The project is co-funded by the European Union, Instrument for Pre-Accession Assistance.

WP 5: ESTABLISHING A TRAINING AND RESEARCH CENTRE TO COMBAT MARINE POLLUTION

ACTIVITY 5.3

GUIDELINES

FOR SELECTION OF OIL SPILL RESPONSE EQUIPMENT

Prepared by

Adriatic Training and Research Centre for accidental marine pollution preparedness and response

adriatic training and research centre

Rijeka, Croatia, August 2015

REMARK

This guideline document has been produced as guide on oil spill response equipment selection and is intended for the use of HAZADR Project Partners and to the general readers who are interested in the marine environment protection issues.

adriatic training and research centre

Rijeka, August 2015

TABLE OF CONTENTS

1 INTRODUCTION

The preparation of this Guidelines for selection of oil spill response equipment has been carried out as an activity under the project entitled "Strengthening common reaction capacity to fight sea pollution of oil, toxic and hazardous substances in Adriatic Sea" (HAZADR). HAZADR project is part of "IPA Adriatic Cross-border Programme" co-financed by the European Commission through the Instrument of Pre-accession Assistance (IPA). The key objective of the Project is to establish a cross-border network for the prevention of risks and the management of emergencies, with a view to reducing the risk of pollution of the Adriatic Sea and to strengthening the capacity of the communities in the Adriatic region to respond to environmental and technological hazards caused by maritime incidents resulting or likely to result in spills of oil or other hazardous and noxious substances (HNS).

Marine pollution, including accidental oil spillage from ships, has become a major issue in the protection of the marine environment over the past decades. Dealing with oil spills is a major task. Clean-up operations should generally be cautious, well planned, and balanced because they can cause more damage than pollution itself. Therefore, it is important to compile and categorize oil response equipment in the spill response plan to protecting the marine environment. Oil spills must therefore always be efficiently dealt with using a variety of response methods and equipment.

The prime focus of oil spill response activities is in prevention and planning. This is achieved through well-designed equipment, good maintenance and operating procedures, sound training techniques, and a high degree of awareness and concern at all levels by employees and management. Despite best prevention practices an incident may occur. In the event of an incident the objective of the oil spill response is to assure that actions are efficient and compatible with the balanced environmental, social, and economic needs of the community. The response strategy includes all viable techniques to reduce damage from a spill. No oil spill response option would be ruled out or limited in advance.

It is an imperative that planners and responders discuss and develop resource protection priorities during contingency planning so that valuable time is not lost during an actual response. Area Contingency Plans (ACPs) and Geographic Response Plans (GRPs) are essential to an effective response.

2 EXECUTIVE SUMMARY

A number of advanced response mechanisms are available for controlling oil spills and minimizing their impacts on human health and the environment. The key to effectively combating spills is careful selection and proper use of the equipment and materials best suited to the type of oil and the conditions at the spill site. Most spill response equipment and materials are greatly affected by such factors as conditions at sea, water currents, and wind. Gauging the performance of oil spill response equipment has long been of interest for government regulators, oil spill responders, and the oil industry.

Response actions can be divided into marine and shore operations. This Guidelines addresses mainly oil spill response in off-shore conditions. Several options are available to respond to oil at sea and can be considered in three broad strategies:

- containment and recovery
- dispersant application
- in-situ burning

Selection of the best response option will depend on site-specific conditions such as type of oil, availability of equipment and personnel, proximity to shore, shallowness of water, sensitivity of the receiving environment, sea state and weather.

Mechanical recovery has traditionally been regarded as a primary response option. The fundamental challenge with mechanical recovery is related to low encounter rates due to oil spreading on the water surface. Another challenge is related to logistics and waste handling, as mechanical recovery is logistic intensive.

Application of chemical dispersants as a response option has been developing for more than 30 years, and should be considered as a potentially relevant response option to oil spills in the Adriatic Sea. In recent years it has been carried out a significant amount of research on use of dispersant and trend that continues. Dispersants used today are less toxic than those used in the past, but long term cumulative effects of dispersant use are still unknown. Many international agencies and regulatory bodies around the world view dispersants as the most practical spill response option. In many cases, dispersing oil into the marine environment can result in the lowest environmental impact.

In-situ burning is one of the response techniques with a high potential at the off-shore conditions. Nevertheless, none of Adriatic coastal states have considered In-situ burning as a response options in their Contingency plans. Regarding to that fact, such Guidelines does not consider In-situ burning response options and related equipment for that response option.

When choosing effective response options including natural recovery, it is necessary to consider trade-offs affecting the options' potential environmental impact, their appropriateness for the habitat, and the timing of the application. The benefits and impacts of response options depend upon incident-specific conditions and affect the options' suitability for use in a habitat during any spill.

Once response techniques and priorities are determined, equipment stockpiles should be identified and/or procured and situated to enable rapid deployment. To be effective, a response organisation must become operational quickly.

This Guidelines summarizes the technical rational for selecting oil spill response equipment. The key elements on response efficiency, such are prevailing climate conditions and maritime traffic, are outlined in Section 3. Section 4 provides an overview of response options used for a spill of oil into the marine environment and presents discussion of each response option. Characteristics of response equipment, its advantages and disadvantages, and equipment maintenance are discussed in Sections 5 and 6, respectively.

3 KEY ELEMENTS OF RESPONSE EFFICIENCY

Selection of the most appropriate methods of timely response and equipment selection depends on many factors, among which the most important are:

- Availability of resources to respond
- National legislation for the implementation of response
- The event scenario and characteristics of the area and the type of spilled oil

3.1 Resources at the Region

Generally, the availability of all types of mechanical oil spill equipment in the Adriatic region is not adequate, particular in case of major oil spill. Most of the countries are well equipped for Tier 1 response but Tier 2 and Tier 3 response could be a great challenge.

List of response equipment in every Adriatic country is available as a part of respective Contingency national plans. All coastal Adriatic states have been ratified OPRC convention which is intended to facilitate international co-operation and mutual assistance in preparing for and responding to a major oil pollution incident and to encourage States to develop and maintain an adequate capability to deal with oil pollution emergencies. Inter alia, this includes, as a minimum, the establishment of stockpiles of oil spill combating equipment, the holding of oil spill combating exercises and the development of detailed contingency plans for accidental marine pollution.

Since that the list of available response equipment already existing in national and regional contingency plans this Guidelines not gives an additional overview of such equipment. Additional issues such as organisation and training are not covered here, but these are also important factors.

3.2 Legislation

Adriatic coastal states require continued reliance on mechanical recovery at sea as the primary response option, and, despite the historically poor open sea recovery record of such equipment, vessel and facility response plans still require large quantities of mechanical containment and recovery equipment for major oil spill responses at sea. Italy decided that the oil combating policy of the Italian part of the Adriatic Sea must be based on mechanical combating and recovery of oil. Nevertheless, some countries have included dispersants use as a response strategy when appropriate. In the offshore armoury, mechanical equipment will continue to be required on the occasions when dispersants cannot be used. Furthermore, in the inshore areas, mechanical equipment has considerable uses, particularly in the protection of sensitive areas and as a Tier 1 response at terminals.

Other response techniques, such as In-situ burning or Bioremediation, are not allowed or they are in early stages of considerations.

Response techniques may change with the seasons, depending on the predominant environmental risk. It is important that all participants in the planning process agree on response actions, so that when a spill occurs, these actions may be implemented rapidly. If dispersants have been included in a response strategy, the necessary pre-approvals should be sought to enable rapid authorisation and use.

3.3 Adriatic Sea

The surface of the Adriatic Sea reads 138,595 sq. km, or 4.6% of the Mediterranean Sea area. It is of elongated, rectangular shape, stretching from the north-west to the south-east, between the Dinaric and Apennine mountain ranges that influence the dominant winds and consequent wave patterns. Surface wind waves in the Adriatic are limited by fetch and wind duration. Average width, across the Adriatic, from the north-east to the south-west is about 200 km.

	Albania	**Bosnia and Herzegovina**	**Croatia**	**Italy**	**Montenegro**	**Slovenia**
Adriatic coastline km	362	23	5.835	1.300	294	45
Island and islets	n/a	n/a	1.185	n/a	n/a	n/a

Table 1: Adriatic coastline

Furthermore, there are more than 1300 islands along the east coast that locally change the wind and wave characteristics. Sea depths are of such scale that cannot be neglected in the greater part of the basin. The shallowest area is in the north, in the Gulf of Trieste, and deepest is in the South-Adriatic pit (1233 m). Overall, more than 2/3 of the Adriatic basin is not deeper than 200 meters.

Figure 1: Adriatic Sea map

3.3.1 Climatic conditions in the Adriatic sea

The Adriatic Sea is a part of the Mediterranean Sea, located in its north, central, part and interconnected to it by the Strait of Otranto on the south east side. For the major part the Adriatic Sea is categorized as the Mediterranean climate type (sub type Csa—Mediterranean climate with dry and hot summers).

The Adriatic Sea climate is greatly determined by its position and surrounding topography. Dominant wind events that cause surface waves are *bura* (N-NE to E-NE, italian *bora*) and *jugo* (E-SE to SS-E, *sirocco* family) in the winter and *maestral* (W-NW to NW) in the summer (Favro & Saganic, 2007). *Bura* and *jugo* reach storm conditions and can cause extreme wave occurrences while *meastral* is of milder character. Maximum recorded wave in the Adriatic was during an event of *jugo* wind with a wave height of 10.8 meters. Theoretical predictions of most probable extreme significant wave heights (for 20 and 100 year return periods) are 7.20 and 8.57 meters respectively. During *bura* wind events maximum wave height that can occur are between 6.2 and 7.2 meters. Other important winds that cause surface waves are *ostro* (S), *lebeccio*, *garbin* (SW), *ponent* (W), *tramontane* (N to NW), *levante* (E), and coastal circulation winds (*burin* or land-breeze and *zmorac* or sea-breeze).

