Kill•Spill

Integrated Biotechnological Solutions for Combating Marine Oil Spills

# Deliverable D1.6

# Report on Previous Oil Spill Incidents and Efficiency of Mitigation Measures

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## 1 About this deliverable

Kill•Spill is a European funded seventh framework programme project focusing on the development of highly efficient, economically and environmentally viable solutions for the clean-up of oil spills caused by maritime transport or offshore oil exploration and related processes.

The aim of the project is to develop novel biotechnologies with a reduced ecological impact for the clean-up of oil spills, to limit the use of non-environmentally friendly solutions. This encompasses the development of biosensors to monitor hydrocarbon degradation, as well as novel dispersants, absorbents, combined microbial and additives formulations, multifunctional bioremediation agents, and tools for sediments decontamination. The impact and toxicity of the developed products will be assessed, and they will then be validated in mesocosms and on real oil spills.

Work Package 1 (WP1) is the in depth analysis of current knowledge and identification of technological gaps. This also includes the review of available techniques and technologies. Specifically we analysed significant pollution incidents in European waters in the last 20 years and worldwide in the last 10 years for the types of incidents, the types of oil involved, the weather conditions, the environmental sensitivities, the response techniques and equipment utilized. Most important, the efficiency of the employed remediation techniques for each incident will be tabulated to provide an overall summary of efficiency of products used in real life medium and large size incidents. This paper presents the results of the review.

Where it has been possible to give the efficiency of a measure it has been included. For example during the ***Sea Empress*** clean up the dispersant-to-oil implied ratio is 1:65 (445 $m^3$ of dispersant dispersing 29,000 $m^3$ of oil); when it is assumed that the application of dispersant will remove 20 $m^3$ of oil for every ton of dispersant (Allen and Dale, 1995); a highly efficient response (3.5 times the expected performance).

However in the majority of incidents it has not been possible to determine the **efficiency of mitigation measures** because of numerous variables involved in oil spill response; the type oil, the 'weathering process', the prevailing weather and sea conditions, the physical, biological and socio-economic characteristic of the location and the time of year.

To determine the **efficiency of a mitigation measure** the results need to be compared to a 'standard'; for example what is the 'standard' for 'at sea recovery'?? It would depend on encounter rate; the weather and sea conditions; the skill (and seamanship) of 'crew' plus many other factors.

**Effectiveness**, the capability of producing a desired result, is easier to establish; in its simplest form - did the countermeasure work or not? : Therefore the effectiveness of a response has been included.

## 2 Scope of the report

The review period for incidents in European waters is from 1993 to 2012; for worldwide incidents; 2003 to 2012. The periods have been selected as it is considered that more complete information should be available on the incidents up to 2012.

Two lists of incidents (European and worldwide) have been presented based on their significance; location and type of oil etc. For example if a comparison of the ***Braer*** and ***Sea Empress*** incidents was made regarding response; the response to ***Sea Empress*** covered a fuller range of remediation techniques than the ***Braer***, therefore it would be more productive to select the ***Sea Empress***. Both the European (64) and the worldwide (42) lists are at Annex A. All the incidents were reviewed to determine which were considered to be the most 'relevant' to the objectives of the Kill-Spill project; 10 European and 10 worldwide incidents were selected and are at Annex B.

Of the relevant incidents 'selected' for detailed review 14 countries involved: European; Denmark 2, France 3, Greece 1; Norway 1, Spain 1, Turkey 1 and United Kingdom. World Wide: Australia 1, Pakistan 1, Philippines 1, Republic of Korea 1, New Zealand 1, Nigeria and United States of America 4. As required the types of incidents are varied; 8 offshore, 8 inshore, 2 ports/harbours and 2 inland waters. The type of oil spilt was mixed: in Europe – HFO x 6, IFO x 1, Crude x 1 and Unknown x 1: Worldwide – HFO x 2, IFO x 1 and Crude x 7. The weather conditions; the environmental sensitivities and the response techniques were carefully considered.

The 'relevant' incidents have been investigated in detail and reports compiled. The 10 reports for the European spills are at Annex C and the 10 reports for the worldwide incidents at Annex D.

# 3 Spill response actions

## 3.1 Observation, Monitoring and Sampling

Following a spill of oil, governments and other organisations will want to know the extent of contamination of key resources or the impact of the incident on the marine environment. This information is important to determine if prompt action may be required to protect human health or sensitive resources. To facilitate decision-making, monitoring programmes may be undertaken, which will often involve surveys and the collection of samples of oil, water, sediment or biota for chemical analysis.

While qualitative analyses can confirm the source of oil contamination, monitoring programmes are often concerned with the quantitative changes in hydrocarbon levels. Monitoring may not always be necessary, especially if the spill is small and resources are not at risk.

**Aerial Observation;** at the outset of an incident, reports from surveillance flights are essential to establish the nature and scale of the incident; where appropriate flights should be made a high priority.

Aerial reconnaissance can help response personnel assess the location, extent of contamination; verify predictions of movement and fate of oil at sea. Once operations are underway, it provides information that facilitates the appropriate deployment of resources at sea, the timely protection of sites along threatened coastlines and the prioritisation of resources for shoreline clean-up.

Helicopters are ideal for surveillance over near-shore waters where their flexibility is an advantage along intricate coastlines with cliffs. Over the open sea, there is less need for rapid changes in flying speed, direction and altitude, and the speed and range of fixed-wing aircraft are more advantageous. However, any aircraft used must feature good all-round visibility and carry suitable navigational aids. Obtaining worthwhile results requires detailed preparation before take-off and careful interpretation of the information gathered.

**Visual observation** of floating oil from the air is the simplest method of determining the location and scale of an oil spill.

**Remote sensing equipment** mounted in aircraft and vessels can be used to detect and monitor accidental oil spills. Remote sensors work by detecting properties of the sea surface: colour, reflectance, temperature or roughness. Oil can be detected on the water surface when it modifies one or more of these properties. Cameras relying on visible light are widely used; they may be supplemented by airborne sensors which detect oil outside the visible spectrum and are able to provide additional information about the oil. Commonly employed combinations of sensors include Side-Looking Airborne Radar (SLAR) and downward-looking thermal infra-red (IR) and ultra-violet (UV) detectors or imaging systems.

However, with remote sensing imagery, it is often difficult to be certain that an anomalous feature on an image is caused by the presence of oil. Consequently, remote sensing imagery requires expert interpretation by suitably trained personnel to avoid other features being mistaken for oil spills.

**Satellite-based remote sensing systems** can also detect oil on water. The sensors on board are either optical (detecting in the visible and near infra-red regions of the spectrum) or use radar. Optical observation of spilt oil by satellite requires clear skies, thereby severely limiting the usefulness of such systems. Synthetic Aperture Radar (SAR) is not restricted by the presence of cloud.

Observation, monitoring and sampling was under taken in all of the 'relevant' incidents to good effect. The principle method was aerial surveillance (fixed wing and helicopter) with local observation at sea from vessels. Floating marker buoys, gliders below the surface and divers were used successfully. There were occasions when bad weather intervened (fog) (***Katja***).

During the ***Athos 1***, Delaware River, it was a major challenge to locate and track submerged oil: a plan was put together that included the placement of fixed monitoring stations that could be used as an early warning system to detect surges of submerged oil concentrations, to record trends in submerged oil concentrations and migration over time.

Satellites images were available but not always timely (***Sea Empress***) but proved useful in the confirmation of other data and the broader picture. A weak point of satellite oil detection was highlighted during the ***Erika*** incident when calm and / or rough weather limited the sensors ability to find the HFO.

Sampling was used during all incidents to 'confirm' oil weathering etc. Sampling by a helicopter was sometimes necessary to differentiate oil slicks from the natural phenomenon of algal bloom (***Montara***).

The air, water, sediment and dispersant monitoring and sampling information were made available to the public (***Deepwater Horizon***).

### 3.2 At Sea Response

An at Sea response is not always necessary. If modelling indicates that the oil will remain offshore where it will dissipate and eventually degrade naturally without affecting coastal resources or wildlife, monitoring the movement and fate of the floating slicks to confirm the predictions may be sufficient.

On this basis in cases, like the ***Braer,*** a combination of light crude oil and severe weather conditions can dramatically reduce the need for a clean-up response, even when very large quantities of oil are spilled close to the coastline.

However, there are several option available to respond to oil at sea if required and can be considered in three broad strategies; containment and recovery, dispersant application and in-situ burning . The selection of the most appropriate strategy will depend on many factors, including; the resources available, the national and local regulations on oil spill response, the spill scenario and the physical and ecological characteristics of the area impacted by the spill.

### 3.3 Containment and Recovery

Containing floating oil within booms for recovery by specialised skimmers is often seen as the ideal solution to a spill at sea as this aims to physically remove oil from the marine environment. As a result, it is the primary at sea response strategy adopted by many governments around the world.

Unfortunately, this approach suffers from a number of fundamental problems, not least of which is the fact that it is in direct opposition to the natural tendency of the oil to spread, fragment and disperse under the influence of wind, waves and currents. Thus, even if containment and collection systems are operating within a few hours of an initial release they will tend to encounter floating oil at an extremely low rate. Wind, waves and currents, even quite moderate ones, also limit the effectiveness of collection systems on the open sea by making correct deployment difficult and causing oil to splash over the top of booms or be swept underneath: because of this it is rare, even in ideal conditions, for more than a relatively small proportion (10-15%) of the spilled oil to be recovered from open water situations.

While at-sea recovery rates may be low when viewed as a percentage of the total volume spilled, the benefit of such operations can be maximised by targeting the heaviest oil concentrations and areas where collection will reduce the likelihood of oil impacting sensitive resources. Greater overall success can be achieved by containment and recovery operations in sheltered coastal areas and where floating slicks are concentrated within port areas or by natural features.

Containment and recovery was used to good effect in most of the incidents within the limitations of the response outlined. In the ***Sea Empress*** the main vessels did not arrive for several days after the accident, which reduced the oil recovery opportunity: however, their contribution was considered be useful.

After a difficult start with very bad weather, highly viscous oil and restricted equipment capabilities the ***Erika*** operation was effective; although it is estimated that less than 3% of the total oil spilt was collected.

The ***Baltic Carrier*** was much more successful with over 50% oil recovery; it was a small spill by comparison.

Severe weather and the heavy fuel oil hampered the ***Prestige*** response; vessels were also unable to discharge collected oil from their unheated tanks.

During the ***Godafoss*** different recovery methods were employed which varied in their effectiveness in the ice conditions. Booms needed to be sufficiently durable to withstand the extra force created by the contained ice which could cause them to tear or become temporarily submerged. Most skimmers operated at a significantly reduced efficiency, due to both the high viscosity of the oil and the presence of drifting sea ice within the slick. Some of the more effective techniques included a combination of brush belt skimmers assisted by steam heating jets, which enhanced the separation of oil from ice. Oil recovery was achieved using vessels equipped with sweeping arms to contain the oil, while mechanical grabs were used to transfer the viscous, weathered oil and ice into containers placed on the vessels' decks. The incident highlighted a number of areas that would benefit from improved technical solutions, such as minimising the quantity of ice recovered with the oil and increasing the effectiveness of pumping highly viscous oil at low temperatures.

A fleet of six skimming units was deployed to recover free-floating oil and help prevent shoreline impacts; a containment boom was deployed around the ***Athos 1***. To recover submerged oil five vessels with subsurface oil recovery systems designed to collect oil on the bottom and throughout the water column were deployed. A hydraulically-driven submersible dredge pump attached to a diver-directed suction hose successfully recovered submerged oil.

The weather conditions, winds over 50 kts and waves of 7.6 m, made it impossible for at sea response at the ***Selendang Ayu.***

More than 4,000 ships and 540 barges had been mobilised, including a barge used to deploy over 750 skimmers of all types for the ***Deepwater Horizon*** oil containment and recovery. It was estimated the oil recovered from the wellhead was 132,600 m3 (17% of the total) and oil skimmed from the surface 23,000 m3 (3%).

The ***Rena*** operations began at sea on four days after the grounding but proved to be of limited efficiency. The pollutant rapidly became very viscous, due to the temperature conditions on site. Vessels in the harbour area worked to clean up the oil; effectively.

### 3.4 Dispersant

The main alternative to containment and recovery is the use of chemical dispersants. Dispersants work by enhancing the natural dispersion of the oil into the water column. The oil is broken down into tiny droplets which are rapidly diluted, carried away by currents and eventually broken down by microorganisms.

As with containment and collection, the rapid spreading and fragmentation of oil spilt on the open sea tends to work counter to the effective application of dispersants. However, the likelihood of success can be increased by using aircraft which are able to deliver the chemical more rapidly than ships and with greater precision to the thickest concentrations of oil or those slicks posing the most significant threat to sensitive resources. For maximum effectiveness, dispersants need to be applied to oil near to the source and before it has become viscous through evaporation or formed an emulsion. A minimum wave height of around 0.2 m or conditions generating an active chop should be present. Any sea condition less than this rely on the mixing energy provided by a vessel. The maximum wave height to apply dispersant should be about 4 m.

Dispersants have little effect on very viscous oils, as they tend to run off the oil into the water before the solvent can penetrate. They are unsuitable for dealing with viscous emulsions (mousse) or oils which have a pour point near to or above that of the ambient temperature. Even those oils which can be dispersed initially become resistant after a period of time (usually a few hours to days) as weathering processes make the oil more viscous.

Dispersants can be applied by a variety of methods. In general, spraying dispersant from vessels and small aircraft or helicopters is more suitable for treating smaller spills and near shore areas. Large multi-engine aircraft are best equipped for handling large offshore spills. The key to successful chemical dispersion is the ability to target the thickest part of the oil slick in a timely manner, before weathering means dispersants are no longer effective.

It is essential that the effectiveness of chemical dispersion is monitored continually and dispersant use terminated as soon as it is no longer effective. Visual observation of effectiveness from a vessel or aerial platform is important but may be difficult in poor weather conditions, in waters with high sediment content, when dispersing pale-coloured oils, or in poor light. Effectiveness can be monitored using Ultra-Violet Fluorimetry (UVF) to provide 'real-time' data on the concentration of dispersed oil in the water column.

The use of dispersants is strictly controlled in most countries because of concerns over increasing the impact on fisheries and on sensitive fauna and flora in the water column or on the sea bed in shallow waters. However, the controlled use of dispersants can result in a net environmental benefit.

