the boom allow diverting oil to a collection point (an angle of 20° for a 2 knots current).

Few manufacturers has developed for many years, containment systems specifically, for use in fast water response to collect oil at speeds of up to 2,5 knots even 5 knots for some models. These systems are more or less design on the same principle*:* reduce the speed of the fluids between the boom inlet and the bottom of the pocket where the pollutant is collected.

These systems may be towed by two vessels or for simplification by one vessel and a paravane(s), they can also be used in static conditions along a quay or in sweeping configuration along a boat using a pole.

The trials conducted in the Loire estuary, had confirmed these containment and recovery systems makes it possible to extend the traditional limits of containment from 0.7 knots to around 3 knots.

Their deployment requires more technicality, in terms of knowledge and implementation of the equipment, but also marine skills. Extensive initial training combined with regular training seems imperative to keep such equipment operational. The effectiveness in the event of real pollution will depend on the integration of this competence within the team in charge of implementation, as well as on a good knowledge of its deployment and operation by the teams involved (initial training). Once acquired, this knowledge should be maintained and developed through regular training.

In addition, this equipment is much more demanding than traditional booms of comparable size. It is necessary to use significant nautical means, qualities incompatible with small boat.

REFERENCES

Cedre, 2012 ; Les barrages antipollution manufacturés. Guide opérationnel. Brest : 95 p.

Cedre, 2014 à 2018 ; Evaluation des dispositifs de lutte en forts courants ; Rapports internes de la programmation technique.

EXXONMOBIL. 2008; Oil Spill Response Field Manual. USA: ExxonMobil Research and Engineering Company, 320 p.

ITOPF. 2011; Use of booms in oil pollution response, Technical information paper. Canterbury, UK: ITOPF Ltd, 11 p.

PEIGNE G. 1995 ; Les barrages flottants dans la lutte contre les pollutions en zone côtière. Etat de l'art des matériels commercialisés. Rapport Cedre R.95.14.C/GP. 1995. 69 p.

U.S. COAST GUARD R&D CENTER. 2001 ; Oil Spill Response in Fast Currents, a Field Guide. Final report, October 2001. 80 p.

HANSEN, Kurt A. 2002; Evaluation of New Approaches to the Containment and Recovery of Oil in Fast Water; U.S. Coast Guard Research and Development Center; 43p.

OMI, 2013 ; Directives pour la lutte contre les déversements d'hydrocarbures dans les courants rapides, OMI, 2013, 50p.

The Norwegian Coastal Administration, NOFO, HISORS, High Sea Oil recovery System, 2012, 2p.

Funded by European Union Civil Protection and Humanitarian Aid