No.	Knots	Description	Effects at sea
0	0	Calm	Sea like a mirror
1	1-3	Light air	Ripples but no foam crests
2	4-6	Light breeze	Small wavelets
3	7-10	Gentle breeze	Large wavelets; Crests not breaking
4	11-16	Moderate wind	Numerous whitecaps; Waves 0,3 – 1,2 m high
5	17-21	Fresh wind	Many whitecaps, some spray; Waves 1,2 – 2,4 m high
6	22-27	Strong wind	Whitecaps everywhere; Larger waves 2,5 – 3,9 m high
7	28-33	Very strong wind	White foam from waves is blown in streaks; waves 3,9 – 6 m high
8	34-40	Gale	Edges of wave crests break into spindrift
9	41-47	Severe gale	High waves; sea begins to roll Spray reduce visibility; 6 m waves
10	48-55	Storm	Very high waves 6 – 9,2 m; blowing foam gives sea white appearance
11	56-63	Severe storm	Exceptionaly high waves; 9,2 – 13 m high
12	> 63	Hurricane	Air filled with foam; visibility reduced; white sea waves over 13 m

Table 2: Beaufort wind scale

Bura (N-NE to E-NE) is the strongest wind by intensity. It blows over the Dinaric Mountains which shape its focus points. By nature it blows in gales up to 20 m/s (72 km/h) of velocity and can exceed 50 m/s (180 km/h). The fastest recorded wind impact of *bura* is 68 m/s (245 km/h) in the mid-Adriatic coast line where the Velebit Mountain forms a funnel. The main limitation for development of *bura* wind waves is the relatively narrow fetch across the Adriatic, especially if considered between the outer islands on the east coast until the west coast.

Jugo blows along the Adriatic (E-SE to SS-E) and usually develops up for two to three days until reaching its maximum speed. Waves, already formed, enter through the Otranto Strait southern boundary and develop further along the Adriatic reaching a more developed sea state and longer waves than those of *bura* which are inherently stepper and shorter. In storm conditions *jugo* can reach a speed up to 30 m/s (over 100 km/h).

Wind speeds and wave heights increases from the northern part of the Adriatic basin towards the south. Maximum mean annual significant wave height obtained is 0.68 meters. The result is an underestimation compared with satellite altimetry measurement that reported mean significant wave height of 0.85 meters for a 14 year period (satellite missions during the 1992–2005 period). It also stated that 80% of the significant wave height data in the Adriatic Sea are less than 1.10 meters.

3.3.2 Maritime transport

International shipping activity in the Adriatic Sea is becoming increasingly dense. This is due to the location of important industrial centres, especially along the western Adriatic coast, but also due to ports serving for transit to other countries in Central Europe, such as particularly in the north of the Adriatic coast (the ports of Trieste, Venice, Koper, Rijeka basin). Moreover, new transit ports are expected to gain significance in the south of the eastern Adriatic coast, such as Ploče in Croatia, Bar in Montenegro, and Vlorë in Albania.

The Adriatic Sea is an important maritime transport route used by merchant ships in international trade, by yachts, fishing vessels, war ships and other non-merchant ships. A significant number of important industrial centres are located along the western Adriatic coast and several mid-European – and in many cases landlocked – countries heavily depend on the Northern Adriatic ports (among others the port of Trieste, Venice, Koper and Rijeka) for the import of energy.

The intensive maritime transport in the Adriatic Sea basin implies a significant risk of accidents and consequently a potentially strong impact on the marine environment. Given the enclosed nature of the Adriatic Sea basin, the impact of a single accident, even though accidents are rare, can be highly disastrous.

The beauty of the Adriatic Sea makes the region an attractive place to live and work. Each year, more tourists spend a holiday in the region. In addition to the maritime transport and fishery activities, these activities make the Adriatic Sea basin a crowded area both on land and at sea. The crowdedness of the area is also likely to have an impact on the environment.

3.3.3 Oil types

One of the important oil transport routes in the Mediterranean leads through the Adriatic Sea, all the way to the north Adriatic ports (Trieste, Venice, Omišalj and Koper). Around 57-58 million tons of oil are transported yearly on that exclusively *import* route, and a major share of that (currently around 37 million tons yearly) is further imported through the Trans-Alpine pipeline into Central Europe.

It is especially oil transportation that, in the last decade, is increasing in the Adriatic Sea. Currently, the most important direction for oil transport in the Adriatic Sea is the *import* route, arriving through the Strait of Otranto and transiting the entire sea to the north Adriatic oil terminals: Trieste (importing annually around 38 million tons), Venice (slightly under 11 million tons), Omišalj (around 7 million tons) and Koper (around 2 million tons). There are also several other important Italian oil ports in the Adriatic Sea (especially Ancona and Ravenna), as well as various coastal routes, mainly for product oil, summing up the current annual volume of oil (crude and product) transported in the Adriatic Sea in the range of 70 million tons. Around 4,500 to 5,000 estimated port calls by ships carrying harmful substances as cargo are performed each year in the Adriatic Sea navigation.

There are many types of oil transported on the Adriatic Sea. Tankers transport crude oil and products refined for use as fuel. Oil types are classified based on various physical and chemical properties of the oil. This is necessary because different types of equipment are used to respond to spills of different oil types.

The general classification of oil is divided into:

1. Non-persistent oil
2. Persistent oil

Oil viscosity ranges		
Low	***Medium***	***High***
Freely Flowing	Slowly Flowing	Barely Flowing
• gasoline • diesel/kerosene • light crude	• slightly weathered crude • lube/hydraulic oil • medium/heavy crude	• highly weathered crude • Bunker C • bitumen
The most toksic to the aquatic environment, evaporate from the surface within a day	Quickly spreads on the surface and its light components evaporate immediately, mix with the mass of water	Congeals in the sea and does not evaporate, some heavy oil are heavier than water

Table 3: Oil viscosity ranges

4 RESPONSE OPTIONS

The aims of oil spill response are both to minimize the immediate damage to environmental and socio-economic resources and to reduce the time for recovery of affected resources. A rapid response is essential for effective spill clean-up. Spill response strategy adopted for a certain area will be indeed an agreed selection of available spill response techniques, with assigned priorities for their implementation, based on certain key criteria (characteristics of the area, availability of resources), as well as on some other factors (social, political) specific for each region, country or its part.

Certain countries base their response strategy on mechanical removal of spilled oil, some others on Its chemical dispersion, whilst some on a combination of both methods. On the other hand, some countries will endeavour to combat spill as much as possible at (open) sea, others will concentrate on combating it on shore. Even when the realistic response policy has defined, very often one question remains: what is the optimal division of limited resources between at-sea and shoreline response? Should the basic principle of the response strategy be to attack the oil at sea or is it better to concentrate efforts near shore, booming off sensitive shoreline and/or deflecting oil towards pre-chosen collection areas? This is an important question because the required types of equipment, training and response plans will depend on where the response is to be focused.

Clearly there is no simple answer to the question. The selection of the response strategy is very often dictated by the availability of specialized equipment or logistic support required for the application of a certain response technique, and entirely depends on conditions specific for the country or part of it.

The most efficient, environmentally preferred, and cost effective spill response is dependent on the following factors: chemistry of the spilled product, quantity, location, response time, environmental conditions, and effectiveness of available response technologies at various degrees of oil weathering.

In spite of several possible ways to respond to an oil spill in a marine environment the only response option covered in this report is mechanical containment and recovery.

Table 4 summarizes practical gudelines or "rules of tumb" to consider when implementing a response.

MECHANICAL METHOD	**BOOMS**	• Booms work for most oil types and large or small oil volumes • Containment is most effective when the booms can be accurately directed towards theoil; a boat is not a good place from which to locate the oil • Booms almost always leak, even under the best of circumstances • A boom is only as good as the crew that deploys and controls it • Booms are not a static piece of equipment; they require constant attention • Offshore containment costs can be high per barrel (but still considerably less than shoreline cleanup and resource damages)
	SKIMMERS	• Different skimmers work for different oil types • Skimmers are inefficient in rough waters • Oil recovery rate equals total volume recovered less the amount of water • Oil recovery cannot exceed storage capacity • Offshore recovery costs can be high per barrel
CHEMICAL METHOD	**DISPERSANTS**	• Disperse when you can • Dispersion can be a very effective method for oil removal from a water surface • Environmental effects of chemical dispersion at sea are much lower than the effects of oil in the coastal zone • Chemical dispersion can be effective with minimal environmental effects in nearshore zone with good water (tidal) circulation • Dispersion does not preclude other actions taking place concurrently (i.e., mechanical recovery, *in-situ* burning) • Aerial spraying can cover very large areas (tens of hectares/acres per minute)

Table 4: Implementation of response

4.1. Mechanical recovery

Experience acquired during previous major oil spills has shown clearly that mechanical at-sea oil “containment and recovery” is the most appropriate technique for removing spilled oil from the marine environment. Mechanical Containment and Recovery is the primary line of defense against oil spills in the Adriatic Region. Containment and recovery equipment includes a variety of booms and skimmers, as well as natural and synthetic sorbent materials. Mechanical containment is used to capture and store the spilled oil until it can be disposed of properly.

Listed here are the three categories of mechanical tools used to contain and recovery spilled oil:

Booms - equipment called containment booms act like a fence to keep the oil from spreading or floating away. Booms float on the surface and have three parts: a ‘freeboard’ or part that rises above the water surface and contains the oil and prevents it from splashing over the top, a ‘skirt’ that rides below the surface and prevents the oil from being pushed under the booms and escaping, and some kind of cable or chain that connects, strengthens, and stabilizes the boom. Connected sections of boom are placed around the oil spill until it is totally surrounded and contained.

Skimmers - Once the oil is contained, it need to be removed from the water surface. Skimmers are machines that suck the oil up like a vacuum cleaner, blot the oil from the surface with oil-attracting materials, or physically separate the oil from the water so that it spills over a dam into a tank. Much of the spilled oil can be recovered with skimmers. The recovered oil has to be stored somewhere though, so storage tanks or barges have to be brought to the spill to hold the collected oil.