Aircraft were able to spray dispersant on the bulk of the slick as it was released from the ***Sea Empress*** and moved into open water: 440 $m^3$ of dispersant was delivered sprayed; dispersing 37,000 $m^3$ of oil; 10,000 $m^3$ naturally and 27,000 $m^3$ chemically. The areas to be treated were defined and supervised by remote sensing aircraft. Dispersants use was deemed to have been effective as samples taken showed that the oil was dispersing in the water column (10 ppm immediately after the dispersant was sprayed and 1 ppm one hour later).

The dispersant operation was of limited success during the ***Katja*** as the oil was viscous and sea was very calm which meant that the dispersant and oil did not mix. The spraying was undertaken without aerial guidance, due to poor visibility.

The HFO released during the ***Erika*** and ***Prestige*** was not dispersible.

Aerial and vessel spraying noticeably reduced the quantity of hydrocarbons visible on the surface of water during the ***Tasman Spirit***. Given the low persistence of Iranian Light crude oil and the high mixing energy in the many damaged cargo tanks generated by the incessant heavy swell, it is likely that most of the spilled oil dispersed naturally.

At sea response for the ***Solar 1*** oil focused on the application of dispersants on the freshly released oil using aircraft and spray arms mounted on tugs and patrol vessels. However, adverse weather conditions delayed response and reduced its effectiveness.

Aircraft dispersant delivery commenced on within 2 days of the ***Montara*** wellhead blowout. Vessel application started a few days later. The large wax percentage of the crude oil, which tends to solidify the slicks depending on temperature variations, had an impact on the window of opportunity for applying dispersant (more efficient in the afternoon). Observations made by experienced personnel indicated that the use of dispersant was highly effective.

Conditions for dispersant use were ideal during the ***Deepwater Horizon***: a continuous flow of crude oil in very deep waters, promoting wide dissemination of the dispersed oil. The treatment was applied mainly by aircraft, near where the oil rose to the surface; by early July, the volume of dispersant spread at the surface exceeded 4,000 $m^3$. To make the most of the deep water column (1,500 m) and disperse oil where it rises to the surface, the responders innovated by injecting over 3,000 $m^3$ of dispersant into the wellhead. Meanwhile, a major system designed to measure the oil concentration in the water mass was set up to assess the effects of this technique in the environment.

During the ***Deepwater Horizon*** dispersant use was considered the most effective and fast tool for minimizing shoreline impact: 62,400 $m^3$ - 8% chemically dispersed, 124,800 $m^3$- 16% dispersed naturally.

In New Zealand, dispersant was used with limited effect due to the weather and type of oil on the ***Rena*** discharge; delivery was stopped when results become inconclusive. However, at the ***Bonga Field*** after 2 days the spill had reduced in size by about 50 % as a result of natural dissipation and evaporation (in the region's warm water and air) as well as aircraft and vessel dispersant application.

### 3.5 In-Stu Burning

In-situ burning is the term given to the process of burning floating oil at sea, at or close to the site of a spill. In order to undertake burning, the oil must be concentrated and an ignition source applied. Burning oil at seas has, in ideal conditions, the potential to remove relatively large amounts of oil from the sea surface.

For a successful in-situ burn the layer of oil on the sea surface needs to be at least 2-3mm thick to counter the cooling effect of the wind and sea and maintain a fuel source to the fire. Spreading of the slick means that the oil may need to be contained against a barrier. This can occur naturally against ice sheets or the shoreline, or by corralling it using fire resistant booms or 'herder chemicals.

Ignition can be achieved using a variety of devices ranging from a diesel-soaked rag to more sophisticated equipment, such as the helitorch; essentially a flame-thrower which is suspended beneath a helicopter; it is generally accepted as being one of the safest methods of ignition in trained hands. However, the device and experience to use it are not readily available in many parts of the world.

The state of the sea can limit the success of any burn and choppy seas may extinguish the fire altogether. Once alight, the slick itself needs to reach sufficiently high temperatures to keep the fire burning. However, as the slick becomes thinner due to the removal of the lighter fractions, the cooling effect of the wind and sea will eventually extinguish the fire.

The viscous residue that can be left following in-situ burning resembles the consistency of toffee, and can be difficult to recover. Residues also have the potential to sink and therefore may smother or be toxic to bottom dwelling (benthic) marine species. There is also the potential that residues might contaminate fishing gear.

Of the incidents reviewed; the incident where in-situ burning was considered most successful was the ***Deepwater Horizon***. Following technique development, 411 controlled burning operations, in favourable weather conditions, enabled 42,000 $m^3$ of oil to be dispersed into the atmosphere (5% of the estimated total). Observations showed that the combustion residues sank rapidly.

### 3.6 Shoreline Protection and Clean-Up

The majority of ship-source oil spills occur close to the coast and, as a result, many spills result in contamination of shorelines. Oil stranding on the shore can cause significant environmental and economic impacts and may largely determine the political and public perception of the scale of the incident.

When oil does reach the shoreline, considerable effort may be required to clean the affected areas. The techniques are relatively straightforward and do not normally require specialised equipment. However, inappropriate techniques and poor organisation can aggravate the impacts caused by the oil itself.

### 3.7 Protecting Sensitive Resources

Given the difficulties of cleaning up oil at sea, coastal resources can often be threatened; protective measures can include closing water intakes to industrial plants or coastal lagoons. It may be possible to protect other sensitive areas by the careful deployment of booms. In such cases highest priority is usually given to those environmental and economic resources which are particularly sensitive to oil pollution and which can be boomed effectively.

Whilst some sites will be relatively easy to protect, others such as marshes, mangroves and amenity beaches are often too extensive for booming to be practical.

In almost all the selected events measures were taken to protect sensitive resources; standard booms were used and were effective other than in harsh weather. Additional improvised barriers were constructed from for example with banana leaves (***Solar 1***)

For shoreline protection during the ***Deepwater Horizon*** containment and sorbent booms were deployed; a portion of were regularly destroyed by high winds. To provide better resistance, to the winds and currents rife in certain narrows between the islands of Louisiana, and to prevent the pollutant from penetrating highly sensitive marshlands, an original system was set up. Known as the rigid pipe boom, it consisted of assembling several kilometres of metal pipes equipped with skirts and positioning them between a double row of metal stakes driven into the mud, using a crane.

In order to prevent shoreline erosion, geotextile socks filled with a mixture of sand and cement were deployed, as well as 'tiger booms', long double-chambered booms, similar in appearance to shore-sealing booms, but filled with sand. These two systems positioned parallel along the beaches were doubled up with sand bunds.

### 3.8 Shoreline Clean-Up

It is impossible to protect an entire coastline and every sensitive resource with equal success and so in a major oil spill some contamination of coastal areas is virtually inevitable, unless winds and currents carry the oil offshore. The removal of floating oil from harbours and elsewhere where it becomes concentrated is relatively straightforward, using a combination of specialised booms and skimmers and locally available resources such as vacuum trucks and similar suction devices, so long as there is good access.

Once oil has impacted shorelines, a combination of clean-up techniques is normally used, including manual and mechanical removal, flushing or washing with water at high or low temperatures and pressures, and even wiping with rags and sorbent materials. Such operations generally rely on locally-available non-specialised equipment and manpower. Shoreline clean-up is often highly labour intensive and not a 'high-tech' business.

Some types of coastline, such as hard packed sandy beaches, are relatively easy to clean whereas others such as cobble beaches can pose considerable problems. It is important to choose techniques which are appropriate for a particular shoreline type and the level of oil contamination, with effort first directed to areas which have the heaviest concentrations of mobile oil, which could otherwise lead to further pollution of surrounding areas. It is important to recognise from the outset that inappropriate clean-up measures can cause longer-term damage than the oil pollution itself. The environmental sensitivity of the site and the use to which it is put will need to be balanced in order to determine the most appropriate approach, as well as the degree of cleaning and its termination.

In all cases when oil came ashore the primary method of clean up was manual recovery. During ***Hebei Spirit*** the primary clean-up technique was manual using buckets, shovels and sorbent pads. Vacuum trucks, skimmers and mechanical means were used at selected sites. For secondary clean-up operations manual wiping of rocks and pebbles using sorbent materials and other textiles, and batch processing of oily substrate by boiling in vats was used. More effective techniques; surf washing, flushing and pressure washing, dependent upon the substrate type and site function were adopted after surveys and trials.

The main technique for shoreline teams at the ***Deepwater Horizon*** was sifting sand, removing tar balls, and digging out tar mats manually or by using mechanical devices. Sand screeners with sand washing machines were used; this consisted of mixing sand with hot water (without additives) to cause the oil to rise to the surface, before centrifuging the mixture to recover the 'spun' sand.

At the ***TK Bremen*** tests were carried out on products and equipment. Few appeared fully efficient, because of the fuel's high viscosity, and manual clean-up proved to be the solution in many areas. Rocks were washed with high-pressure cleaners and the effluents recovered on sorbent booms. Screening belts proved extremely useful to recover oil cakes deposited on sandy beaches. Surf-washing tests were conducted; this involves moving sand down to the lower foreshore to be cleaned by natural wave action. The pollutant placed in suspension through this technique was recovered using mop nets and sorbent booms.

Various different types of equipment and techniques, new or improved, were tested successfully in France (***Erika***):

- The recovery of oil splashes on non-woven polypropylene wintering film, during the washing of heterogeneous rocks and breakers with high-pressure hoses.
- The filtration, with glass-eel fishing nets and building site nets, of effluents resulting from both manual rock washing and natural pebble washing on the mid-tide zone.
- The alternate use, on beaches, of a tilling (or deep harrowing) device and a screening belt to recover tar balls buried under 25 to 30 cm of sand.
- The tilling of intertidal areas of sandy beaches, to allow recovery by the sea of tar balls buried in the sand and their further deposit on the beaches.

### 3.9 Bioremediation

Bioremediation is the term used to describe the range of processes, and related products, which can be used to accelerate the natural degradation of oil into simple compounds. Natural biodegradation can usefully be accelerated in areas where nutrients or microbes are limited. Use of this process on the open shoreline is rarely advocated.

During the ***Sea Empress*** response bioremediation was investigated as a method of treating a mixture of Forties Crude and HFO. A randomised block design in triplicate was used to test the efficacy of two bioremediation treatments: a weekly application of mineral nutrients dissolved in seawater and a single application of a slow-release fertilizer. Each treatment supplied an equivalent amount of nitrogen and phosphorus. Concentrations of residual hydrocarbons normalised to the biomarker 17alpha (H), 21beta (H)-hopane showed that after two months the oil was significantly ($p<0.001$) more biodegraded in the treated plots than in the controls. On average, the oil in the nutrient amended plots was 37% more degraded than that found in the controls. There was no evidence that the bioremediation treatments increased the toxicity of the oiled sediment. **The results confirm that bioremediation can be used to treat a mixture of crude and heavy fuel oil on a pebble beach. In particular, the data suggest that the application of a slow-release fertilizer alone may be a cost-effective method of treating low-energy, contaminated shorelines after a spill incident.**

In Denmark (***Baltic Carrier***) tests were conducted with biological decomposition of the oil in a polluted area. An important criterion was that the authorities did not want to add bacteria, oil dispersants or mixtures of surfactants and solvents to the environment. Field studies involving the addition of two bioremediation products and one surface washing agent were conducted by suppliers of the products (Petrotech and Biogard) or biologists from the county (Inipol).

- Petrotech 25: A surface-washing agent. Petrotech was added before high-pressure flushing of the stones; this gave no better results than cleaning with pure hot water.
- Biogard 293: A bio-remediation product containing a mixture of nutrients, clay and cement. The product forms a hard crust, under which the oil is to decompose. No such decomposition could be ascertained during the testing. After a year, in certain locations, there was a hard crust, under which no decomposed oil has been found.
- Inipol EAP 22: An oleophilic fertiliser containing N and P and a surfactant. The product had a visible effect on surfaces treated. Whether the oil was decomposed or simply dispersed was not investigated. After a year it could be ascertained that substantial part of the oil had been removed on the test stretch of the coast. This was also the case outside the test areas, and it

can therefore be summarised that the remediation tests on the stony stretch of coast did not produce significant increase in the rate of removal of the oil.

On a beach of the Cantabrian coast (North Spain) which was affected by the ***Prestige*** oil spill a bioremediation field assay using the oleophilic fertilizer S200 was carried out successfully 10 months after the accident. The field survey showed that S200 significantly enhanced the biodegradation rate, particularly of high molecular weight n-alkanes, alkylcyclohexanes, and benzenes, and alkylated PAHs, paralleling the results previously found in vitro. The most significant molecular bioremediation indicators were the depletion of diasteranes and C-27 sterane components. Enhanced isomeric selectivity was also observed within the C1-phenanthrenes and dibenzothiophenes (Jimenez et al., 2006).

## 4 Consideration

Reference is made to the ITOPF paper by Dr Ian White, entitled New Directions in Marine Pollution Control. The paper was presented at 'Shipping in the New Millennium', 17-19 March 1999, Brisbane, Australia. It is considered that this document fitted ideally into the Kill•Spill review period of European oil spills; 1993 – 2012 and worldwide oil spills: 2003 – 2012. Amongst the topics the paper discussed were the response options (mitigation measure); their strengths, weaknesses and limitations. The comment was based on the experience of ITOPF over a number of years and numerous operations they attended. In view of the subject matter of this Kill-Spill report entitled 'D1.6 Report on Previous Oil Spill Incidents and Efficiency of Mitigation Measures' it was deemed a very good starting point. The content of Dr White's paper was reviewed and used; however a new set of incidents were studied to either confirm or dispute his finding.

It is considered that this review has confirmed Dr White's findings regarding the known strength, weakness and limitations of the various oil spill mitigation measures. When the many various elements come together; type of oil, weather, equipment, human capability (skill and ingenuity); a response can be effective and efficient.

**Observation, surveillance and monitoring** are essential for effectiveness and efficiency; without good 'situation awareness' it is probable that the correct option(s) will not be chosen and considerable effort wasted. Whilst aerial surveillance is the principle method of monitoring other processes were used to track the oil; ***Athos1,*** monitoring stations in the river.

The incident reports show that at sea **containment and recovery** can make a significant contribution, provided the weather and sea conditions are calm and stable, in limiting the amount shoreline contamination despite a low percentage of oil collection; ***Sea Empress, Erika, Prestige and Deepwater Horizon*** . The review show the success of the operation in icy conditions; ***Godafoss.*** Conversely the limited success of this response caused by the characteristics and fate fuel oils is highlighted (***Erika and Prestige***).

Where the use of **dispersant** is deems effective it is normally highly efficient (***Sea Empress, Tasman Spirit, Montara, Deepwater Horizon and Bonga Field***). The HFO released during the ***Erika*** and Prestige was not amenable to dispersant – another feature of this type of oil.

**In-situ burning**, in favourable weather, effectively dispersed into the atmosphere 42,000 $m^3$ of oil during the ***Deepwater Horizon***.