Sorbents - These are materials that soak up liquids by either absorption or adsorption. Oil will coat some materials by forming a liquid layer on their surface (adsorption). This property makes removing the oil from the water much easier. This is why hay is put on beaches near an oil spill or why materials like vermiculite are spread over spilled oil. One problem with using this method is that once the material is coated with oil, it may then be heavier than water.

5 RESPONSE EQUIPMENT

In the Adriatic region oil spill response is primarily based on the so-called conventional clean-up methods. The use of appropriate equipment is limited by the following three basic parameters:

- wave height,
- current velocity,
- viscosity of spilled oil.

The oil spill clean-up equipment types, which can be used at off-shore response methods, are:

1. response vessels
2. booms
3. skimmers
4. pumps
5. sorbents
6. storage equipment

5.1 Response vessels

The oil spill response vessels can be used to:

- contain and collect oil with assistance of boom and skimmer
- applay dispersants
- position other oil spill equipment
- store the recovered oil in on-board storage tanks
- pump the recovered oil to another vessel or tank

Typically, the response vessels in the Adriatic Sea States are multipurpose vessels, normally used as patrol vessels, tugboats, navy supply vessels, tankers, etc. Some of them have oil spill response equipment constantly on board so they can start response operations immediately when reaching the accident site.

Every country has own approach in defining of characteristics and purposes of such vessels. Since that response vessels are capital investment which require a very detailed and specific approaches this guideline is not envisage further analyze of characteristics and purposes of specialised response vessels.

5.2 Booms

A boom specifically designed for pollution response is a floating physical barrier used to control the movement of oil. Boom is typically the first mechanical response equipment taken to a spill site. It is used to:

- contain oil slicks for removal by skimmers,
- deflect or divert oil slick towards a collection area or away from sensitive resources,
- exclude oil from selected areas and protect sensitive shorelines.

Containment is deploying a boom to contain and concentrate the oil until it can be removed. Deflection is moving oil away from sensitive areas. Diversion is moving oil toward recovery sites that have slower flow or better access. Exclusion is placing boom to prevent oil from reaching sensitive areas. Booms must be properly deployed, maintained and re-adjusted to changing water flow directions, water levels, and wave conditions. Deployment involves use of mooring systems and skilled teams. Personnel responsible for selection and use of boom should:

- Understand the function of basic components and ancillary fittings common to most boom.
- Identify the boom in terms of its expected location of use, sea conditions, and spill response operation.
- Consider the listed design factors that affect a boom's performance including its durability, storage, deployment, and oil containment potential.
- Select an appropriate size of boom according to environmental conditions and expected performance.
- Consider which boom types can be most effectively used on a spill. Refer to data for each boom type, which includes a description, recommended uses, and operational considerations.

Wind	***Waves***	***Current***	***Boom performance***
0 – 10 kts (0 – 20 km/hr)	calm	0 – 0,5 kts (0,25 m/s)	good
> 20 kts (> 40 km/hr)	< 1 m	> 1 kts (> 5 m/s)	poor

Table 5: Boom performance

5.2.1 Type of Booms

Generally, booms can be divided into two basic types:

- Curtain booms
- Fence booms

Figure 2: Curtain boom

Figure 3: Fence boom

Curtain booms

Curtain booms have a longitudinal flotation element, acting as a freeboard, with subsurface curtain (skirt) suspended from it. Ballast is normally attached to the base of the skirt to keep it in a vertical position. The tension member can either be integrated (built in) in the boom or attached to it. In somedesigns ballast chain also acts as a tension member. Most commercially available curtain boom can be categorized into one of these basic design types:

- Pressure-inflatable
- Internal foam flotation

	Type of boom
	Pressure inflatable
General comments	• Pressure-inflatable boom allows for compact storage and high buoyancy to weight ratio. • Fabric is PVC, neoprene, nitrile rubber-nylon, or polyurethane-coated material. • Up to several hours might be required to inflate sections of some open water models. Other protected water models inflate much more quickly.
Recommended use	• For coastal and offshore operations for both stationary and towed boom configurations. • For use where storage space is limited. • For situations where wave heights can reach 2 m. • Pressure-inflatable boom is generally not suitable for deployments longer than 1 week due to the potential loss of air.
Operational considerations	• On-site air blower and power supply are required for inflation. • Plan on sufficient working platform that can accommodate boom, auxiliary equipment, and adequate personnel. • Monitor and tend frequently once deployed to ensure that flotation remains intact. • Large models require a mechanized handling system and an adequate number of personnel for deployment and recovery. • Some manufacturers offer a non-standard piano hinge connector that may cause problems when the hinge is bent or the boom must be connected to other booms.

Table 6: Pressure inflatable boom

Tables 6-7 show the general comments on curtain booms, (both pressure inflatable and internal flotation booms), when to use them and some operational considerations.

	Type of boom
	Internal flotation
General comments	• Internal foam flotation boom is generally the most widely used and available boom. • PVC or polyurethane-coated fabric encloses flexible foam flotation. • Ballast and tension members may be enclosed within the fabric. • Durability varies depending on the material and strength of the fabrics.
Recommended use	• Use for containment of oil or deflection of slicks in low currents (<1 kt or 0.5 m/s). • Select for use where adequate boom storage facilities are available. • Generally, terminal facilities and marinas can be protected using this type of boom. • Extended deployment (several weeks) in waves up to 1 m is feasible.
Operational considerations	• In areas where currents are more than 0.5 kts , select round flotation booms with top and bottom tension members for deflecting and containing slicks. • In quiet, shallow water, it is reasonable to expect that booms with square or rectangular internal flotation can be successfully used. • Long lengths of boom can be deployed, which can sustain loads usually encountered during most nearshore operations. • Straight-line towing (streaming) is possible at low speeds (up to 0.5 kts) to the location of use.

Table 7: Internal flotation boom

Fence booms

Fence booms have a vertical screen extending above and below the water surface thus acting at the same time both as freeboard and skirt. A flotation element is either bonded to the "fence" or integrated in it to provide for the buoyancy of the boom. Their cross section is usually (but not always) more flat than that of curtain type booms. Fence booms are kept in position perpendicular to the water surface byweights (ballast) attached to the bottom of the screen.

	Type of boom
	Fence
General comments	• Fence boom with rigid or semi-rigid fabric provides a vertically stiff and horizontally flexible "fence". • Fabric durability ranges from low to high tensile strength options. • Fence boom provides effective, long-term, low maintenance protection and/or containment. • Some models are suitable for long-term/permanent deployment in harbors
Recommended use	• For routine or permanent deployment situations. • Fence boom is applicable to stationary containment of oil in quiet waters or deflection of slicks in low currents of 0.5 kts (0.25 m/s). It is only suitable for low wave height. • Use at facilities or on vessels with sufficient boom storage space. • Use where debris resistance is required.
Operational considerations	• Fence boom can be towed at low speeds (up to 5 kts or 2.6 m/s) to location of use. • Long lengths of boom (several hundred meters) can be deployed which can sustain loads usually encountered during nearshore operations.

Table 8: Fence boom

Some of recommendations and operational concerns in use of fence booms are shown in table 8.

When a spill occurs and no containment equipment is available, barriers can be improvised from whatever materials are at hand. Although they are most often used as temporary measures to hold or divert oil until more sophisticated equipment arrives, improvised booms can be an effective way to deal with oil spills, particularly in calm water such as streams, slow-moving rivers, or sheltered bays and inlets. Improvised booms are made from such common materials as wood, plastic pipe, inflated fire hoses, automobile tires, and empty oil drums. They can be as simple as a board placed across the surface of a slow-moving stream, or a berm built by bulldozers pushing a wall of sand out from the beach to divert oil from a sensitive section of shoreline.

All boom types are greatly affected by the conditions on the water; the higher the waves swell, the less effective booms become (Table 9).

Sea state	***Wave height (m)***	***Boom size***	
		freeboard	***draft***
Calm	< 0,3	10 - 25	15 – 30
Protected	0,3 – 1	25 – 45	30 – 60
Open water	> 1	> 45	> 60

Table 9: Ratio of waves hight and boom size

Table 10 shows the applicability of boom towing configurations for the three basic boom types in calm, protected, and open water.

Boom use		***Internal flotation***	***Pressure inflatable***	***Fence***
Calm water	U/V	2	1	3
	J	1	1	2
Protected water	U/V	1	1	3
	J	1	1	2
Open water	U/V	2	1	3
	J	1	1	3
Legend: 1 – good; 2- fair, 3 – poor				

Table 10: Applicability of boom towing configurations

Boom is pulled by towboats in various configurations to contain and recover slicks. Boat speed is typically less than 0,7 knot.

Boom lengths of 150 to 500 m are typically used when towing boom in a U, V, or J configuration to maximize the oil encounter rate.

5.2.2 Selection of booms

The list of criteria for boom's selection is given in Table 11 and may help in defining the requirements. Not all the booms of a particular type have the rating, but at least one or more commercially available booms of the type in question have the rating shown.

		Type of boom		
		Internal flotation	***Pressure inflatable***	***Fence***
Environmental conditions	Open water	2	1	3
	Protected water	1	1	2
	Calm water	1	1	1
	High current (> 1 kt)	2	2	3
	Shallow water (< 0,3 m)	1	2	3
Performance characteristics	Operation in debris	1	2	2
	Excess buoyancy	2	1	3
	Wave response	2	1	3
	Strenght	2	1	1
Convenience features	Ease of handling	2	2	2
	Ease of cleaning	1	1	1
	Compactibility	3	1	3
Legend: 1 – good; 2- fair, 3 – poor				

Table 11: Boom Selection Matrix

Potential boom user should know which parameters will determine the performance of a boom, as well as the approximate magnitude of these parameters for a certain envisaged location or use. It is only when these parameters have been defined that a serious selection of boom can be considered. Some of main required characteristics of booms based on operational use are given in Table 12.