The measures to **protect sensitive resources** were effective in most cases; however were the weather was rough replacement, innovation and adaption necessary.

**Shoreline clean-up** effectiveness is probably best assessed by how soon the area can be returned to the pre-spill state: there are numerous variables not least the enthusiasm of local people, their organisation and management as this response is heavily reliant on manual recovery.

There is a myriad of equipment available for shoreline cleaning; some effective (efficient) some less. Response authorities and / or agency are normally responsible for determining their capabilities, including efficiency against a 'standard'. The testing is done both prior to an accident or during as in the case of ***Hebei Spirit, TK Bremen, Deepwater Horizon and Erika.***

Trials carried out in Wales (***Sea Empress***), Denmark (***Baltic Carrier***) and Spain (***Prestige***) showed that bioremediation can be effective; there was the occasional failure and it can take a long time to get results: however, it is not widely used.

The oil spill mitigation measures in the paper are well established; their strengths and limitations are understood. The review has emphasised the difficulties of response to heavy fuel oil for which new technological advances are needed.

## 5 References

The comment in paragraphs 3 and 4 of this paper is referenced in the individual studies given at Annexes C and D. In addition the paper of White, IC (1999) New Directions in Marine Pollution Control. Paper presented at "Shipping in the New Millenium", 17-19 March 1999, Brisbane, Australia was quoted

# 6 ANNEX A: Significant European and worldwide oil spills

**Table 1 Significant European oil spills 1993-2012**

| Date | Name | Quantity – t | Oil Type | Location |
|---|---|---|---|---|
| 05/01/1993 | BRAER | 84,000 | CRUDE | UNITED KINGDOM |
| 03/06/1993 | BRITSH TRENT | 4,000 | FUEL OIL (CARGO) | NORTH SEA |
| 17/08/1993 | LYRIA | 2,200 | CRUDE | FRANCE |
| 09/10/1993 | ILIAD | 300 | CRUDE | GREECE |
| 17/11/1993 | BORODINSKOYE POLYE | 370 | FUEL OIL | UNITED KINGDOM |
| 13/03/1994 | NASSIA | 95,000 | CRUDE | TURKEY BOSPORUS |
| 01/10/1994 | LA GAUARDIA | 400 | CRUDE | GREECE |
| 02/10/1994 | CERCAL | 1,700 | CRUDE | PORTUGAL |
| 31/10/1994 | PIONERSK | 600 | FUEL OIL | UNITED KINGDOM |
| 21/12/1994 | NEW WORLD | 3,500 | CRUDE | SPAIN |
| 15/02/1996 | SEA EMPRESS | 72,400 | CRUDE | UNITED KINGDOM |
| 18/01/1997 | BONA FULMAR | 7,000 | FUEL OIL (CARGO) | ENG. CHANNEL |
| 08/02/1997 | LEROS STRENGTH | 150 | FUEL OIL | NORWAY |
| 07/08/1997 | KATJA | 187 | HFO | FRANCE |
| 21/10/1997 | BLACK SEA | 180 | FUEL OIL | GREECE |
| 30/10/1997 | SERIFOS | 900 | FUEL OIL (CARGO) | GREECE |
| 19/11/1997 | GREEN LILY | 340 | FUEL OIL | UNITED KINGDOM |
| 07/12/1997 | CELTIC WARRIOR | 115 | FUEL OIL | GREECE |
| 19/09/1998 | NUNKI | 100 | FUEL OIL | DENMARK |
| 06/11/1998 | BOBO | 300 | UNKNOWN | SPAIN |
| 22/11/1998 | LONDON MEARSK | 200 | FUEL OIL | ITALY |
| 12/12/1999 | ERIKA | 19,800 | HFO | FRANCE |
| 29/12/1999 | VOLGANEFT 248 | 1,500 | HFO | TURKEY BOSPORUS |
| 29/08/2000 | NORDLAND | 100 | FUEL OIL | GREECE |
| 06/09/2000 | EUROBULKER X | 700 | CRUDE | GREECE |
| 08/09/2000 | EUROBULKER IV | 170 | HFO | ITALY |
| 15/12/2000 | GREEN ALESUND | 140 | IFO 380 | NORWAY |
| 25/12/2000 | CORAL BULKER | 630 | HFO | PORTUGAL |
| 29/03/2001 | BALTIC CARRIER | 2,700 | HFO | DENMARK |
| 18/06/2001 | VASILIKI | 100 | FUEL OIL | GREECE |
| 26/09/2001 | AVERITY | 150 | DIESEL | UNITED KINGDOM |
| 15/10/2001 | GECO SAPPHIRE | 115 | UNKNOWN | NORWAY |
| 13/11/2002 | PRESTIGE | 62,700 | HFO | SPAIN |
| 14/12/2002 | TRICOLOUR | UNKOWN | HFO | ENG. CHANNEL |

| Date | Name | Quantity – t | Oil Type | Location |
|---|---|---|---|---|
| 21/12/2002 | ALBERT MEARSK | 1000 | FUEL OIL | SPAIN |
| 29/01/2003 | COUGAR | 250 | FUEL OIL | ALGERIA |
| 21/01/2003 | SPABUNKER IV | 900 | FUEL OIL | SPAIN |
| 19/05/2003 | DRAUGEN FIELD | 750 | CRUDE | NORWAY |
| 31/05/2003 | FU SHAN HAI | 1,800 | HFO | BALTIC |
| 07/11/2003 | SVYATOY PANTELEY. | 500 | UNK. OIL | TURKEY BOSPORUS |
| 19/01/2004 | ROCKNES | 280 | IFO 380 | NORWAY |
| 23/11/2005 | NORNE FIELD | 340 | CRUDE | NORWAY |
| 04/01/2006 | HAPPY BRIDE | 60 | HFO | FRANCE |
| 24/10/2006 | ROKIA DELMRAS | UNKNOWN | UNKNOWN | FRANCE |
| 24/11/2006 | DRAUGEN FIELD | 100 | CRUDE | NORWAY |
| 12/01/2007 | AMBES (Storage Tank) | 13,500 | CRUDE | FRANCE |
| 12/01/2007 | SERVER | 388 | IFO 180 | NORWAY |
| 18/01/2007 | NAPOLI | 50 | IFO 380 | UNITED KINGDOM |
| 10/11/2007 | ‘VOLGANEFT 139’ | 1,300 | HFO | BLACK SEA |
| 12/12/2007 | STATFJORD A | 4,000 | CRUDE | NORWAY |
| 15/01/2008 | ICE PRINCE | UNKNOWN | IFO | ENG. CHANNEL |
| 16/03/2008 | DONGAS REFINERY | 400 | HFO | FRANCE |
| 14/02/2009 | ADMIRAL KUZNETSOV | 300 TO 500 | FUEL OIL | CELTIC SEA |
| 31/07/2009 | FULL CITY | 293 | IFO 180 | NORWAY |
| 19/02/2010 | STRAUSS | 180 | HFO 500 | ITALY |
| 20/06/2010 | MAERSK RESOLUTE | 130 | CRUDE | NORTH SEA |
| 12/10/2010 | MINDORO | 5,700 | FUEL (CARGO) | NETHERLANDS |
| 11/12/2010 | NORTH SPIRIT | 400 | FUEL OIL | BAY OF BISCAY |
| 17/02/2011 | GODAFOSS | 112 | HFO | NORWAY |
| 29/03/2011 | ALPSRAY | 900 | FUEL (CARGO) | GERMANY |
| 10/09/2011 | GOLDEN TRADER | 205 | IFO 180 | DENMARK |
| 10/08/2011 | GANNET ALPHA | 216 | CRUDE | NORTH SEA |
| 16/12/2011 | BREMEN | 220 | IFO 120 | FRANCE |
| 05/03/2012 | ALFA 1 | < 100 | IFO 380 + IFO 180 | GREECE |

**Table 2 Significant worldwide oil spills 2003-2012**

| Date | Name | Quantity - t | Oil Type | Location |
|---|---|---|---|---|
| 27/07/2003 | TASMAN SPIRIT | 28,000 | CRUDE | PAKISTAN |
| 12/09/2003 | DUCK YANG | 300 | UNKNOWN | REPUBLIC OF KOREA |
| 12/09/2003 | KYUNG WON | 100 | UNKNOWN | REPUBLIC OF KOREA |
| 32/12/2003 | JEONG YANG | 700 | UNKNOWN | REPUBLIC OF KOREA |
| 28/02/2004 | BOW MARINER | 626 | HFO | USA |
| 22/03/2004 | EVERTON | 494 | CRUDE | OMAN |
| 10/09/2004 | LUCKY LADY | 1,200 | CRUDE | INDONESIA |
| 15/11/2004 | VICUNA | 400 | BFO | BRAZIL |
| 18/11/2004 | GOOD HOPE | 1,600 | CRUDE | EGYPT |
| 26/11/2004 | ATHOS 1 | 1,000 | CRUDE | USA |
| 07/12/2004 | SELENDANG AYU | 1,700 | BFO | ALASKA |
| 07/12/2004 | ILONA | 450 | FUEL OIL | CHINA |
| 14/12/2004 | AL SAMIDOUN | 8,600 | CRUDE | SUEZ CANAL – EGYPT |
| 04/02/2005 | GENMAR KESTREL | 1,557 | CRUDE | EGYPT |
| 15/02/2005 | AL AMINE | 100 – 150 | HFO | TUNISIA |
| 07/04/2005 | RATNA SHILINI | 200 | CRUDE | MONBASSA – KENYA |
| 06/11/2005 | MEARSK HOLYHEAD | 550 | FUELOIL | VENEZUELA |
| 03/02/2006 | TUGEN | 3,900 | FUEL OIL | MADAGASCAR |
| 27/02/2006 | GRIGORUSSA I | 1,300 | HFO | SUEZ CANAL – EGYPT |
| 11/08/2006 | SOLAR 1 | 2100 | HFO | PHILIPPINES |
| 14/08/2006 | BRIGHT ARTEMIS | 4,500 | CRUDE | INDIAN OCEAN |
| 20/10/2006 | FRONT VANGUARD | 6,000 | CRUDE | SUEZ CANAL – EGYPT |
| 07/11/2007 | COSCO BUSAN | 220 | HFO (IFO 380) | USA |
| 07/12/2007 | HEBEI SPIRIT | 10,000 | CRUDE | REPUBLIC OF KOREA |
| 16/02/2008 | DALIA | UNKNOWN | CRUDE | ANGOLA |
| 21/06/2008 | PRINCESS OF THE STARS | UNKNOWN | HFO | PHILIPPINES |
| 10/10/2008 | FEDRA | 200 | FUEL OIL | GIBRALTA |
| 11/03/2009 | PACIFIC ADVENTURER | 270 | FUEL OIL | AUSTRALIA |
| 23/06/2009 | IOANNIS NK | 310 | FUEL OIL | SOUTH AFRICA |

| Date | Name | Quantity - t | Oil Type | Location |
|---|---|---|---|---|
| 21/08/2009 | MONTARA | 4,800 | CRUDE | AUSTRALIA |
| 21/08/2009 | WEST ATLAS | 34,000 | CRUDE | AUSTRALIA |
| 26/08/2009 | GULSER ANA | UNKNOWN | HFO | MADAGASCAR |
| 23/01/2010 | EAGLE OTOME | 1,800 | CRUDE | TEXAS |
| 03/04/2010 | SHEN NENG 1 | 3 | FUEL OIL | AUSTRALIA |
| 20/04/2010 | DEEPWATER HORIZON | 780,000 +/- | CRUDE | GULF OF MEXICO |
| 02/05/2010 | BRIGHT CENTURY | 500 | FUEL OIL | CHINA |
| 25/05/2010 | BUNGA KELANA 3 | 6,000 | CRUDE | SINGAPORE |
| 07/08/2010 | KHALIJIA 3 | 800 | FUEL OIL | INDIA |
| 16/03/2011 | OLIVA | 1,500 | HFO | TRISTAN DA CUNHA |
| 05/10/2011 | RENA | 360 | FUEL OIL | NEW ZEALAND |
| 21/12/2011 | BONGA FIELD | 5,500 | CRUDE | NIGERIA |
| 15/3/2012 | BARELI | 100 | HFO | CHINA |

# 7 ANNEX B: Relevant significant European and worldwide oil spills

**Table 3 'Relevant' significant European oil spills 1993-2012**

| Date | Incident | Spillage | Location | Area |
|---|---|---|---|---|
| 15/02/1996 | SEA EMPRESS | 72,400 t CRUDE | UNITED KINGDOM | INSHORE |
| 07/08/1997 | KATJA | 187 t HFO | FRANCE | PORT/HARBOUR |
| 12/12/1999 | ERIKA | 19,800 t HFO | FRANCE | OFFSHORE |
| 29/03/2001 | BALTIC CARRIER | 2,700 t HFO | DENMARK | OFFSHORE |
| 13/11/2002 | PRESTIGE | 62,700 t HFO | SPAIN | OFFSHORE |
| 11/11/2007 | VOLGANEFT 139 | 1,300 t HFO | TURKEY | INSHORE |
| 17/02/2011 | GODAFOSS | 112 t HFO | NORWAY | INSHORE |
| 10/09/2011 | GOLDEN TRADER | 205 t IFO I80 | DENMARK | OFFSHORE |
| 16/12/2011 | BREMEN | 70 t IFO 180 | FRANCE | INSHORE |
| 05/03/2012 | ALFA 1 | UNK. ( < 100 t) | GREECE | OFFSHORE |

**Table 4 'Relevant' significant worldwide oil spills 2003-2012**

| Date | Incident | Spillage | Location | Area |
|---|---|---|---|---|
| 27/07/2003 | TASMAN SPIRIT | 28,000 t CRUDE | PAKISTAN | PORT/HARBOUR |
| 26/11/2004 | ATHOS 1 | 1,000 t CRUDE | USA | INLAND WATERS |
| 07/12/2004 | SELENDANG AYU | 1,700 t IFO 380 | USA - ALASKA | INSHORE |
| 11/08/2006 | SOLAR 1 | 2,100 t HFO | PHILIPPINES | INSHORE |
| 07/12/2007 | HEBEI SPIRIT | 10,000 t CRUDE | REPUBLIC OF KOREA | INSHORE |
| 21/08/2009 | MONTARA | 34,000 t CRUDE | AUSTRALIA | OFFSHORE |
| 23/01/2010 | EAGLE OTOME | 1,800 t CRUDE | USA | INLAND WATERS |
| 20/04/2010 | DEEPWATER HOR. | 780,000m$^3$ CRUDE | USA - GULF OF MEXICO | OFFSHORE |
| 05/10/2011 | RENA | >200 t HFO | NEW ZEALAND | INSHORE |
| 21/12/2011 | BONGA FIELD | 5,500 t CRUDE O | NIGERIA | OFFSHORE |

Notes:
**Crude Oil:** A naturally occurring, unrefined petroleum product composed of hydrocarbon deposits
**Heavy Fuel Oil (HFO):** Pure or nearly pure residual oil – Density > 0.95 $^{O}$API < 17.50$^{o}$
**Intermediate Fuel Oil (IFO):** A blend of gasoil and heavy fuel oil, with less gasoil than diesel oil
**IFO 180** - Intermediate fuel oil with a maximum viscosity of 180 Centistokes (<3.5% sulphur)
**IFO 380** - Intermediate fuel oil with a maximum viscosity of 380 Centistokes (<3.5% sulphur)

# 8 ANNEX C: Oil spill summaries (European oil spills 1993-2012)

## 8.1 SEA EMPRESS

1 **Date of Incident:** 15 February 1996

2 **Location**: Milford Haven, Pembrokeshire, Wales United Kingdom

3 **Description of Incident:** Sailing against the outgoing tide and in calm conditions the ship was pushed off course by the current and became grounded after hitting rocks in the middle of the channel. The collision punctured the starboard hull causing oil to pour out into the sea. During the initial rescue attempts, she detached several times from the tugs and grounded repeatedly – each time slicing open new sections of her hull and releasing more oil.