Oil retention	• Ability to follow the movement of sea surface • Ability to prevent escape of oil underneath the skirt • Ability to prevent splash –over
Reliability	• Resistance to environmental conditions (sea, wind…) • Tensile strength • Length of flotation element
Storage and utilisation	• Dimensions (overall width, freeboard, draft, section length) • Weight • Storage volume • Transportation requirements • Operational requirements (personnel, logistic support) • Simplicity of (handling, deployment, connecting, retrieval)
Maintenance and cost	• Resistance to: chemical action of oils, UV radiation, temperature, abrasion, floating debris • Easiness of maintenance and cleaning • Long shelf life • Price and delivery times

Table 12: Main required characteristics of booms

When selecting a specific boom type there may be a choice of fabrics (e.g., polyester, nylon, or aramid). Several protective coatings may be available. Table 13 outlines the advantages and disadvantages of four common coating materials.

Coating	*Advantages*	*Disadvantages*
PVC	Excellent flexibility	Limited long-term resistance to sunlight, heat, hydrocarbons and organics
Inhibited PVC	Resistant to sunlight, heat, hydrocarbons and organics	Not as resistant to organics as urethanes
Polyether urethane	Best weather and water resistance	Not as resistant to organics as polyester urethane
Polyester urethane	Best resistance to organic	Not as weather-resistant as polyether urethane

Table 13: Boom coating materials

Furthermore, the following table (Table 14) is giving the specifications of the oil containment boom which are recommended regarding to prevailing weather conditions (winds and waves) at the Adriatic Sea.

Offshore containment boom	
Maximum boom height (deflated)	1800 mm
Operational freeboard of minimum	300 mm
Operational draft of minimum	500 mm
Ballast (galvanized) chain with a tensile strength of at least	180 kN
Minimum tensile strength of boom should be at least	280 N/mm
The boom has to be stable in currents	up to 2 knots
The boom has to be fully functional in waves	up to 1,2 m
The boom has to be fully functional in wind speeds	up to 8,5 m/s
Temperature range	-5°C to +50°C
• Oil booms having a high buoyancy-to-weight ratio will be preferred • The boom should be divided into individual inflatable air chambers with an approximate length of 3 meters • The air valves on the boom should be as flat as possible to avoid stress concentration in the boom material when stored on the reel • The boom material has to be able to withstand UV-radiation, seawater and all types of oil • The boom must have seawater resistant connectors capable of fitting, directly or via an included adapter • It is preferred that booms are connectable to existing booms without the use of adapters	

Table 14: Specifications of containment boom

5.3 Skimmers

A skimmer is a device for recovering spilled oil from the water's surface. Skimmers may be self-propelled, used from shore, or operated from vessels. The efficiency of skimmers is highly dependent upon conditions at sea. In moderately rough or choppy water, skimmers tend to recover more water than oil.

There are numerous types of skimming devices, described in the annually published World Catalog of Oil Spill Response Products: brush, disc, drum, paddle, belt, rope mop, sorbent belt, submersion plan, suction, and weir.

Skimmer category	Examples
Weir	Simple, self-leveling, screw-auger assisted, stationary and advancing, boom/weir system
Oleophilic surface	Drum, disc, rope, belt and brush, deployed independently, mounted on a vessel or used with a boom
Hydrodynamic	Water jet, submersion plane and rotating vane
Other devices	Vacuum system, air conveyor and paddle belt

Table 15: Main types of skimmers

Two types of skimmers, the most common within the Adriatic region, mechanical and oleophilic are described here. Each type of skimmer offers advantages and drawbacks depending on the type of oil being recovered, the sea conditions during clean-up efforts, and the presence of debris in the water.

Advantages	*Disadvantages*
• Physically remove oil from aquatic environment • Available in practically every equipment stockpile • Can be used in any water environment (bays, inlets, etc.) • Their use is widely approved	• Relatively low encounter and recovery rates, especially in thin slicks • The use in high seas and fast currents is often not practical • Considerable ancillary and supporting equipment must be planned for • Can be clogged by debris

Table 16: Skimmers use advantages&disadvantages

5.3.1 Mechanical skimmers

Weir skimmer

Weir skimmers use a dam or enclosure positioned at the oil/water interface. Oil floating on top of the water will spill over the dam and be trapped in a well inside, bringing with it as little water as possible. The trapped oil and water mixture can then be pumped out through a pipe or hose to a storage tank for recycling or disposal. These skimmers are prone to becoming jammed and clogged by floating debris.

Expected performance						
Oil viscosity			***Mode***	***Sea state***	***Debris tolerance***	***% Oil recovery***
low	***medium***	***high***				
fair	good	good	stationary	calm	good	fair

Table 17: Weir skimmer performance

Figure 4: Simple weir skimmer

Skimmers outfitted with screw auger pumps can recover heavy, viscous oils; however, oil must flow readily for these skimmers to function well. They are also suitable for processing debris. Some viscous oils may not flow freely over the weir.

High percentages of water pickup (70–90%) should be expected and temporary storage/separation equipment must then be considered.

Advantages	***Disadvantages***
• Can operate in shallow water • Screw-auger pump neither requires priming nor forms oil/water emulsion • Easy deployed and operated • Capable of pumping highly viscous oils and debris (seaweed, wood chips,…)	• Limited to calm water and protected water with heavy, viscous oil • High water recovery • Can develop high back-pressure in the discharge line • Manual push of heavy oils sometines required over the weir lip

Table 18: Weir skimmer use – advantages&disadvantages

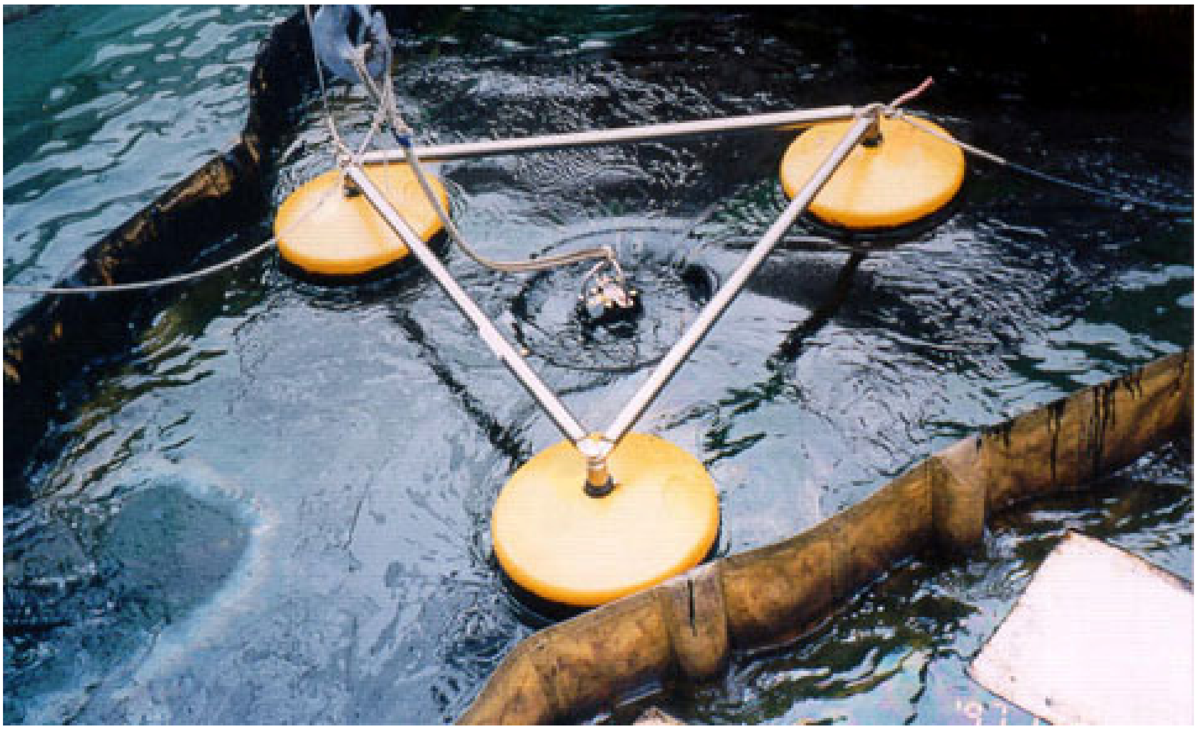

Figure 5: weir skimmer in action

5.3.2 Oleophilic skimmers

Oleophilic ("oil-attracting") skimmers use belts, disks, or continuous mop chains of oleophilic materials to blot the oil from the water surface. The oil is then squeezed out or scraped off into a recovery tank. Oleophilic skimmers have the advantage of flexibility, allowing them to be used effectively on spills of any thickness. Some types, such as the chain or "rope-mop" skimmer, work well on water that is choked with debris.

Disc skimmers

Banks of oleophilic discs are arranged in a linear (i.e., single row), triangular (3 banks of discs), circular ("toroidal"), or square (4 banks of discs) configuration. Each group of discs is rotated downward into the oil, driven by hydraulic, pneumatic, or electric motors. PVC or aluminum scrapers remove oil adhering to the discs, and it flows down tubes or directly into a sump.

Expected performance						
Oil viscosity			***Mode***	***Sea state***	***Debris tolerance***	***% Oil recovery***
low	***medium***	***high***				
fair	good	fair	stationary	calm/protected	fair	good

Table 19: Disc skimmer performance

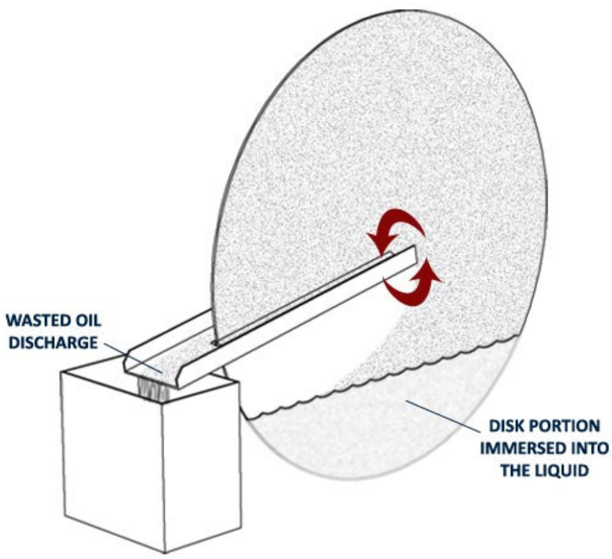

Figure 6: Disc skimmer principle

Advantages	***Disadvantages***
• Simple design / good reliability • Small units can be operated in shallow water • Not so heavy • High oil/water pickup ratio • Can tolerate some debris • Can be used in calm, harbor and some offshore applications	• Limited to calm and protected water • Limited capacity sump • Will not recover highly viscous oil due to pumping • Reduced recovery rate in thin slicks can occur if drum water wets • Large units can be relatively expensive

Table 20: Disc skimmer – advantage & disadvantage

Disc skimmers recover liquid containing a high percentage of oil but can clog with debris. Down-tubes, scrapers, and discs should be cleaned frequently even when operating in what appears to be debris-free water.
A disc speed of approximately 40 rpm optimizes oil recovery rate in most oils. Light oils, e.g., diesel, may require a lower rpm to reduce water uptake. Skimmer operation is optimal in calm and low wave conditions, but deteriorates if there is splash against the discs or skimmer body.

Figure 7: Disc skimmer in action

Drum skimmers

One or more oleophilic drums that are driven by hydraulic, pneumatic, or electric motors are rotated downward into an oil slick. Recovered oil is then scraped off the drum(s) into a trough and, in some models, a sump. Either external or onboard discharge pumps are available. Some newer skimmers feature a mechanism to allow an operator to adjust the drum submersion depth.

Expected performance						
Oil viscosity			***Mode***	***Sea state***	***Debris tolerance***	***% Oil recovery***
low	***medium***	***high***				
fair	good	fair	stationary	calm/protected	fair	good

Table 21: Drum skimmer performance

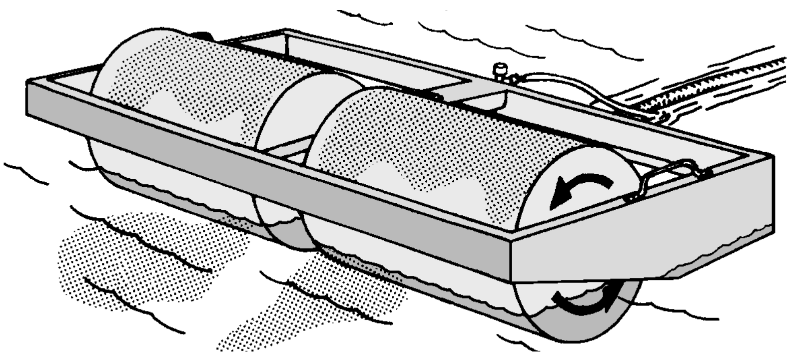

Figure 8: Drum skimmer

Rotational speeds of approximately 40 rpm (revolutions per minute) result in the maximum recovery rate of medium viscosity oils. Reducing the rotational speed to 20 rpm generally improves the oil content in the recovered liquid by 10% but lowers the recovery rate by 50%.

Waves often significantly decrease the recovery rate of self-contained (i.e., not vesselmounted) drum skimmers. Calm water operation is recommended.

Advantages	Disadvantages
• Simple design / good reliability • Small units can be operated in shallow water • Not so heavy • High oil/water pickup ratio • Can tolerate some debris • Can be used in calm, harbor and some offshore applications	• Limited to calm and protected water • Limited capacity sump • Will not recover highly viscous oil due to pumping • Reduced recovery rate in thin slicks can occur if drum water wets • Large units can be relatively expensive

Table 22: Drum skimmer – advantages & disadvantages

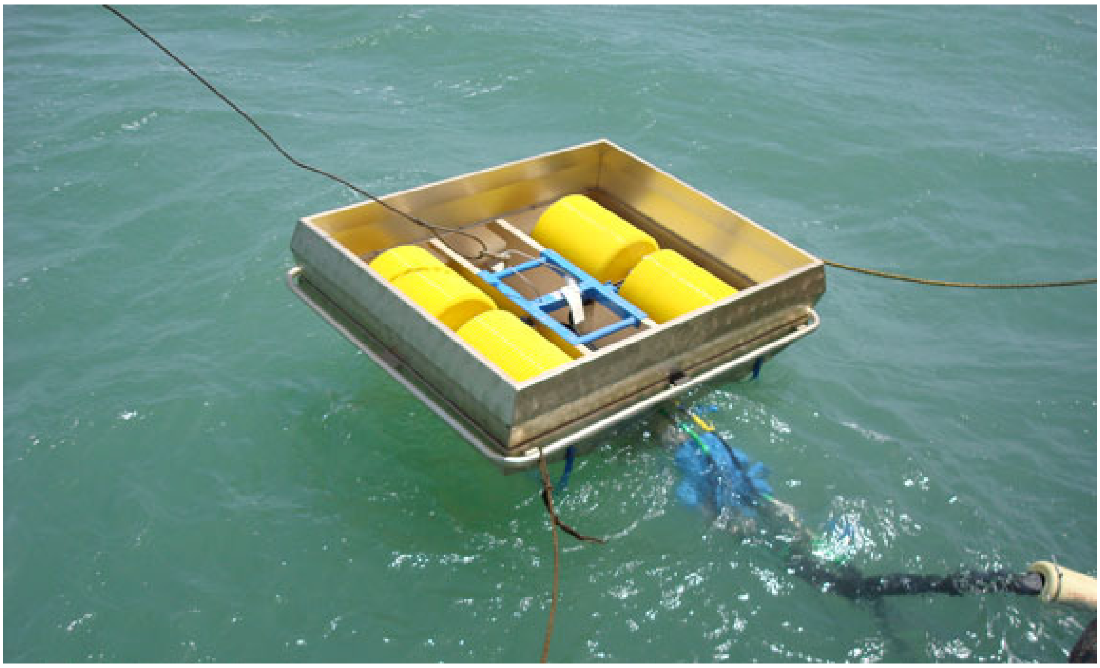

Figure 9: Drum skimmer in action

Rope mop skimmers

Single or multiple polyethylene fiber ropes are pulled through a slick by wringerrollers. The rope mop is wrung and then continuously returned to the slick, repeating the cycle. Recovered oil is collected below the wringer assembly or pumped via a suction hose. Some models require a return pulley while those operated vertically are simply suspended above the slick so that the rope mop contacts the oil.

Expected performance						
Oil viscosity			***Mode***	***Sea state***	***Debris tolerance***	***% Oil recovery***
low	***medium***	***high***				
fair	good	poor	stationary	all	good	good

Table 23: Rope mop skimmer performance

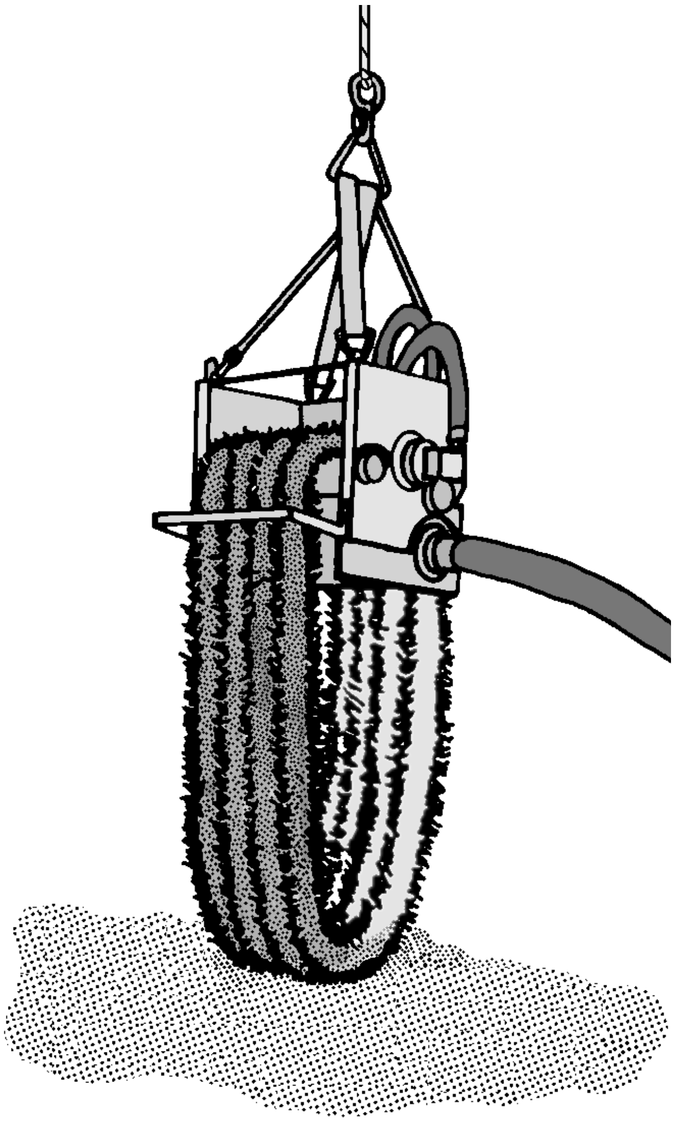

Figure 10: Vertical rope mop skimmer

Advantages	***Disadvantages***
• Effective in calm, protected and open water • Wide, effective reach • Good pickup rate • Can operate in any water depth • Tolerate most debris • Rope can recover oil in low currents	• Not effective in highly viscous oil • Inefficient unless oil is a confined or pooled • Ropes and wringer-rollers will wear if oil is mixed with sand • Tail pulley may have to be repositioned in tide changes

Table 24: Rope mop skimmer – advantages & disadvantages

Rope mop skimmers generally function best in warm weather (>20ºC) in medium viscosity oils that adhere to the mop. Operation in colder weather and lighter oils is possible. The oil content in the collected liquid declines as mop speed exceeds about 0.4 m/s. Recovery in low waves of 30–60 cm should be possible. If oil is emulsified and viscous, rope mop strands can mat together and jam the wringer assembly. Low pickup rates of light oils, e.g., diesel, are common.