4 **Type of Incident** Grounding

5 **Quantity and Type(s) of Oil Spilt:** 72,000 t Forties Blend North Sea crude oil; API Density: 36.9 and Viscosity (cSt): 9.6 at 10°C, 7 at 20°C. Thirty to forty per cent of the oil evaporated after 24 hours. Emulsion: viscosity > 10 000 cSt in seawater after 5 days at 5°C

6 **Type(s) and Quantities of other substances spilt:** 370 t HFO

7 **Weather conditions over the period of the response:** Generally Good.

8 **At sea response**

8.1 **Monitoring**: Regular surveillance flights by two dedicated and full equipped aircraft throughout the day; from one hour before first light to darkness. The aircraft controlled the dispersant spraying operation and provided guidance to the containment / recovery vessels. Beach surveys were flown to assist the clean up. A helicopter was used for close investigation and sampling. Satellite surveillance; radar sat, was used to reaffirm the over flights. Environmental monitoring was carried out by an aircraft with a multispectral scanner. During the dispersant spraying operation a vessel with a laser fluorosensor was used to determine the efficiency of the response

8.2 **Containment and Recovery**: Coastal oil recovery was commenced as soon as the 15th and involved two specialised vessels, the Sea Mop and the Sea Sweep and both were fitted with an oleophilic rope skimmer.
On the 20th, the Forth Explorer with a Foxtail system and the Seftan Supporter with a Marflex Arms system and a Vikoma Sea Skimmer reached the area.
On the 21st, the French Navy assigned two vessels to the operation, the Ailette with a Transrec 250 skimmer system and the Elan a supply vessel that was used for boom deployment and containment.
On the 23rd, two other skimmer vessels arrived from the Netherlands; the Small Agt and the Rijn Delta.
Shoreline skimming was conducted by two barges fitted with a Roskim skimmer system and an Egmopol barge. Two small fishing boats were used to contain the oil in coastal waters and then trawl it out to sea for recovery. On the 4th March two more Egmopol barges arrived from France. A total of 8,500 m3 of emulsion were recovered at sea containing 1,500 $m^3$ of oil.

8.3 **Dispersant Spraying:** Initially aircraft were able to spray dispersant on the bulk of the slick as it moved into open water. After the vessel was moved inside the Haven, spraying was discontinued because there was no oil outside amenable to dispersion. By this time, some 445 t had been sprayed - dispersing 37,000 t of oil (10,000 t naturally and 27,000 t chemically); with evaporation removing perhaps 29,000 t (40%) of the oil.

Seven DC-3s and a C-130, fitted with dispersant spraying systems, sprayed dispersants from 16 February onwards with the core objective to spray the fresh oil as close to the wreck as possible. Dispersant spraying was discontinued on the 23 February for reasons of efficacy.
The areas to be treated were defined and supervised by remote sensing aircraft. Airborne spraying was conducted one nautical mile offshore outside the Bay during ebb tide.
Dispersants was deemed to have been effective as samples taken showed that the oil was dispersing in the water column (10 ppm immediately after the dispersant was sprayed and 1 ppm one hour later).
The dispersants used during the period were Dasic NS, Dasic LTSW and Finasol OSR52

9 **Protection and Shoreline Clean Up:** Protective booms were deployed in the rivers and the marsh areas that opened out onto the Bay and also at the entrance to ports and harbours (360 m of boom upstream of Pembroke harbour, 300 m of boom at Milford Haven harbour, 120 m of boom at Neyland harbour and 740 m of boom to protect the marshes and the mudflats in Milford Haven Bay).

Shoreline clean-up operations were focused on the immediate vicinity of Milford Haven and particularly in West Angle Bay, Angle Bay and Blucks Pool. Conventional coastal clean-up resources were used and collection was conducted with squeegees, shovels, bags, drums and vacuum tanks. In areas where mechanical collection was impracticable, recovery and collection were done by hand; recovered materials were stored on the spot in bags.

Most collection sites were able to use resources such as Desmi 250 recovery pumps, Vaculite recovery systems, Komara skimmers plus vacuum tanks, liquid manure trucks, HP sprayers for water flushing.

Approximately 14,000 $m^3$ of liquid emulsion and 3,000 $m^3$ of oiled waste (including seaweed) were recovered; they contained 3,000 to 4,000 t of oil.

**Bioremediation** by nutrient enrichment was investigated as a method of treating a mixture of Forties Crude Oil and Heavy Crude Oil stranded on Bullwell Bay, Milford Haven, UK, after the grounding of the Sea Empress in 1996 (Swannell et al., 1999). A randomised block design in triplicate was used to test the efficacy of two bioremediation treatments: a weekly application of mineral nutrients dissolved in seawater and a single application of a slow-release fertilizer. Experimental results showed that the oil was significantly more biodegraded (37%) after two months as a result of application of the fertilizer. There was no evidence that the bioremediation treatments increased the toxicity of the oiled sediment. The results confirm that bioremediation can be used to treat a mixture of crude and heavy fuel oil on a pebble beach. In particular, the data suggest that the application of a slow-release fertilizer alone may be a cost-effective method of treating low-energy, contaminated shorelines after a spill incident.

**10 Employed Response / Remediation Techniques and Equipment Used in Tabulated Form**

| **At sea response** | | |
|---|---|---|
| **Response** | **Equipment** | **Comments** |
| Monitoring | Dedicated Surveillance Aircraft | Highly Effective / Essential to all aspects of the Response |
| Containment and Recovery | Numerous Vessels with standard recovery booms etc. | Highly Effective in calm conditions / 4000 t recovered - |
| Dispersant Delivery | Aircraft + Dispersant Delivery Systems | Highly efficient. Able to deliver dispersant on fresh oil. |

| Protection and shoreline clean-up | | |
|---|---|---|
| **Response** | **Equipment** | **Comments** |
| Protective Measures | Booms | Effective to a degree |
| Manual Recovery | Hand Tools | Effective to a degree but very time consuming |
| Mechanical Recovery | Suction Tankers, Pressure Washers, Oil Absorbent Scrubbers. | All were effective to a degree |
| Dispersant | - | Effective |
| Trenching | - | Effective |
| Beach Washing | - | Effective |
| Sorbents | - | Effective |
| Bio-Remediation | Trial with inorganic or slow release fertilizers | Effective |

**11** **Environmental Impact**: The Sea Empress disaster occurred in Britain's only coastal national park and in one of only three UK Marine Nature Reserves. The tanker ran aground very close to the islands of Skomer and Skokholm – both national nature reserves, Sites of Special Scientific Interest (SSSI) and Special Protection Areas.

Birds at sea were hit hard during the early weeks of the spill, resulting in thousands of deaths.

The Pembrokeshire grey seal population didn't appear to be affected too much and impacts to sub tidal wildlife were limited.

Much damage was caused to shorelines affected by bulk oil. Shore seaweeds and invertebrates were killed in large quantities. Mass stranding of cockles and other shellfish occurred on sandy beaches. Rock pool fish were also affected. However, a range of tough shore species were seen to survive exposure to bulk oil and lingering residues.

The Pembrokeshire coast is home to Common Porpoises and Bottlenose Dolphins: The effects of the oil and chemical pollution on these species remains unknown. Significant numbers of both species were recorded in the waters off the Skomer Marine Nature Reserve during the spring and summer of 1996.

The main containment and dispersal of the oil slick at sea was completed within six weeks. However, the removal of oil on shore took over a year until the late spring of 1997. Small amounts of oil were still found beneath the sand on sheltered beaches and in rock pools in 1999 – three years after the spill.

The effects of the spill were not as bad as initially predicted. This was due in part to the time of year when the spill occurred. In February, many migratory animals had not yet arrived back in Pembrokeshire for breeding. Much of the Pembrokeshire coastline recovered relatively quickly.

By 2001, the affected marine wildlife population levels had virtually returned to normal.

**12** **Economic Impact:** A temporary ban was imposed on commercial and recreational fishing in the region and there was concern that tourism, important to the local economy, would be badly affected by the heavily oiled beaches. Several thousand oiled birds washed ashore, leading to a major cleaning and rehabilitation operation

**13** **Comments:** The subsequent clean-up operations were wide-ranging and effective. At sea these included dispersant spraying, mechanical recovery and the use of the protective booms. This, coupled with a high rate of evaporation and natural dispersion, greatly reduced the quantity of oil reaching inshore waters. Source: ITOPF

## 14 References

http://www.cedre.fr – Sea Empress
http://en.wikipedia.org – Sea Empress Oil Spill
http://www.itopf.com/ case-studies – Sea Empress
Swannell, R. P. J., Mitchell, D., Lethbridge, G., Jones, D., Heath, D., Hagley, M., Jones, M., Petch, S., Milne, R., Croxford, R., and Lee, K. (1999) A field demonstration of the efficacy of bioremediation to treat oiled shorelines following the Sea Empress Incident. Environmental Technology. 20: 863-873.

### 8.2 KATJA

1 **Date of Incident:** 7 August 1997

2 **Location**: Port of Le Havre, France

3 **Description of Incident**: The tanker, carrying 80,000 t of crude oil was about to moor when the port side of the stern hit a corner of the wharf causing structural damage. The spill occurred just before ebb tide. As the tugs finished positioning the Katja for berthing, almost half of the oil escaped from the terminal, drifted southwards through the harbour basins polluting port facilities. Approximately 30 to 60 t of oil escaped from the harbour area during the morning and drifted out to sea with the outgoing tide.
Persistent fog lasted 4 days; north easterly winds pushed the oil towards the Calvados beaches and the oil began to hit the shore on 8 August from Trouville to Villerville.

4 **Type of Incident** Berthing Error

5 **Quantity and Type(s) of Oil Spilt** 187 $m^3$ HFO bunker fuel oil (Bunker C)

6 **Type(s) and Quantities of other substances spilt**

7 **Weather conditions over the period of the response**: Persistent fog lasted 4 days; north easterly winds

8 **At sea response**

**8.1** Monitoring: To assess the impacts, surveys were carried out, but due to the heavy fog and the darkness the surveys could not be considered accurate. Persistent fog lasted 4 days making aerial reconnaissance impossible.

**8.2** **Containment and Recovery:** Two hours after the spill, floating booms were set up to contain the spill.

**8.3** **Dispersant Usage:** The tug the Acharné, fitted with dispersant spraying equipment, was sent to spray the slick that was drifting in the Seine estuary. The spraying operation was of limited success as the oil was viscous and sea was very calm which meant that the dispersant and oil did not mix. The spraying was undertaken without aerial guidance, due to poor visibility.

9 **Protection and Shoreline Clean Up:** The beaches in Le Havre and Saint Addresse were cleaned up on a large scale once the risk of pollution had been averted; 4 days after the spill.

10 **Employed Response / Remediation Techniques and Equipment Used in Tabulated Form**

| **At sea response** | | |
|---|---|---|
| **Response** | **Equipment** | **Comments** |
| Monitoring | Helicopters | Not used first 4 days because of heavy fog. |
| Containment and Recovery | | |
| **Dispersant Delivery** | Tug with specialist equipment | The spraying operation was of limited success as the oil was viscous and sea was very calm which meant that the dispersant and oil did not mix |
| **Protection and shoreline clean-up** | | |

| Response | Equipment | Comments |
|---|---|---|
| Protective Measures | Booms | In Le Havre harbour |
| Manual Recovery | Hand Tools | Effective |
| Mechanical Recovery | Equipment + Machinery | Approximately 900 $m^3$ of sand polluted by oil were collected by mechanical means |
| Dispersant | | |
| Trenching | | |
| Beach Washing | | |
| Sorbents | | |
| Bio-Remediation | | |

## 11 Environmental Impact

## 12 Economic Impact

## 13 Comment

## 14 References

http://www.cedre.fr
Fanch Cabioc'h and Gérard Cariou (*1999*) French Response to the *Katja* Incident. International Oil Spill Conference Proceedings: March 1999, Vol. 1999, No. 1, pp. 91-93. http://dx.doi.org/10.7901/2169-3358-1999-1-91

### 8.3 ERIKA

1 **Date of Incident:** Date of Incident: 12 December 1999

2 **Location**: Bay of Biscay; 48 km South of Penmarc'h (Southern Brittany)

3 **Description of Incident**: On 11 December 1999, the tanker, Erika, laden with 31,000 t of HFO was faced with structural problems. After sending an alert message, then proceeding to transfer cargo from tank to tank, the Captain informed the French authorities that the situation was under control and that he was heading to the port of Donges, at reduced speed.

By 6:05 am on the 12 December the ship was breaking into two and finally split at 8:15 am spilling; between 7,000 and 10,000 t.

The bow sank the following night, a small distance away from the place where the ship had broken up. The stern was taken in tow and it sank the following day at 2:50 pm. The two parts of the wreck ended up 10 km apart from each other, 120 m deep.

The weather and sea conditions at the time of the incident were a westerly wind, force 8 to 9, with 6 m swell and a very rough sea.

4 **Type of Incident:** Structural damage to the vessel

5 **Quantity and Type(s) of Oil Spilt:** 19,000 to 20,000 t HFO

6 **Type(s) and Quantities of other substances spilt**

7 **Weather conditions over the period of the response**

8 **At sea response**

8.1 **Monitoring:** Initial aerial surveys reported slicks drifting at sea, one of which was 15 km long and estimated at 3,000 t. The slicks were moving eastwards at a speed of about 1.2 kts. On the following days, the aerial observations highlighted a series of slicks made up of thick patches (5 to 8 cm) which tended to split up while continuing to drift parallel to the coast. On 16 December, small slicks of approximately 100 m in diameter gathered in a 25 km long and 5 km wide zone. As of 17 December, they showed a tendency to sink a few centimetres underneath the sea surface.

From 16 February, a program for spotting oil slicks floating beneath the sea surface or lying on the sea bottom was set up in the vicinity of the wrecks and near the coast. Divers carried out underwater inspections along the coast of Loire Atlantique and Morbihan. From 21 February, two vessels searched for sunken oil with dredges along the 10 m depth line. A survey vessel searched the 50 m depth line. No oil was detected in the water column. Only small, isolated tar balls were found on the sea bottom.

Satellites had little chance of locating the slicks. Those which "see" night and day (Radarsat and ERS) with their radar are able to detect differences in the sea surface caused by an oil slick, lose this capacity when the sea is too calm or too rough. Those which "see" in the visible spectrum and the infrared (SPOT) are blind at night and in cloudy weather. Here, periods of cloudless sky were rare and the observations were obstructed by the swell breaking on the slicks. Both types of satellite, in polar orbit, only passed over the zone every ten days; for these reasons, no exploitable satellite image was obtained.

8.2 **Containment and Recovery:** Since the heavy fuel could not be dispersed, the only response option at sea was containment and recovery. The decision was made to pump the oil. The operation was difficult because the product was highly viscous and the sea was rough. On the other hand, it was facilitated by the thickness of the slicks.

On 15 December, in fairly rough sea conditions an unsuccessful attempt to operate a Transrec recovery device was made. Further pumping tests, carried out on 16 December, finally resulted in a Foilex heavy oil, a smaller capacity, recovery device. It worked, but harsh sea conditions forced teams to postpone the response attempts, after damages to equipment. On 18 December an asphalt tanker joined the response fleet to receive the pumped oil. On 20 December, 60 $m^3$ of oil were recovered, confirming the technical feasibility of the operation. On 21 December, the volume recovered at sea reached 500 $m^3$. On 22 December, in spite of the difficult weather conditions, the volume recovered neared 1,000 $m^3$. When meteorological conditions forced operations to stop, on 23 December, the quantity of emulsion recovered at sea had reached 1,200 $m^3$. On 30 December, fair weather conditions allowed short pumping operations off the coast of Vendée. They were carried out with a Dacama device and a Foilex pump, and by fishing boats using Seynip oil trawls; 8 $m^3$ of pollutant were recovered.
In total, response at sea recovered 1,200 m3 of oil.

## 9 Protection and Shoreline Clean Up

An exceptional south-western storm on the 24-25 December scattered the oil on the beaches, high on dunes and cliffs. Booms had already been installed in pre-determined highly sensitive areas. Others were urgently added. Little cleaning could be carried out in the harsh prevailing weather conditions.
Over a number of weeks, with calmer weather conditions, the operational situation improved. Coarse clean-up operations were organised on beaches, rocks and breakers as soon as the slicks reached the shore.
Unfortunately, re-oiling occurred in many areas, ruining the clean-up work already achieved. In addition, particularly in Loire Atlantique and Vendée, rough weather conditions combined with strong tide coefficients, burying oil slicks under several tens of centimetres of sand, in layered deposits, subsequently subjected to phases of erosion and accretion according to the tide.
Tests were carried out on products and equipment. Few appeared fully efficient, because of the fuel's high viscosity, and manual clean-up proved to be the only start-up solution in many areas. Rocks were further washed with high-pressure cleaners and the effluents recovered on sorbent booms. Screening belts proved extremely useful to recover oil cakes deposited on sandy beaches.
Various different types of equipment and techniques, new or improved, were tested successfully. The resulting information was communicated to the response centres as follows:

- The recovery of oil splashes on non-woven polypropylene wintering film, during the washing of heterogeneous rocks and breakers with high-pressure hoses.
- The filtration, with glass-eel fishing nets and building site nets, of effluents resulting from both manual rock washing and natural pebble washing on the mid-tide zone.
- The alternate use, on beaches, of a tilling (or deep harrowing) device and a screening belt to recover tar balls buried under 25 to 30 cm of sand.
- The tilling of intertidal areas of sandy beaches, to allow recovery by the sea of tar balls buried in the sand and their further deposit on the beaches.

## 10 Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:

| At sea response | | |
|---|---|---|
| **Response** | **Equipment** | **Comments** |
| Monitoring | Dedicated Surveillance Aircraft | Effective |
| Containment and Recovery | Numerous Vessels | In 15 days of operations 1,200 $m^3$ of oil/water mixture were collected, mainly during a 24-hour period of relatively calm weather and reduced swell. It has been estimated that less than 3% of the total spill volume was collected during the response operations at sea. |
| **Dispersant Delivery** | | |
| **Protection and shoreline clean-up** | | |
| **Response** | **Equipment** | **Comments** |
| Protective Measures | Booms | Effective to a degree |
| Manual Recovery | Hand Tools | Effective to a degree but very time consuming. |
| Mechanical Recovery | Suction Tankers, Pressure Washers, Oil Absorbent Scrubbers. | All were efficient to a degree |
| Dispersant | | |
| Trenching | | |
| Beach Washing | | |
| Sorbents | | effective |
| Bio-Remediation | | |

## 11 Environmental Impact

**Seabirds:** The main environmental impact of the spill was on sea birds. Almost 74,000 oiled birds were recorded ashore along the coast of the Bay of Biscay, of which almost 42,000 were dead.

**Shellfish**: From 20 December sampling on shellfish farming sites was carried out; they were the reference oil contamination index before the arrival of the pollution. In January, the French Agency for Food Safety (AFSSA) made the following recommendations: Shellfish production or harvest zones should be closed on the basis of visual observations of the contamination.
Follow-up of shellfish contamination should be carried out on the basis of the analysis of 16 Polycyclic Aromatic Hydrocarbons (PAH) usually measured in shells, in the framework of the National Network of Observation of the marine environment quality (RNO). The concentration reference value should be assessed at 500 µg/kg (total of the 16 Polycyclic Aromatic Hydrocarbons) and the concentration limit value (beyond which shellfish were declared unfit for human consumption) on a level ranging between 2 and 5 times the reference value. The factor 2 (1,000 µg/kg) was chosen by the Ministry of Agriculture and Fishing.

In addition to these recommendations a network for the follow-up of shellfish contamination was set up to support administrative measures for the management of the production zones, in the four regions concerned (approximately 80 sampling points).
In Finistère, the levels of contamination seldom exceeded the reference value of 0.5 ppm fixed by the Agency for Food Security (AFSSA). In Morbihan, the values were at times intermediate between the reference value and the concentration limit of 1 ppm (except in the heavily polluted sector of Belle-Ile). The highest concentrations, exceeding the limit value of 1 ppm, were found in shells in Loire Atlantique and on the island of Noirmoutier (Vendée).

**Salt production** areas were also affected by oil pollution

## 12 Economic Impact

## 13 Comment

## 14 References

http://www.cedre.fr – Erika
http://en.wikipedia - Erika
http://www.itopf.com/ case-studies - Erika

### 8.4 BALTIC CARRIER

1 **Date of Incident:** 29 March 2001.

2 **Location:** In the western Baltic Sea, near the naval border between Germany and Denmark approximately 20 km from Denmark / Germany coast.

3 **Vessel (s):** The tanker Baltic Carrier and the bulk carrier Tern.

4 **Type of Incident:** Collision

5 **Type(s) and Quantities of Oil Spilt:** Approximately 2.700 t HFO 380.

6 **Description of Incident:** The collision occurred due to failure of the Baltic Carrier's steering gear resulting in the ship turning into the Tern's path. The Baltic Carrier was hit on the side by the Tern's bow, and an oil tank containing 2,700 t of oil sprang a leak.

7 **Weather Conditions over the period of the Response:** On 29 March 2001 there was a strong inward bound current, 4-5 kts, and a wave height 2-3 m. When the oil entered Grønsund, the current changed direction (improved weather conditions) and part of the oil was collected by means of environmental vessels.

8 **At Sea Response:**

8.1 **Monitoring:** From day 1 and throughout the operation the oil was tracked by vessels while airborne and satellite-based surveillance was applied. Unlike in the case of the *Erika*, the weather conditions enabled the slicks to be detected by satellite and the images were made available by the European Space Agency.

8.2 **Containment and Recovery:** On the 29 March attempts to collect the oil slick at sea had to be abandoned due to the bad weather conditions. Four days after the accident, the oil collected at sea was estimated at 1,222 t; 15 vessels were involved in the operations.

9 **Protection and Shoreline Clean Up:** Late afternoon on 29 March the slick entered Grønsund, the current changed direction, and about 1,100 t of oil drifted ashore on the south side of Farø, Bogø and Møn. Sensitive areas such as ports and minor inlets (Fanefjord and Letten) were protected by containment booms.

On 30 March the beach clean-up started. The amount of oil collected on the shoreline was estimated around 630 $m^3$. The total shoreline affected was estimated between 30 and 50 km.

Large parts of the Grønsund waters are shallow, particularly the area south of Bredemade Hage, where a large oil slick became stranded. Towing the oil slick contained within booms out to sea and collecting it there, was considered. However, the plan was abandoned because of the risk of bursting the booms and uncontrolled oil drifting. The oil contained within booms was instead towed close to the shore such that it could be scooped up and placed into truck containers. This procedure entailed collecting, in addition to oil, quite substantial amounts of sand, stones, reed etc. In areas not very accessible, such as Malurtholm and the coasts of Falster at Hestehoved, the oil was collected manually and placed in pallet containers of 1$m^3$. When full, the containers were too heavy to carry and had to be moved by helicopter to a barge at sea or to onshore sites. Along the dam between Bogø and Møn, part of the oil was sucked up by the mammoth sludge exhausters.

In spite of the thick consistency of the oil, sludge exhausters were capable of sucking up the oil directly from the water surface. As the sludge exhausters were very heavy and required firm ground, they could, unfortunately, only be employed on a few locations.

The final clean-up at Sortsø and Hestehoved in the Municipality of Nørre Alslev and Stubbekøbing caused problems because of large stones in the area; the area was cleaned by steam flushing of the stones.

At Hestehoved, the authorities conducted tests with biological decomposition of the oil (bio-remediation) in a polluted area. An important criterion was that the authorities did not want to add bacteria, oil dispersants or mixtures of surfactants and solvents to the environment. Field studies involving the addition of two bio-remediation products and one surface-washing agent were conducted by suppliers of the products (Petrotech and Biogard) or biologists from the county (Inipol).

- Petrotech 25: A surface-washing agent. Petrotech was added before high-pressure flushing of the stones; this gave no better results than cleaning with pure hot water.
- Biogard 293: A bio-remediation product containing a mixture of nutrients, clay and cement. The product forms a hard crust, under which the oil is to decompose. No such decomposition could be ascertained during the testing. After a year, in certain locations, there was a hard crust, under which no decomposed oil has been found. This product cannot be recommended for the type of oil in question.
- Inipol EAP 22: An oleophilic fertiliser containing N and P and a dispersant. The product had a visible effect on surfaces treated. Whether the oil was decomposed or simply dispersed was not investigated. In May 2002 it could be ascertained that substantial part of the oil had been removed on the test stretch of the coast. This was also the case outside the test areas, and it can therefore be summarised that the remediation tests on the stony stretch of coast did not produce significant increase in the rate of removal of the oil.

## 10 Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:

| AT SEA RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Specialist Aircraft, satellite | Effective |
| **Containment and Recovery** | Up to 15 Specialist vessels | Very Effective - 1,222 t recovered |
| PROTECTION AND SHORELINE CLEAN UP | | |
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Protective Measures** | Booms | Effective |
| **Mechanical Recovery** | Heavy equipment such as vacuum truck, backhoe and front-end loader were used to clean up beaches. | 991 t of oil in 11,266 t of contaminated material + 3,000 $m^3$ of contaminated water |
| **Beach Washing** | Steam flushing of the stones | Final cleaning of the beaches |
| **Bioremediation** | Petrotech 25; Biogard 293; Inipol EAP 22 | Just a small area – pilot test<br>Comparable efficiency with control areas |

**11** **Environmental Impact:** Bogø, Møns, Farø and North Eastern Falter were among affected areas; they are located in the Grøndsund region. The region is characterized with shallow sea banks which constitute wetland with marsh forest. The environmental quality is generally high as both submerged and riparian vegetation are rich and serve as breeding areas of wild life and fish. The oil disturbed the marine plants and animal species, and migratory birds along this region.

**12** **Comment:** 2,213 t of oil was collected. Minor amounts of oil have been found on the Swedish coast.

**13** **References:**

Maria Pécseli, Gunnar Pritzl, Ole Andersen, Gary Banta, Asger B. Hansen, Jan Christensen, Torben Hviid, Lars Malmborg, Kirsten Johansen, Jakob Lysholdt. The Baltic Carrier Oil Spill Monitoring and Assesment of Environmental Effects in Grønsund (DK). 2002

Agnes Debime Enongene: The Baltic Carrier oil spill at the south-eastern coasts of Denmark: ten years on, an ecological assessment of biota and sediment compartment to evaluate cleanup operations. Master thesis 2013 Roskilde University

ACCIDENT OF THE OIL TANKER “BALTIC CARRIER” OFF THE DANISH COASTLINE European Task Force in Denmark Final Report S. Le Floch – B. Le Guen / Cedre G. Vincent / European Commission April 2001

## 8.5 PRESTIGE

1 **Date of Incident:** 13 – 19 November 2002.

2 **Location:** On 19 November the vessel broke into two, 210 km west of Vigo, off the Spanish coasts, west-southwest of Cape Finisterre.

3 **Description of Incident:** During the afternoon of 13 November, the tanker, carrying a cargo of 77,000 t of HFO, suffered hull damage in heavy seas. She developed a severe list and drifted towards the coast, and was eventually taken in tow by salvage tugs. Although attempts were made to minimise the stresses on the vessel, she broke into two early on 19 November some and the two sections sank some hours later in water 3.2 km deep. In all, it is estimated that some 63,000 t were lost.

Owing to the highly persistent nature of cargo, the released oil drifted for extended periods with winds and currents, travelling great distances. Oil first came ashore in Galicia, where the predominantly rocky coastline was heavily contaminated. Remobilisation of stranded oil and fresh stranding of increasingly fragmented weathered oil continued over the ensuing weeks, gradually moving the oil into the Bay of Biscay and affecting the north coast of Spain and the Atlantic coast of France, as far north as Brittany. Some light and intermittent contamination was also experienced on the French and English coasts of the English Channel. Although oil entered Portuguese waters, there was no contamination of the coastline.