Figure 11: Rope mop skimmer in action

Brush skimmers

Closely spaced brushes collect oil, which is then removed by a comb-like scraper before being conveyed to storage. On some smaller models, brushes are mounted on a drum.Most larger models employ multiple linear chains deployed from the side or bow of a dedicated vessel or a vessel of opportunity. Side collectors require a jib, boom, multiple cables, and onboard storage and are often positioned on existing vessels used for multiple purposes, including spill response and fire fighting.

Expected performance						
Oil viscosity			***Mode***	***Sea state***	***Debris tolerance***	***% Oil recovery***
low	***medium***	***high***				
poor	good	good	advancing	all	good	fair

Table 25: Brush skimmer performance

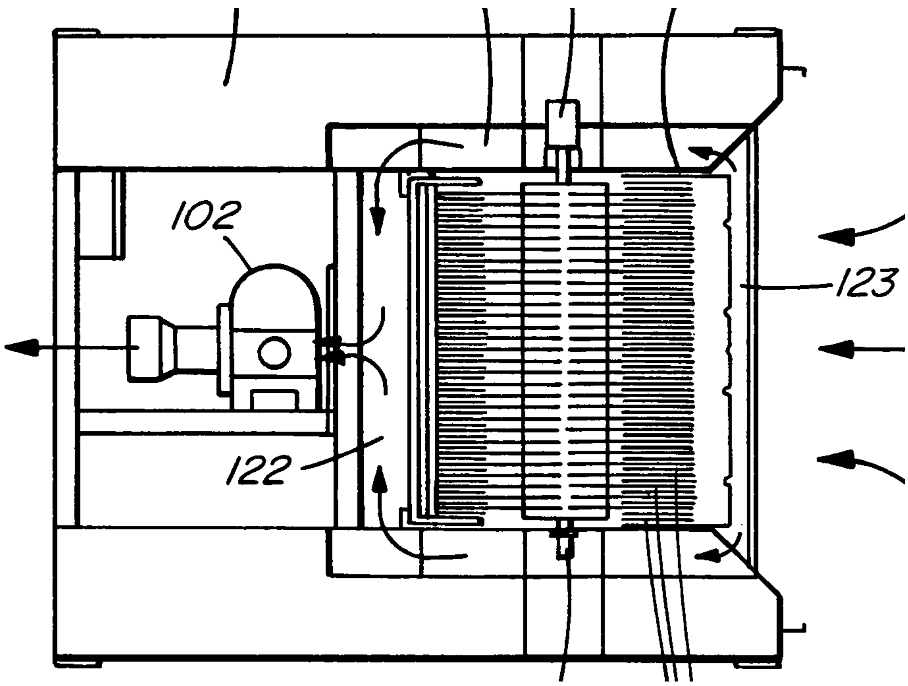

Figure 12: Brush skimmer

Advantages	**Disadvantages**
• Relatively simple mechanical design • Effective oil removal comb/scraper system • Suitable for weathered or emulsified oil • Can tolerate some debris	• Oil losses under booms of side collectors possible • Low pickup rate of light oil • Require relative movement between skimmer and oil • Bow mounted collectors affected by vessel movment

Table 26: Brush skimmer – advantages & disadvantages

Brush skimmers function optimally in medium and high viscosity oils, provided that a suitable pump is used to transfer the latter to storage. Highest oil recovery rates in viscous products occur when brush drums are operated at approximately 20 rpm. However, the percent oil recovered in the collected liquid is highest at 5 to 10 rpm. The higher oil content is achieved at the expense of oil recovery rate, which decreases in direct relation to the decrease in rpm.

Linear brushes work best at 0.3 m/s. Their wave tolerance is generally good since water flows through the brushes, but response of the entire skimming system depends on the sea-worthiness of the working platform. Excessive movement of the brush packs in waves due to vessel pitch and roll reduces oil recovery rate, particularly if brush packs are bow-mounted (side collectors are more common). Light oils, e.g., diesel, are not effectively recovered with most standard brushes due to low recovery rate and percent oil recovered.

Figure 13: Brush skimmer in action

5.3.3 Selection of skimmers

Bellow table can be used to select a skimmer best suited for a particular clean-up need. The matrix indicates the expected performance of various generic types of skimmers according to the operating environment, oil viscosity and skimmer characteristics.

			Generic type of skimmer						
			Oleophilic				Weir		
			Brush	Disc	Drum	Rope	Screw /Auger	Saucer	Vortex
Evaluation criteria	Operating environment	Open seas	2	2	2	1	3	3	3
		Harbours	1	1	1	1	3	3	2
		Shallow water	1	1	1	1	1	1	1
		High currents	2	3	3	2	2	3	3
		Debris	1	3	2	1	1	3	3
	Oil viscosity	High (> 1000 cSt)	1	3	2	3	2	3	3
		Medium (100-1000 cSt)	1	1	1	1	1	1	1
		Low (< 100 cSt)	3	2	2	2	2	1	1
	Skimmer characteristics	Oil/Water pickup rate	2	1	1	1	2	2	3
		Recovery rate	2	2	2	3	2	2	3
		Deployment	1	1	1	2	2	1	1
Legend: 1 – good; 2- fair, 3 – poor									

Table 27: Skimmer Selection Matrix

The parameters rated in the Table 26: Skimmer Selection Matrix must be considered together with other aspects when assessing a skimmer. The ratings of some criteria are independent of the size of a skimmer while the ratings of other criteria are directly proportional to skimmer size. For example, oleophilic discs operate poorly in debris but have high recovery efficiencies (low water pickup) regardless of disc or skimmer size.

Recovery rate and suitability for use in open water, however, strongly depend on the size of a skimmer. A “good” rating, in any case, means that a commercial version of that skimmer type is available that will deliver the indicated performance.

Unfortunately there is no such thing as a "universal" skimmer exists. Each type of recovery unit has its own advantages in certain spill situations and its drawbacks in others.

Table 27 gives criteria that may be useful in selecting appropriate skimmers.

Oil recovery	• Recovery rate • Selectively (percentage of oil in mixture collected) • Sensitivity to the type of oil - specific gravity, viscosity • Sensitivity to: debris, thickness of the slick, currents, waves (choppy sea, swell), winds
Reliability	• Sea worthiness • Complexity of the mechanism • Solidity • Possibility and simplicity of “on site” repairs
Storage and utilisation	• Transport and loading requirements • Operational requirements (personnel and materials) • Speed of deployment • Dimensions, draft, freeboard
Maintenance and cost	• Wear resistance of the material(s) • Resistance of the material(s) to chemical action of pollutant(s) • Ease of cleaning, maintenance and repairing by not necessarily qualified operators • Price and delivery times (if possible, terms of lease or hire) • Manufacturer’s warranty

Table 28: Criteria in selecting skimmers

5.4 Pumps

Pumps are used during oil spill response to transfer oil, water, emulsions, and dispersants. Recovered liquids typically need to be transferred:

- from a skimmer to interim storage
- from interim storage to a transportation vessel
- from a transportation vessel to a final storage/disposal facility

Generally, spill cleanup does not require pumps with extreme capabilities. The head through which the pump must push liquid is usually about 2 to 6 m and suction lift from a skimmer to a pump is often much less (i.e., only about a meter). In some cases, a large head is required, especially when oil is pumped from a skimmer to a large, unballasted barge or storage vessel. In this case, the head required may be 10 m or more.

Transfer equipment must be selected to suit the quantities and types of liquids being moved. Although a wide range of pumps can be used for fresh, unemulsified oils, pump options can become limited as transfer conditions become more difficult. Careful consideration must be given to each specific transfer situation, particularly in the case of long-term mechanical recovery operations since over time, oil weathers, viscosity increases, and debris is collected.

During the response actions some pumps are not suitable for work due to following reasons:

- Limited suction capacity
- They neither self-prime nor maintain prime when the skimmer rolls
- Pumping capacity decreases in case of slight increase in oil viscosity
- Cavitation occurs in warm or high viscosity oil
- Debris blocks the pumping mechanism
- Damaged is caused by running dry

Four pumps that are both suitable and commonly used for spill cleanup are:

- centrifugal
- diaphragm
- screw/auger
- peristaltic

Centrifugal Pump

Liquid enters a pump at the center of a rapidly rotating fan-shaped impeller. Centrifugal force then accelerates fluid toward the impeller's outer edge. From there, the fluid exits through a nozzle on the periphery of the impeller housing. Pressure generated by this pump is from the kinetic energy imparted to fluids by the impeller.