4 **Type of Incident:** Structural damage to the vessel

5 **Quantity and Type(s) of Oil Spilt**: 64,000 t HFO

6 **Weather Conditions over the period of the Response:** Weather conditions varied widely with winds up to force 7 and sea wells up to 5 m.

7 **At Sea Response:**

7.1 **Monitoring:** The oil was tracked throughout using floating buoys, ship-based and aerial data that was fed into various slick drift forecast models. A command vessel complete with a helicopter provided slick reconnaissance, tactical co-ordination and guidance to response vessels to the scene of operations.

7.2 **Containment and Recovery:** The major offshore cleanup operation was hampered by severe weather and by the inability of those vessels that lacked cargo heating to discharge recovered oil. Over a thousand fishing vessels also participated in the cleanup in sheltered coastal waters and during favourable weather. The combined activity reportedly recovered approximately 50,000 t of oil water mixture.

8 **Protection and Shoreline Clean Up:** Despite the enormous effort at sea and the extensive booming of estuaries and sensitive areas with over 20 km of boom, extensive coastal contamination occurred. Altogether, approximately 1,900 km of shoreline were affected. The shorelines of Spain were largely cleaned manually. The process was slow, especially in rocky areas where access was difficult. A further problem was re-oiling of previously cleaned areas by remobilised oil. On the French Atlantic coast beach contamination took the form of numerous tar balls which were relatively easy to remove. In total, some 141,000 t of oily waste was collected in Spain and 18,300 t in France.

The cleaning campaign was a success, recovering most portions of coastline from not only the effects of the oil spill but also the accumulated usual contamination. A year after the spill, Galicia had more 'Blue Flags' for its beaches (an award for those beaches with the highest standards in the EU) than in the previous year's Bioremediation field assay using the oleophilic fertilizer S200 was carried out 10 months after the Prestige heavy fuel-oil spill on a beach of the Cantabrian coast (North Spain). The field survey showed that S200 significantly enhanced the biodegradation rate, particularly of high molecular weight n-alkanes, alkylcyclohexanes, and benzenes, and alkylated PAHs, paralleling the results previously found in vitro. The most significant molecular bioremediation indicators were the depletion of diasteranes and C-27 sterane components. Enhanced isomeric selectivity was also observed within the C1-phenanthrenes and dibenzothiophenes (Jimenez et al., 2006).

## 9 **Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:**

| AT SEA RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Aircraft, vessels and floating buoys | Very Effective |
| **Containment and Recovery** | Numerous Vessels | Effective. Approx. 50,000t oil-water mixture. Response hampered by severe weather. Lack of oil heating tanks prevented discharge. |
| PROTECTION AND SHORELINE CLEAN UP | | |
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Protective Measures** | Booms | Part. Effective |
| **Manual Recovery** | Hand Tools | Effective but slow. Difficult access + re-oiling. 159,000 t oily waste recovered. |
| **Bioremediation** | S200 | Just a small area – pilot test Effective compared to control areas |

**10** **Environmental / Economic Impact:** Fisheries exclusion zones were put in place in Galicia shortly after the incident, banning virtually all fishing along about 90% of the coastline. All bans had been lifted by October 2003. The impact on fisheries in France was less extensive. In both countries, an impact on tourism was reported for 2003.

**11** **Comment:** It was the ensuing fate of the oil and how it behaved in the marine environment that dictated the choice of techniques, equipment and materials to deal with the pollution. There can be no doubt that if specialised resources were to be brought to bear on an ever fragmenting oil slick that was constantly breaking up into smaller and smaller oily patches that manual techniques and resources also had to be fielded as the oil spread wider and wider over the entire area of the Bay of Biscay

## 12 **References:**

http://www.cedre.fr
http://en.wikipedia
http://www.itopf.com/ case-studies
Jiménez N, Viñas M, Sabaté J, Díez S, Bayona JM, Solanas AM and Albaiges J (2006) The Prestige oil spill. II. Enhanced biodegradation of a heavy fuel oil by the use of an oleophilic fertilizer under field conditions. Environmental Science and Technology 40:2578–2585.

### 8.6 KERCH STRAIT – VOLGONEFT-139

1 **Date of Incident**: 11 November 2007

2 **Location:** The Kerch Strait, channel between the Black Sea and the Sea of Azov.

3 **Vessels Involved:** The tanker Volgoneft-139; M/V Volnogorsk; M/V Nahichevan and M/V Kovel. A second oil tanker, the Volgoneft-123, was damaged in the storm; there was an "insignificant spill".

4 **Description of Incident:** The tanker Volgoneft-139 broke into two parts. Leaving the front part anchored; the back part drifted causing the oil spill. Oil from the bow discharged in to the sea during the first 12 hrs. Three hours later oil started leaking from the stern section which had run aground approaching the Tuzla Island and the leakage went on for another 12 hrs.

The M/V Volnogorsk sank with 2,436 t of sulphur on board; there was no observed leakage of oil. The M/V Nahichevan sank with 2,365 t of sulphur on board.The M/V Kovel sank in the middle of the Kerch Strait channel and drifted to near the Ukrainian shoreline; where it sank with about 2,100 t of sulphur on board. A slight marine diesel fuel leak was observed.

5 **Type of Incident:** Weather; anchored vessels were sunk or torn apart: winds of up to 68 kts and waves 3-5 m high.

6 **Type(s) and Quantities of Oil Spilt:** 1,300 t of HFO (Type M-100 - IFO 280-600); 2.3 t of oil lubricants; 25 t of marine diesel fuel oil and 5.5 t of heating oil.

Approximately 2,000 t (including 1 300 t spilled in the accident) of HFO had been spilled by July 2008 (leak of front part of the tanker Volgoneft-139).

7 **Type(s) and Quantities of Other Substances Spilt:** Approximately 6,726 t of technical sulphur

8 **Weather Conditions during the Response:** Treacherous weather conditions at sea (18-20 m/s wind, 2.5 m waves), hampered the clean-up efforts at sea during the initial 24 hours, resulting in oil being transported to the shorelines on both sides of the Kerch Strait.

9 **At Sea Response:**

9.1 **Monitoring:** Aerial, satellite and ground surveillance.

9.2 **Containment and Recovery:** On 15 November, the stern of the Volgoneft-139 was brought afloat and towed to the port of Caucasus, then surrounded by booms. A numerous, variety, of vessels were used to collect oil at sea. In particularly from leakage around the bow part of Volgoneft-139. On 22 May 2008, due to higher air temperature which heated the heavy fuel oil remained in the Voloneft-139 stern part oil spots started appearing on the water surface. Additional booming was installed and sorbent agents were used and the spilled oil products were collected.

10 **Protection and Shoreline Clean Up:** On 14 November, in the vicinity of the Tuzla Spit, works were carried out to put 400 m (two branches) booms between the spit and the Tuzla Island preventing further distribution of the oil. About 1 t of sorbent was applied in the area of the Tuzla Island and fore body of the tanker Volgoneft-139.The oil film around was collected from the sea surface by specialized vessels

By the end of November, the volunteer workers had completed collecting most of the oil at the beaches of the Crimean and Taman coast. In total, 7,140 t of wastes were collected at that time on the Crimean coast. At the Russian coast, about 47,000 t of oily wastes (oil- contaminated substrate and seaweeds) were collected on the beaches. Other source mentioned the slightly less volumes of oil-contaminated substrate collected from the coastline, i.e., about 40,000 t. Thus, one could assume that nearly all oil products discharged into the sea by an accident arrived ashore and were later collected.

Human resources (manpower) exceeding 2,500 and more than 300 units of technical equipment were involved in the coastline clean-up operation. In total, the sea-based resources employed to rectify the Kerch Strait catastrophe consequences stood as 12 vessels, 3,000 m of booms, two oil-gathering trawls, four skimming devices and two oil-pumping systems. The total number of employed personnel was more than 500 persons.

## 11 Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:

| AT SEA RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Helicopter + Satellite | Aerial and Satellite data was used to monitor the movement and impact of the oil spill |
| **Containment and Recovery** | Booms + Sorbents<br>Numerous Vessels | Continued to work until May 2008 |
| PROTECTION AND SHORELINE CLEAN UP | | |
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Protective Measures** | Booms | |
| **Manual Recovery** | Hand Tools + Manual Beach Washing | Collected more than 50,000 t of contaminated material |
| **Mechanical Recovery** | Machinery + Trenching | |

**12** **Environmental Impact:** The Kerch Strait linking the Black and Azov Seas plays an important role in the formation of hydrological and hydro-chemical peculiarities of the whole Azov-Black Seas Basin. The accident caused that more than 664 km$^2$ of sea surface of the Black and the Azov Seas and about 183km of the coastline were contaminated. More than 40,000t of oily trash was collected from the shore. Despite of all the sea and land response operations carried out to halt oil pollution, the expectations emerged that the consequences of the accident would be felt for several years on – environmentally and socio-economically.

**13 References:**

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http://wwz.cedre.fr/
http://www.greenpeace.org/international/en/news/features/kerch-oil-spill/
http://bellona.org/news/fossil-fuels/oil/2007-11-update-black-sea-storm-splits-oil-tanker-spilling-thousands-of-gallons-and-sinking-other-ships
http://www.blacksea-commission.org/_publ-KerchReport.asp
European Commission United Nations Environment Programme; Oil Spill in the Kerch Strait Ukraine Post-Disaster Needs Assessment 2008

### 8.7 GODAFOs

1 **Date of Incident:** 17 February 2011.

2 **Location:** Hvaler in the county of Østfold near the city of Fredrikstad in the Oslo fjord in southeast Norway.

3 **Vessel(s) Involved:** MS Godafoss.

4 **Type of Incident:** Grounding

5 **Weather and Sea Conditions at the Time of Incident:** It was dark but clear. There was no wind and the visibility was good. Large amounts of ice were drifting down the river.

6 **Description of Incident:** The vessel was leaving Fredrikstad by the Glomma River and heading out to sea: it failed to make a starboard turn and grounded on a rock. She was carrying 3,457 t IFO 380 + 430 containers: 4 of the tanks were found to be leaking after the accident.

7 **Quantities and Type(s) of Oil Spilt:** It was estimated that 112 t IFO 380 was spilt.

8 **Weather Conditions over the period of the Response:** Cold weather; temperature -20°C and -2°C in the water, high pressure, and almost no wind during the first days of the operation.

9 **At Sea Response:**

9.1 **Monitoring:** New vessel and aircraft technologies enabled teams to monitor and collect the oil that was drifting under the influence of the prevailing marine currents.

9.2 **Containment and Recovery:** During the night, the first traces of oil were observed and two floating containment systems were deployed around the vessel.

In the following days, several spill response vessels and tugs, some of which were specially designed for response in cold waters, arrived from Sweden and Norway.

The low temperatures (-20°C and -2°C in the water) were a challenge for response. Firstly, they caused the water to freeze, trapping the oil in the ice. These small quantities frozen into the ice were recovered with difficulty using excavators. The low temperatures made it impossible to use pumps as the oil's viscosity had risen. The teams therefore used grabs to remove the oil from the booms. In the process, a lot of ice and snow was also recovered. The oil was separated from the water on board. The ice and snow had to be melted to prevent pipes from freezing.

The oil that froze into the ice (from drifting on ice-free water) was hard to collect because the amount of oil collected as compared to ice was miniscule. The percentage of oil versus ice/water was 3-5%.

Despite the difficulties, the at sea response was considered successful; after four days 50% (compared to the usual 10 to 15%) of the pollutant had been recovered (55 $m^3$ recovered out of 112 $m^3$ spilt).

10 **Protection and Shoreline Clean Up:** Along the east coast of Norway, 130 sites were lightly oiled. The high proportion of oil recovered at sea resulted in lower impact on the shoreline. Bird sanctuaries and public beaches were the first to be cleaned, by mid-April.

As long as the temperature was below freezing, all oil grounded on shores was easily collected. Almost 5 $m^3$ of oil was “rolled off” the bedrock at the Ryvingen lighthouse. Later, when the temperature rose above freezing, the oil became more “normal”: sticky, running into crevasses and in-between rocks and pebbles

## 11 Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:

| AT SEA RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Specialist Aircraft + Helicopters | Effective |
| **Containment and Recovery** | Booms<br>Booms + Skimmers. Excavators + Grabs | Effective – weather + sea + ice dependant<br>Oil recovered from the wellhead 50% (55 $m^3$) |
| PROTECTION AND SHORELINE CLEAN UP | | |
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Manual Recovery** | Hand Tools | Effective – being frozen made it easy to collect the oil. |

**12 Environmental Impact:** The accident occurred in the Ytre Hvaler National Park (Norway).

Studies concluded that the oil had a very limited impact on the marine environment and had fully recovered within half a year of the accident. The lobster population hadn't been affected by the accident. It was estimated that 1,500 - 2'000 Common Eider ducks died, as well as at least 1,000 individuals of other species.

**13 Comment:** Different recovery methods were employed which varied in their effectiveness in the ice conditions. Booms needed to be sufficiently durable to withstand the extra force created by the contained ice which could cause them to tear or become temporarily submerged. Most skimmers operated at a significantly reduced efficiency, due to both the high viscosity of the oil and the presence of drifting sea ice within the slick. Some of the more effective techniques included a combination of brush belt skimmers assisted by steam heating jets, which enhanced the separation of oil from ice. Oil recovery was also achieved using response vessels equipped with sweeping arms to contain the oil, while mechanical grabs were used to transfer the viscous, weathered oil and ice into containers placed on the vessels' decks. The incident highlighted a number of areas that would benefit from improved technical solutions, such as minimising the quantity of ice recovered with the oil and increasing the effectiveness of pumping highly viscous oil at low temperatures.

Due to the viscous nature of the oil stranded on the coastline, manual removal with hand tools proved an effective recovery option at most locations.

**14 References:**

S. Boitsov, J. Klungsøyr and H. Dolva: Experiences from oil spills at the Norwegian coast - A summary of environmental effects (2013) Institute of Marine Research

http://www.cedre.fr/en/spill/godafoss/godafoss.php

http://www.interspill.com/previous-events/2012/13-March/pdfs/Lessons%20Learned%20the%20Godafoss%20Acccident%20in%20Feb%202011.pdf

http://www.kystverket.no/en/EN_Preparedness-against-acute-pollution/Operations-archive/Godafoss/

### 8.8 GOLDEN TRADER

1 **Date of Incident:** 10 September 2011

2 **Location:** Approximately 32 km off the western coast of mainland Denmark

3 **Vessel(s) Involved:** The bulk carrier Golden Trader; FV Vidar.