Suitable Uses

- Pumping low viscosity fluids at high rates for short distances
- Supplying water to dispersant spray booms or fire nozzles
- Flooding shoreline with seawater to prevent oil from sticking to soil
- Unloading drums of chemicals, fuels, etc.
- Mixing demulsifier chemical into emulsified oil

Advantages	***Disadvantages***
• Small, lightweight, easy to handle • High capacity with low viscosity fluids • Mechanically simple • Tolerant of most debris • Easy to repair in the field	• Output decreases markedly with increasing viscosity of fluid • May generate oil/water emulsions • Pump performance impaired by stringy debris

Table 29: Centrifugal pump – advantages & disadvantages

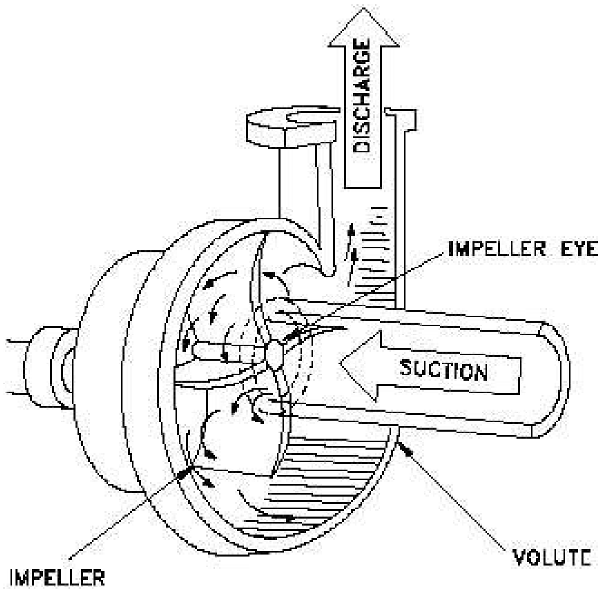

Figure 14: Cenrifugal pump

Diaphragm Pump

As a diaphragm moves to one side of its housing, it creates a vacuum in one chamber and pressure in the other. The vacuum opens one inlet valve and closes an outlet valve. Pressure opens the other outlet valve and closes the remaining inlet valve. When a diaphragm moves to the other side of its chamber, the action of all valves is reversed. Pumping action gives rise to a slight pulsating discharge. A diaphragm pump has a flexible elastomer piston (diaphragm) with wide clearances between moving parts.

Advantages	*Disadvantages*
• Can run dry indefinitely • Can tolerate high concentrations of fine solids • Good suction lift • Small, portable, easily repaired	• Diaphragms sometimes burst • Some diaphragm materials are not compatibile with oil • Some models require compressor • Cannot operate against high back pressure

Table 30: Diaphragm pump – advantages & disadvantages

Suitable Uses

- Pumping fluid from small skimmer to nearby storage
- Pumping fluid in hazardous atmospheres (air-operated units)
- Pumping water and/or oil from storage containers to incinerators

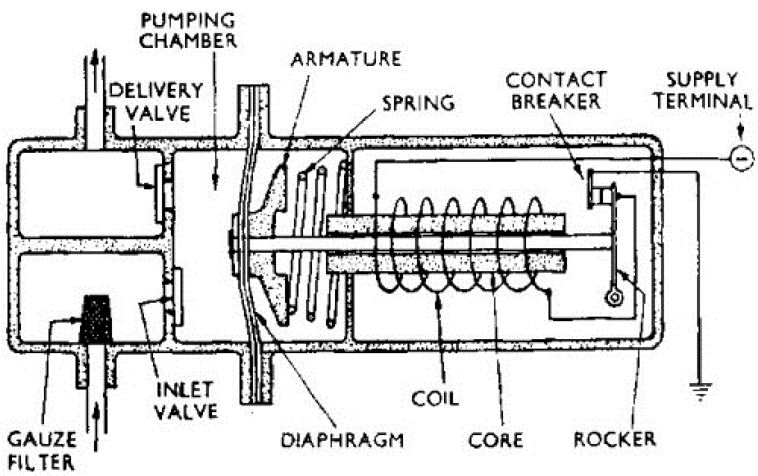

Figure 15: Diaphragm pump

Screw/Auger Pump

Oily material is gravity fed to a screw through a large hopper. As the screw rotates, it carries an oily mixture forward until a special rotary lobe scrapes oil from the groove and forces it out the front of a pump. Debris that fits between the "threads" of a screw is processed. A special cutter at the edge of a hopper can cut long stringy debris, so it can also be pumped. Because of its low rotational speed and the relatively loose clearance between screw, housing, and lobe, this pump has very little self-priming or suction capability.

Advantages	***Disadvantages***
• Can pump highly viscous or semi-solid materials • Procesess most debris • Does not emulsify oil/water • Some models are integral with weir skimmer	• Poor suction/lift capacity • Relatively low pumping rate for its power • Can develop high back pressure • Relatively expensive for capacity • Not self-priming

Table 31: Screw/Auger Pump advantages & disadvantages

Suitable Uses

- Pumping weathered crude or mousse
- Off-loading recovered oil from storage barges
- Transferring contents of earthen storage pits to incinerator
- Transferring oil/ice/snow slush

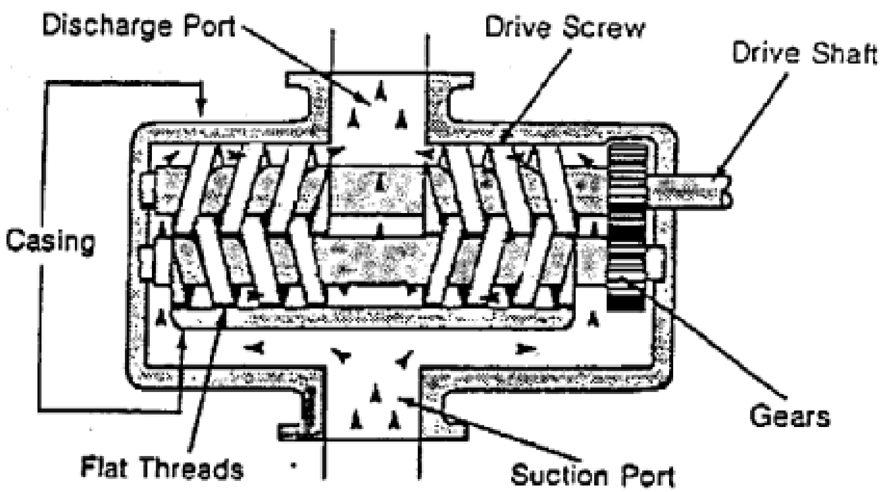

Figure 16: Screw/Auger Pump

Peristaltic pump

The pumping action of a peristaltic pump (also called a “hose pump”) results from alternate compression and relaxation of a specially-designed resilient hose. The hose is compressed between the inner wall of the housing and the compression shoes of a rotor. A liquid lubricant in the housing minimizes sliding friction. The fluid being pumped is in contact only with the inner wall of the hose. During compression, abrasive particles in the fluid are cushioned in the thick inner hose wall — returning to the fluid stream after compression. The pump has no seats, seals or valves. It is self-priming and can be run dry without damage. Suction, even for medium viscosity materials, is generally excellent.

Advantages	***Disadvantages***
• Self-priming • Can pass most debris (up to 25 mm) • Can process a low to medium viscosity oils • Can be run dry without damage • Easy repaired in fild	• Internal hose wears and can require frequent replacement • Vacuum on suction line can be lost on medium viscosity oils • Have pulsating flow • Speed control is overly simple

Table 32: Peristaltic pump advantages & disadvantages

Suitable Uses

- offloading emulsions from skimming vessels or oil storage barges
- moving low and medium viscosity products.

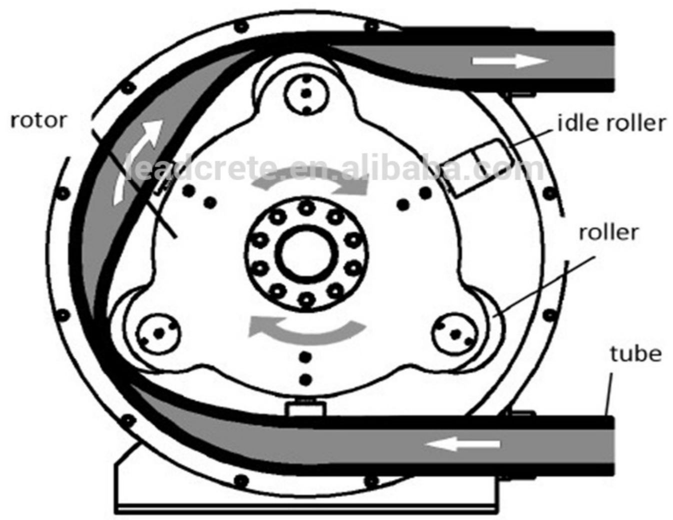

Figure 17: Peristaltic pump

5.4.1 Selection of pumps

An overall evaluation of each pump follows the Table 33. To use the Pump Selection Matrix, follow these steps:

- Step 1 Identify the type of fluid and/or debris that needs to be transferred. Select pumps that will perform well in moving such material(s).
- Step 2 Identify other criteria critical to the situation and rank them in order of importance. Search the Matrix for these criteria in descending order of importance, each time selecting the highest rated pump(s) which have not been eliminated in a previous step.

			TYPE OF PUMP			
CHARACTERISTIC OF PUMPS			**Centrifugal**	**Screw/auger**	**Diaphragm**	**Peristalic**
	OIL VISCOSITY	**Low**	1	3	2	1
		Midium	2	1	2	1
		High	3	1	2	2
	DEBRIS TOLERANCE	**Sand**	1	1	1	1
		Gravel	1	1	2	1
		Seaweed	3	3	2	2
	OTHER CRITERIA	**Transfer rate**	1	3	2	1
		Self-priming	3	3	2	1
		Ability to run dry	1	2	1	1
		Operative continuously	1	2	2	1
		Ease of repair	1	2	1	1
		Portability	1	2	2	1
		Back pressure	3	2	2	1
Legend: 1 – good; 2- fair, 3 – poor						

Table 33: Pump Selection Matrix

5.5 Sorbents

Organic, inorganic, and synthetic materials that remove oil through absorption (uptake into the sorbent material, like a sponge) or through adsorption (coating of the sorbent's surface). Sorbents are placed on the floating oil or water surface, allowing them to sorb oil, or are used to wipe or dab stranded oil. Efficacy depends on the capacity of the particular sorbent, wave or tidal energy available for lifting the oil off the substrate, and oil type and stickiness. All sorbent material must be recovered. Loose particulate sorbents must be contained in a mesh or other material.

Sorbents can be of both organic and inorganic origin, natural or man-made products. They are available in various forms: sausage boom, pads, powder, granules, pillows, mats, rolls. The absorbent must be at least 70 percent insoluble in excess fluid. Adsorbents are insoluble materials that are coated by a liquid on its surface, including pores and capillaries, without the solid swelling more than 50 percent in excess liquid. To be useful in combating oil spills, sorbents need to be both oleophilic (oil-attracting) and hydrophobic (water-repellent).

Figure 18: Sorbents

Although sorbents may be used as the sole cleanup method in small spills, they are most often used to remove final traces of oil, or in areas that cannot be reached by skimmers. The use of (floating) sorbents to fix and agglomerate oil or some other pollutants in case of an accident is an efficient technique widely applied on shore and in ports to recover small contaminations.

The treatment of a certain volume of oil necessitates the use of at least equivalent volume of sorbent, which must be disposed of in accordance with approved local, state, and federal regulations. Any oil that is removed from sorbent materials must also be properly disposed of or recycled. These problem render the use of sorbents limited to small or medium size spills in sheltered areas near the shore. Sorbents are often used in shore clean-up operations when more common recovery methods either give poor results or are inapplicable. This refers particularly to the treatment of viscous oils for which few pieces of recovery equipment are efficient and dispersants are useless. Sorbents are also used to facilitate the collection of oil on shore, on beaches or to complement cleaning of rocks.

Sorbents can be divided into three basic categories:

- natural organic
- natural inorganic
- synthetic

Natural organic sorbents include peat moss, straw, hay, sawdust, ground corncobs, feathers, and other readily available carbon-based products. Organic sorbents can adsorb between 3 and 15 times their weight in oil. Some organic sorbents tend to adsorb water as well as oil, causing the sorbents to sink. Many organic sorbents are loose particles such as sawdust, and are difficult to collect after they are spread on the water.

Natural inorganic sorbents consist of clay, perlite, vermiculite, glass wool, sand, or volcanic ash. They can adsorb from 4 to 20 times their weight in oil. Inorganic sorbents, like organic sorbents, are inexpensive and readily available in large quantities. These types of sorbents are not used on the water's surface.

Synthetic sorbents include man-made materials that are similar to plastics, such as polyurethane, polyethylene, and polypropylene and are designed to adsorb liquids onto their surfaces. Other synthetic sorbents include cross-linked polymers and rubber materials, which absorb liquids into their solid structure, causing the sorbent material to swell. Most synthetic sorbents can absorb up 70 times their own weight in oil.

The following characteristics of both sorbents and oil types must be considered when choosing sorbents for cleaning up oil spills:

Rate of absorption	The absorption of oil is faster with lighter oil products. Once absorbed the oil cannot be re-released. Effective with light hydrocarbons (e.g., gasoline, diesel fuel, benzene).
Rate of adsorption	The thicker oils adhere to the surface of the adsorbent more effectively.
Oil retention	The weight of recovered oil can cause a sorbent structure to sag and deform, and when it is lifted out of the water, it can release oil that is trapped in its pores. Lighter, less viscous oil is lost through the pores more easily than are heavier, more viscous oils during recovery of adsorbent materials causing secondary contamination.
Ease of application	Sorbents may be applied to spills manually or mechanically, using blowers or fans. Many natural organic sorbents that exist as loose materials, such as clay and vermiculite, are dusty, difficult to apply in windy conditions, and potentially hazardous if inhaled.
Reusability	Reusable sorbents reduce waste. Some sorbents work better when "primed" or previously wetted with oil. Repeated handling and the need for wringers and storage containers increase the difficulty of applying reusable sorbents.
Biodegradability	In situations where material is difficult to recover, a sorbent should be environmentally safe and biodegradable. Sorbent products that incorporate nutrients can enhance biodegradation; however, the need for nutrients should be determined to avoid creating a eutrophic environment.
Disposal	Sorbent selection should consider the ultimate disposal plan. Disposal facilities, whether for burial or incineration, generally need to be approved by regulatory authorities prior to the disposal of sorbents. Bag and/or drum requirements for storage of recovered sorbents should be calculated based on the quantity of sorbent to be distributed and the volume of oil likely to be sorbed. Sorbents must be burnable and not contain too much water for incineration.

Table 34: Characteristics of sorbents

Synthetic materials, such as polyethylene and polypropylene, generally offer superior oil recovery efficiency compared to organic and inorganic materials, such as peat moss or vermiculite. Typical materials and suitable applications are presented in Table 34.

Synthetic	Polyethylene/polyurethane foams and pads Polypropylene fabric, nets and ribbons Nylon fabrics and strips Polyester/cotton fabrics (windshield cleaner cloth)	Generally the most effective (some polyurethane foams absorb up to 25 times their weight of and pads oil); highly oleophilic / hydrophobic Available in many forms; rols, sheets, blankets, pom-poms, etc Not biodegradable but most are environmentally safe (inert) White or light-colored products are preferred for oil visibility
Organic	Straw Peat moss Sawdust Wool Wood chips Cellulose fiber	Generally absorb 5 – 10 times their weight Biodegradabile Many sink fairly rapidly when soaked Primarily loose meterials that are difficult to recover Have been used to immobilize oil in sensitive environmental areas to protect vegetation and wildlife
Inorganic	Perlite Vermiculite Glass wool Volcanic rock	Generaly absorb 3 – 6 times their weight Relatively inexpensive Some sink and cannot be recovered Difficult and sometimes hazardous to apply

Table 35: Sorbent oil recovery efficiency

5.6 Storage equipment

Waste disposal is a major oil spill response consideration. A vast quantity of oil and oily debris can result from a major oil spill and careful planning is needed in order to provide for its disposal. For large spills, as much waste can be generated as the amount of oil spilled and in some cases considerably more. In the 1999 Erica spill, more than ten times as many tonnes of waste were collected as were spilled (230.000 vs. 19.000 spilled). Temporary storage and final disposal of oil and oiled material collected during an oil spill accident are two issues which are often neglected in the planning of oil combating operations. Unfortunately such an attitude may easily hamper the entire operation.

The first principle is to minimize the amount of waste generated by prudent isolation of oiled material from non-oiled material. Also, a good practice is to remove debris from shorelines before the oil impact. Since oil recovery operations are rarely conducted near existing waste management facilities, resources must be committed to identify, evaluate, and select storage and disposal options. Decisions concerning storage and disposal will depend on the size of a spill, its location, and local or regional regulatory requirements.

Oil spill response operations can very quickly generate large volumes of waste. Completing arrangements for permanent disposition of wastes may require a great deal of time that could delay recovery operations. Therefore, facilities for temporary storage of waste should be provided. There are many temporary storage options that will meet operational requirements, including commercial products specifically designed for oil spill response, general-purpose devices, and containers of opportunity.

There are two types of storage alternatives for oil-contaminated materials:

Offshore storage	***Onshore storage***
• Vessel with deck tank • Tank barge • Open top barge • Floating towable tank	• Drums • Mobile tanks • Vacuum trucks • Tank trucks • Damp trucks • Earthen pit

Table 36: Types of storage

Selection is based on storage volume requirements and type of materials to be stored. Selection of an appropriate storage method depends on the following factors:

- Storage location (offshore or onshore)
- Storage capacity required
- Type of material to be stored
- Degree of performance (days, weeks or months)
- Method of final disposal

Figure 19: Collapsible storage tank

6 MAINTENANCE

For the operators and owners of oil spill pollution equipment there are a number of factors to consider if a reliable response is to be achieved. Pollution control equipment is often stored for long periods of time without being required. Then suddenly it is required to operate continuously in all conditions for extensive periods, this is a very tall order for any item of machinery or equipment.

A number of factors must be consider to ensure that equipment will work in the field when responding to an oil spill, these range from ensuring that the equipment is well designed and tested, that it is used by trained operators and that the equipment has been well maintained.

Equipment	Interval	Operations
Oil pumping units	Monthly every 6 months	simple starting handling / training
Mechanical recovery devices	every 6 months	operational trials
Booms	every 6 months	deployment of a considerable length unfolding the entire length
Floating, flexible and rigid barges and storage capacities for collected oil	Once a year	inflation of inflatable units mounting/erecting other units filling with water

Table 37: Recommended dynamic of equipment maintenance

Booms can be stored in a variety of ways that include reels, containers, vessel decks and racks. Storage options should be chosen that facilitate keeping boom clean and dry, out of direct exposure to sunlight, and away from activities that might damage it.

Quick deployment should also be a criteria used in selecting storage sites and methods.

7 SUMMARY AND CONCLUSIONS

Some of previous studies in the HAZADR project already recommended that all the coastal Adriatic states should follow international best practice and convention guidance and implement a three-tiered approach to all aspects of marine oil spill readiness and response. This approach ensures an appropriate response capability is readily available to deal with oil spills commensurate to the risks. A multi-tier oil spill response approach is recommended for offshore oil spill response planning. The tier system allows maximum flexibility in developing response strategies and Spill Management Team structure, instead of a "one-size-fits-all" approach.

Decades of statistics show that the greatest numbers of spills are under a 7 tonnes. For such spills it is not difficult to prepare detailed response strategies, purchase suitable equipment for the expected type and quantity of oil. Simultaneously, in responding to major marine pollution incidents that might affect one or several countries in the Adriatic region, existing national preparedness and response systems in all the Adriatic coastal countries present a good base for cooperation, but lack of adequate specialised equipment on that level of response is significant. In line with that it is a need to review national response policies or strategies with a view to defining whether the envisaged policies can be realistically implemented with the equipment available in the Adriatic region.

Typically, mechanical containment and recovery at sea is the first response options among the Adriatic coastal countries since that other methods are not allowed or they are not locally-available. Unfortunately, because of limited budgets, simply outfitting every equipment stockpile with every possible piece of equipment is not a viable solution. It is necessary that all the Adriatic coastal states and their respective authorities will agree on mutual response policy within the Adriatic region which will consider both the sensitive ecology of the Adriatic Sea and the potential and limitations of all other available response methods.

Because both equipment budgets and storage capacity on vessels will always be limited, it is advantageous to avoid dependency on overly sophisticated devices. In fact, experience has shown that the most efficient strategy is often to use low-tech approaches. Planning, coordinated training, and using a mix of standard oil spill response equipment and locally-available resources would seem to be the best approach.

LIST OF TABLES

LIST OF FIGURES