4 **Type of Incident by Primary Cause:** Collision

5 **Weather and Sea Conditions at the Time of Incident:** The weather was relatively calm; south westerly winds of 12 kts; wave height of 0.5 m; visibility was reduced.

6 **Description of Incident:** A close quarter situation developed; the fishing vessel took avoiding action by altering course to starboard and the Golden Trader altered her course to port, the collision occurred soon afterwards. The stern of the fishing vessel hit the starboard side of Golden Trader aft. Consequently, a considerable amount of heavy fuel oil leaked into the sea.

After the collision, Golden Trader remained adrift and in communication with the Danish authorities. Initially, the Master estimated that a small amount of heavy fuel oil was lost. An entry in the deck log made at 14:55 indicated "no leakage outside." Subsequently, the master reported that approximately 4 $m^3$ of heavy fuel oil were lost.

7 **Type(s) and Quantities of Oil Spilt:** 205 t IFO 180; it had a high viscosity and formed lumps when released into the water. Following the spill, the wind increased, which meant that the oil was pushed below the surface of the relatively high seas. Furthermore, the oil emulsified increasing the density. The emulsification took place over time so the oil that was collected between 11 and 12 September had a water contamination of about 10% to 15%. The oil that contaminated the Swedish west coast had water content of up to and over 50%.

8 **Weather Conditions over the period of the Response:** 11-15 September wind speeds of 20 kts and a wave height of 1 m.

9 **At Sea Response:**

9.1 **Monitoring:** The day after the incident a helicopter observed collectable oil, about 10 nautical miles north-east of the position of the collision. The calculated thickness of the oil was about 1 cm and the estimated the amount to be about 150 t. The environmental vessel, GUTH, also found the oil slick.

On 12 September a Danish aircraft surveyed the area and reported the oil.

On 13 September a Danish surveillance aircraft found traces of oil on its Side Looking Airborne Radar (SLAR) in the area off Hanstholm to Lökken but it was not possible to see the oil visually.

The next day the Swedish Coast Guard carried out the airborne surveillance in the area off Hanstholm to Lökken but no oil was observed.

The first indication of pollution on the Swedish west coast was observed around noon on 15 September at Klädesholmen and Skärhamn. In order to get reliable data on the extent of the oil spill, the Swedish Coast Guard carried out an aerial reconnaissance by helicopter during the morning and early afternoon on 16 September. The amount of oil was estimated to be between 25 and 30 t. It was later discovered that the oil layer was very thick - up to one metre. Analysis of the oil recovered showed that it originated from the Golden Trader.

9.2 **Containment and Recovery:** On 11 September, the vessel, GUTH started to collect the oil and succeeded to gather about 30 $m^3$ of oily-water before darkness set in.

The next day GUTH collected about 60t of oily-water mixture before the oil collecting equipment developed a fault as a result of the bad weather. The amount collected a totalled of around 50 t of oily-water mixture.

On 13 September 2011 the weather conditions prevented any collection of oil.

10 **Protection and Shoreline Clean Up:** On 16 September reports of oiling in the municipality of Tjörn in Sweden were received. Approximately 15 km of coastline was oiled to a significant degree. Sporadic patches of light oil stranding were observed as far as 150km to the north, in Strömstad, and 15 km south of the main stranding area. The pollution response teams used pumps, brush skimmers and mechanical excavators to recover the emulsified oil from the water. Other teams manually collected oil stranded along the coastline and conducted surveys of the many small islands impacted.

The emergency phase of the response ended on 5 November with some 550 $m^3$ of emulsified oil (>70% average water content) and around 15 $m^3$ of oily kelp and debris having been collected.

The remaining oily debris and oil patches were removed over a period of approximately fifteen months.

11 **Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:**

| AT SEA RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Specialist aircraft and helicopters, SLAR | Effective – Visual obs. Limited by weather |
| **Containment and Recovery** | Vessel with pumps, brush skimmers and mechanical excavators | Effective – weather + sea. Equipment broke due to weather. |
| PROTECTION AND SHORELINE CLEAN UP | | |
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Manual Recovery** | Hand Tools | Effective – being frozen made it easy to collect the oil. |
| **Mechanical recovery** | Pumps, brush skimmers and mechanical excavators | Effective |

12 **Environmental Impact:** It is very fortunate that the accident occurred in late summer and therefore the consequences for the marine wildlife were very limited.

13 **References:**

http://www.havkom.se/virtupload/reports/goldentrader_vidar_interim.pdf
http://www.itopf.com/in-action/case-studies/case-study/golden-trader-denmark-2011

### 8.9 TK BREMEN

1 **Date of Incident:** 16 December 2011

2 **Location**: On the coast 2 km south of the mouth of the Ria d'Etel, Morbihan, France.

3 **Vessel(s) Involved:** The cargo vessel Bremen

4 **Type of Incident by Primary Cause:** Grounding

5 **Weather and Sea Conditions at the Time of Incident:** On the night of 15 to 16 December there was a storm; 50-60 kts winds and 5-7 m waves.

6 **Description of Incident:** The vessel, caught in a storm attempted to move to a more sheltered area. As it was making the move it grounded.

7 **Type(s) and Quantities of Oil Spilt:** 150 t IFO 120 and 40 t MDO

8 **Protection and Shoreline Clean Up:** On the 16 December a slick, 1 km long by 5 m wide, was detected. The pollution affected Kerminihy beach in Erdeven, as well as the Ria d'Etel, oiling the shores of Etel, Belz and Locoal-Mendon to varying extents.

Reconnaissance surveys were conducted on the coastline and the southern bank of the Etel River to identify and characterise the different areas polluted. An organisation was set up to define, monitor and inspect clean-up sites with the different parties involved, taking into account the health-related, technical and environmental constraints specific to each site.

Near the vessel, mop nets were laid to recover pollutant in suspension in the water.

Booms were deployed in the Ria d'Etel to protect the most sensitive sites. Booms were also deployed in Etel marina.

On 17 and 18 December around 200 people cleaned up the bulk of the oil and oiled seaweed at risk of being remobilised at the mouth of the ria and on Erdeven beach.

**Surf-washing tests** were conducted from 19 to 21 December. This technique involves moving sand down to the lower foreshore to be cleaned by natural wave action. The pollutant placed in suspension through this technique was recovered using mop nets and sorbent booms. Two surf-washing operations were conducted from 19 to 21 January and 13 to 15 February.

From 26 December final clean-up operations began. The clean-up was completed by mid-March 2012.

9 **Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:**

| PROTECTION AND SHORELINE CLEAN UP | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Beach Surveys by experts | Effective |
| **Protective Measures** | Booms – Traditional<br>Mop Nets – around the wreck | Effective |
| **Manual Recovery** | Hand Tools | Effective but time consuming. |
| **Surf-Washing** | Bulldozer, mop nets and sorbent booms | Surf-Washing tests on two sides |

**10** **Economic Impact:** On 29 December, all leisure and professional shellfish harvesting in the Ria d'Etel was temporarily banned. This ban was lifted on 19th January 2012 for professionals.

**11** **Environmental Sensitivities:** Shoreline clean-up priorities were set according to local sensitivities, with the highest priority afforded to oyster farms, followed by amenity sites, and lastly inaccessible or infrequently visited areas. Clean-up of the oyster farm facilities was achieved by the first week of February.

**12** **References:**

http://www.theatlantic.com/photo/2012/01/salvaging-the-tk-bremen/100231/
http://www.cedre.fr/en/spill/bremen/bremen.php
http://www.itopf.com/in-action/case-studies/?tx_itopfacasestudies_itopfacasestudies%5Buid%5D=33&tx_itopfacasestudies_itopfacasestudies%5Baction%5D=view&tx_itopfacasestudies_itopfacasestudies%5Bcontroller%5D=ItopfaCaseStudies&cHash=16cff385209c0bb6d124b1282729b73f

### 8.10 ALFA 1

1 **Date of Incident:** 5 March 2012

2 **Location:** Elefsis Bay, Piraeus, Greece

3 **Vessel(s) Involved:** The tanker Alfa I + Wreck of the *City of Mykonos*

4 **Type of Incident by Primary Cause:** Collision with submerged object (the wreck of the *City of Mykonos*)

5 **Description of Incident:** The tanker Alfa I made contact with a submerged wreck in Elefsis Bay, Greece which resulted in a 30 m lateral shear to the hull. The vessel listed over onto her starboard side and sank. She came to rest in 18-20 m of water with her stern in contact with the seabed but the bow still visible above water.

6 **Type(s) and Quantities of Oil Spilt:** An unknown amount of oil (but estimated to be less than 100t) was spilt at sea.

7 **On Water Response:**

7.1 **Containment and Recovery**: A salvage company was engaged to stop the release of oil into the water by closing and tightening the manholes, vent pipes and sounding pipes. No further loss of oil was reported. A perimeter consisting of two sets of booms was placed around the wreck of the tanker and anchored at regular intervals to maintain it in the prevailing weather conditions. An unknown quantity of oil was recovered at sea by vessels using booms and skimmers.

8 **Protection and Shoreline Clean Up:** Some 200 to 300 m of booms were deployed to protect a marina and an oyster farm nearby. The amount of oil which impacted the shoreline and the quantity of waste material removed during the clean-up operations is not known. Some 30 to 50 people were employed to manually remove the oil along with beach sediment (mainly gravel and pebbles). It is understood that clean-up operations were completed by 30 June.

9 **Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:**

| ON WATER RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Containment and Recovery** | Booms<br>Vessels with booms and skimmers | Effective |
| PROTECTION AND SHORELINE CLEAN UP | | |
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Protective Measures** | Booms | Effective |
| **Manual Recovery** | Hand Tools | Effective |

10 **Environmental Sensitivities:** Oil impacted along some 13 km of the shoreline of Elefsis Bay, contaminating a number of local beaches in Loutopyrgos, Neraki and Nea Peramos, and also the Salamina Island (Faneromenis and Batsi).

11 **References:**

http://www.iopcfunds.org/uploads/tx_iopcpublications/incidents2013_e.pdf
http://www.itopf.com/in-action/case-studies/case-study/alfa-1-greece-2012/
http://www.osraint.com/content/press-release-oil-spill-response-services-during-alpha-1-capsize-and-sinking-eleusis

# 9 ANNEX D: Oil spill incident summaries (worldwide oil spills 2003 – 2012)

## 9.1 TASMAN SPIRIT

1 **Date of Incident:** 27 July 2003.

2 **Location:** Entrance to Karachi Port, Pakistan

3 **Description of Incident**: The oil tanker Tasman Spirit grounded in the channel of the port of Karachi. Significant quantities of oil were spilled when the Tasman Spirit broke during the evening of 13 August. By 18 August approximately 27,000 t of cargo had been lost. On 22 August further structural collapses lead to a loss of about 100 to 200 t. On 29 August and on the 4 September further releases of oil were reported.

4 **Type of Incident:** Structural damage to the vessel

5 **Quantity and Type(s) of Oil Spilt:** 27,000 t Iranian Light Crude; it has a gravity of 33.1 and a sulfur of 1.5%

6 **At Sea Response:**

6.1 **Monitoring:** Visual Monitoring

6.2 **Containment and Recovery:** Floating booms were deployed around the wreck. Offshore recovery operations were difficult because of the presence of large waste in the oil.

6.3 **Dispersant Spraying:** Aerial spraying was carried out from 15 to 17 August; noticeably reducing the quantity of hydrocarbons visible on the surface of water. In total, 16 t of dispersants were sprayed on the oil slicks.

On the 18 August the application of dispersants from tug boats to deviate and keep the oil from entering the port.

On 22 August after more oil spillage from the vessel aerial spraying was recommenced. The total volume of dispersants used rose to 31 t from the aircraft and 6 t from the boats.

7 **Protection and Shoreline Clean Up:** Booms were deployed at suitable collection sites. Skimming and manual clean up of the floating oil debris was carried out; in total some 140 $m^3$ of oil were recovered by skimmers.

The oil reached Clifton Beach (next to Karachi), with an estimated volume of 300 $m^3$ covering some 6 km. Some areas around the harbour and some mangrove swamps were also affected. Oleophilic disc skimmers were used on the harbour shoreline for the cleaning operations.

On the coastline a coarse cleaning operation was carried out manually and by mechanical recovery; then harrowing eased natural cleaning.

By September there were no significant traces of hydrocarbons left on Clifton Beach. Nevertheless, pollution remained deeply buried in different places. In order to avoid accumulation of small unpolluted waste, this pollution was left for natural degradation. 2,500 t of polluted materials (mainly polluted sand) were collected.

## 9 Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:

| AT SEA RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Visual | Effective |
| **Containment and Recovery** | Floating Booms<br>Vessel with recovery systems | Effective<br>Difficult due to floating waste |
| **Dispersant Delivery** | Aircraft + ADDS System<br>Tug boats with spray systems | Efficient<br>Efficient |
| PROTECTION AND SHORELINE CLEAN UP | | |
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Protective Measures** | Booms | Effective |
| **Manual Recovery** | Hand Tools | Effective to a degree but very time consuming. |
| **Mechanical Recovery** | Unknown | Unknown |

**10 Environmental / Economic Impact:** Whilst there were few reports of impacts of the oil on fisheries, a three-month fishing ban was imposed by the Marine Fisheries Department along the coastline directly affected by oil, extending five nautical miles offshore.

**11 Comment:** Given the low persistence of Iranian Light crude oil and the high mixing energy in the many damaged cargo tanks generated by the incessant heavy swell, it is likely that most of the spilled oil dispersed naturally.

Field surveys conducted showed little or no impact on mangroves, salt pans and other sensitive resources in the vicinity.

**12 References:**

http://www.cedre.fr – Tasman Spirit
http://en.wikipedia – Tasman Spirit
http://www.itopf.com/ case-studies – Tasman Spirit

### 9.2 ATHOS 1

1 Date of Incident: 26 November 2004.

2 **Location:** Delaware River, Philadelphia

3 **Description of Incident:** The vessel was approaching the unloading terminal when she hit part of a metal pipe.

4 Type of Incident: Collision

5 **Quantity and Type(s) of Oil Spilt:** 1,000 $m^3$ Bachaquero Crude; the oil is slightly buoyant, very viscous and sticky. It is a cargo that is heated, has high asphalt content and weathers slowly and can easily form into tar balls.

6 **Weather and Sea Conditions at the Time of Incident:** The weather was clear; the wind calm, the temperature 3°C; the tide was incoming and the current was approximately one and a half to two knots.

7 **On Water Response:**

7.1 **Monitoring:** Assessment teams were deployed by air, water, underwater (divers) and ground to track the oil migration and determine the extent of oil contamination. The assessment teams determined that the oil spill impacted both shorelines of the relatively narrow Delaware River, and each tide cycle provided net movement of oil slowly to the south. In all, the shoreline between the Tacony-Palmyra Bridge and Artificial Island, including the shorelines of creeks, marshes and other tributaries, were impacted. However, only five miles of shoreline were heavily impacted with oil, while the remaining shoreline impacts were light or minimal.

A major challenge for the assessment teams was tracking and locating submerged oil. The team put together a plan that included the placement of fixed monitoring stations that could be used as an early warning system to detect surges of submerged oil concentrations heading toward two nuclear power plants and to record trends in submerged oil concentrations and migration over time.

7.2 **Containment and Recovery:** As the assessments were being completed, response resources were deployed to control, contain, protect sensitive areas and recover oil. Initially, containment boom was deployed around the vessel. A fleet of six on-water skimming units was deployed to recover free-floating oil and help prevent shoreline impacts. To recover submerged oil five vessels subsurface oil recovery systems designed to collect oil on the bottom and throughout the water column were deployed. A hydraulically-driven submersible dredge pump attached to a diver-directed suction hose successfully recovered submerged oil.

8 **Protection and Shoreline Clean Up:** Deflection and containment boom (floating barriers) were deployed by several on-water task forces established to protect sensitive shorelines, river inlets, marinas, marshes, boats and commercial vessels and piers. At the height of the response, over 30 km of boom was deployed.

Despite the best protective efforts oil still impacted the shorelines due to rapid spreading attributed to weather and environmental factors (current, tide, wind, etc.). Efforts focused on removal of oil from sensitive habitats and from shorelines where oil could be re-floated and remobilized by changing tides, winds and currents. Labourers and heavy machinery removed tons of contaminated debris from the shoreline of the Delaware River. Because of the complexity of the contaminated shoreline, the spill cleanup operation was divided into over 20 different geographic work divisions. Cleanup operations continued into the spring and summer of 2005.

According to the Coast Guard, 318 $m^3$ of oil and oily liquid and 68.8 $m^3$ of submerged oil have been recovered. Another 30 $m^3$ of oily solids (cleanup materials and oil) have been collected.

## 9 Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:

| ON WATER RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Assessment Teams in the air, on the water, sub-surface and on the ground | Effective |
| **Containment and Recovery** | Numerous Vessels with recovery systems. | Effective |
| **Submerged Oil Recovery** | The operation involved a diver with a helmet-mounted video camera using a pump system with a suction hose rigged with a duckbill attachment. | Considered Successful |
| PROTECTION AND SHORELINE CLEAN UP | | |
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Protective Measures** | Booms | Effective |
| **Manual Recovery** | Hand Tools | Effective to a degree but very time consuming |
| **Mechanical Recovery** | Heavy Machinery | Effective |

**10 Economic / Environmental Impact:** In response to the initial threat two reactors at the Salem Nuclear Power Plant along the river at Artificial Island, New Jersey temporarily closed.

After a three-day shutdown of the Port of Philadelphia immediately after the spill, commercial vessels were allowed back into the port.

Bottom dwelling fish, including shellfish, juvenile fish and larvae, and the endangered short-nose sturgeon were at risk of being exposed to submerged oil.

To date, over 585 birds have been impacted by the spill and 361 have been successfully cleaned and released or are awaiting release. Other dead wildlife such as mammals, reptiles, and fish were also recovered.

Recreational such as fishing, shell fishing, boating, and hunting were also impacted.

## 11 References:

http://www.cedre.fr
http://www.itopf.com
http://www.incidentnews.noaa.gov
http://www.darrp.noaa.gov/northeast/athos/
http://www.nrt.org/AthosIEvaluationReport

### 9.3 SELENDANG AYU

1 **Date of Incident:** 8 December 2004

2 **Location:** Western shore of Unalaska Island, Alaska, USA

3 **Vessel(s) / Installations Involved:** Bulk Carrier Selendang Ayu

4 **Type of Incident by Primary Cause:** Grounding

5 **Weather and Sea Conditions at the Time of Incident:** Winds over 50 kts and waves of 7.6 m.

6 **Description of Incident:** After going through Unimak Pass and travelling north of the Aleutians the Master shut down the engine to make repairs to a cracked cylinder liner. The cylinder was isolated but the engine could not be restarted. The vessel drifted downwind, rolling in a trough at about 1.6 kts.

Early on 7 December the Coast Guard was notified that the vessel was adrift and requesting assistance to take them in tow. After numerous attempts to get a tow on board and save the vessel on the 8 December the Selendang Ayu grounded offshore just north of Spray Cape on the western shore of Unalaska Island; 54 hours after the main engine was shut down to make repairs.

7 **Type(s) and Quantities of Oil Spilt:** 1,326 $m^3$ of IFO 380, 70 $m^3$ MDO.

8 **Type(s) and Quantities of Other Substances Spilt**: Approximately 60,000 t of soybeans

9 **At Sea Response:** Pollution response operations at sea became practically impossible, due to the difficult weather conditions and the movement of the zone.

10 **Protection and Shoreline Clean Up:** The initial phase of the response began with the assessment of the situation, providing **protective booming** to important streams and other locations. Later, personnel assessed the effectiveness of the booming that had been done, and some sites were eliminated, while others were adjusted to be more efficient. Manual and in situ techniques were used where possible due to the logistical challenges of bringing equipment in and removing waste, with surfwashing and tilling used to clean oiled beach material. Clean-up was terminated in September 2005, some 10 months after the incident.

**Winter Operations Plan:** Oil removal from the heavily impacted beaches was considered impractical, due to severe winter weather that would prevent such activities from being safely accomplished. The shoreline impacts were assessed through a series of over flights and beach surveys with helicopters, placing multi-agency teams of personnel trained to document the distribution and extent of oiling for the purpose of identifying gross oil removal priorities.

**Spring/Summer Operations:** Mobilization for this phase began in early April, surveys provided appropriate information for decisions regarding shoreline treatment, clean up operations and tactics, and end points for clean up. The surveys began with two helicopter-based teams and two boat-based teams and determined that 113 km of shoreline required further clean-up.

The shoreline clean up was done from a vessel based support system. Shoreline clean up personnel were berthed on vessels and accessed their assigned segments of beaches during favourable weather and tides.

## 11 Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:

| PROTECTION AND SHORELINE CLEAN UP | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring + Surveying** | Helicopters + Specialist Teams | Effective |
| **Protection** | Booms | Effective |
| **Manual Recovery** | Hand Tools | Effective |

**12 Environmental Sensitivities:** Unalaska Island is part of a protected natural reserve that provides seasonal feeding, breeding, reproducing, and staging grounds for large numbers of migratory birds and marine and terrestrial mammals. Skan Bay is home to First Nations' archaeological sites and subsistence fishing and hunting grounds, as well as seabirds, bald eagles, sea otters, Steller sea lions and whales. Commercial crab and herring fisheries are also important to the local economy. As a result of the spill, approximately 2,000 marine birds and 10 sea otters were reportedly oiled. Oil has been found in sub tidal habitats and has contaminated commercially important fishing grounds, near the spill site and thus fishing activities in the immediate vicinity of the wreck were suspended.

**13 References:**

http://gcaptain.com/mv-selendang-ayu-oil-spill-sinking/
http://officerofthewatch.com/2012/12/10/mv-selendang-ayu-grounding/
The Selendang Ayu Oil Spill: Lessons Learned Conference Proceedings August 16-19, 2005 unalaska, Alaska; Editor Reid Brewer. (http://www.uscg.mil/iccopr/files/2006_Selendang_Ayu_Oil_Spill_Proceedings.pdf)
http://www.itopf.com/in-action/case-studies/case-study/selendang-ayu-united-states-2004/

### 9.4 SOLAR 1

1 **Date of Incident**: 11 August 2006

2 **Location:** The Panay Gulf approximately 20.5 km off the southern coast of Guimaras Island, Republic of the Philippines

3 **Vessel(s) Involved:** Oil tanker Solar 1

4 **Type of Incident by Primary Cause:** Structural damage -Sinking

5 **Weather and Sea Conditions at the Time of Incident:** Storm

6 **Description of Incident:** **T**he oil tanker was transporting 2,000 t of oil when she sank in waters 300 m deep near the island of Guimaras in the Philippines. Over 1,300 t of oil were spilled at sea very rapidly; the coast was heavily polluted by regular release of oil though leaks in the hull.

7 **Type(s) and Quantities of Oil Spilt:** 1,300 t IFO 180

8 **At Sea Response:**

8.1 **Monitoring:**

8.2 **Dispersant Spraying:** At-sea response focused on the application of dispersants on the freshly released oil using aircraft and spray arms mounted on tugs and patrol vessels. However, adverse weather conditions delayed response and therefore reduced its effectiveness.

9 **Protection and Shoreline Clean Up:** Attempts were made to protect sensitive resources using conventional booms and a series of improvised booms made from banana leaves and similar material.

Shoreline clean-up was conducted for three months carried out and was undertaken using predominantly manual methods and primarily focused on sandy beaches.

**Natural clean-up** was eventually chosen as in order to prevent human intervention from damaging the environment.

10 **Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:**

| AT SEA RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Aircraft | Effective |
| **Dispersant Delivery** | Aircraft + Vessels with spray systems | Adverse weather conditions delayed response and reduced dispersants effectiveness. |
| PROTECTION AND SHORELINE CLEAN UP | | |
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Protective Measures** | Conventional booms and a series of improvised booms made from banana leaves and similar materials | Effective |
| **Manual Recovery** | Hand Tools | Effective |

**11** **Economic Impact:** The spill had a major impact on the small-scale fisheries; a number of fishpond operators, seaweed farmers and tourist businesses suffered losses.

Temporary bans on the consumption of sea produce were imposed.

**12** **Environmental Sensitivities:** About 125 km of shoreline were contaminated to varying degrees on the south and south-west coasts and a number of small islets off the south-east coast. The oil reached marine sanctuaries and mangrove reserves in three out of five municipalities and reached the shores of Iloilo and Negros Occidental.

There was massive loss of mangroves, leaving large areas of deforestation; approximately 6.5 $km^2$ was affected.

The growth of phytoplankton, primary source of marine nutrition, was affected by the spill, coral secreted too much mucus, the autonomy and buoyancy of seabirds and dolphins were reduced.

Three years after the accident, scientific studies showed abnormalities in the breeding and growth of mangroves, sea grass, marine animals and sea cucumbers, which were attributed mainly to the contamination of the marine environment by the oil.

**13** **Comment:** Limited resources and difficulties accessing this relatively remote area posed substantial challenges for the spill response and cleanup. Due to difficult or non-existent road access, waste had to be collected from many temporary storage sites by small pump boats and canoes

**14** **References:**

R. B. Sadaba; A. P. Barnuevo: Status of Mangroves Within Taklong Island National Marine Reserve, Nueva Valencia, Guimaras, Philippines: A One-Year Post Spill Monitoring Study (2010) Mem. Fac. Fish. Kagoshima Univ 9 Special Issue, pp. 9-17

http://coordination-maree-noire.eu/spip.php?article3881

http://www.itopf.com/in-action/case-studies/case-study/solar-1-philippines-2006/

http://wwz.cedre.fr/en/Our-resources/Spills/Spills/Solar-1

http://newsinfo.inquirer.net/inquirerheadlines/regions/view/20090205-187648/Oil-spill-keeps-punishing-mangroves

http://www.wildsingapore.com/news/20070304/070315-2.htm

http://www.iopcfunds.org/uploads/tx_iopcpublications/incidents2013_e.pdf

http://www.mangroverestoration.com/pdfs/Balena.2015.PhillipinesMgoilspill.pdf

### 9.5 HEBEI SPIRIT

1 **Date of Incident:** 7 December 2007

2 **Location**: Near the Port of Incheon on the Yellow Sea, Republic of Korea

3 **Vessel(s) Involved**: Oil tanker Hebei Spirit and Barge Samsung 1

4 **Type of Incident by Primary Cause:** Collision

5 **Weather and Sea Conditions at the Time of Incident:** Gale-force winds from the northwest and 4 meter waves.

6 **Description of Incident:** The Hebei Spirit was anchored in front of the Port of Incheon on the west coast of South Korea, south of Seoul, when it was hit by the barge Samsung 1 which was drifting. The crane barge was being towed by two tugs when the tow line broke. The crane on board of Samsung 1 punctured tanks 1, 3, and 5 on the port side of the tanker.

7 **Type(s) and Quantities of Oil Spilt:** 10,900t of three different types of crude oil: United Arab Emirates Upper Zakum (Gravity 33.9 and Sulfur 1.84%) Kuwait Export Crude (Gravity 30.2. and Sulfur 1.77%) and Iranian Heavy Crude (Gravity 30.2 and Sulfur 2.72%). These oils are light crudes, with fairly similar characteristics.

8 **Weather Conditions over the period of the Response:** The wind on December 7 and for most days after the spill was predominately northwest, which caused the spreading oil to move in a southerly direction. The Ministry of Maritime Affairs and Fisheries (Republic of Korea) initially said the leaked oil would quickly freeze in the cold winter temperatures, and since the accident took place about 10km from the shore, the environmental damage would not be large. However, due to rather warm weather, an unforeseeable wind direction and high waves, the spill expanded and reached shoreline.

9 **At Sea Response:**

8.1 **Monitoring:** Aerial Surveillance by helicopter

8.2 **Containment and Recovery:** Vessels used skimmers and sorbents to recover floating oil. The drifting oil slicks soiled over 300 km of shoreline.

8.3 **Dispersant Spraying:** Dispersants were applied from vessels, from helicopters equipped with spray systems and small fixed-wing crop sprayers.

10 **Protection and Shoreline Clean Up:** Response teams deployed oil booms in front of sensitive areas along the shoreline. The primary clean-up technique was manual using buckets, shovels and sorbent pads. Vacuum trucks, skimmers and mechanical means were used at selected sites. Bulk oil removal was completed by the end of March 2008.

For secondary clean-up operations manual wiping of rocks and pebbles using sorbent materials and other textiles, and batch processing of oily substrate by boiling in vats was used. More effective techniques, comprising surf washing, flushing and pressure washing, dependent upon the substrate type and site function were adopted after surveys and trials. The majority of secondary clean-up operations were completed by the end of June 2008, with operations in more remote areas continuing to October 2008.

Total 4,175t of liquid oils (not fully separated from water) and 32,074 t of oiled solid waste including the disposable response equipment were recovered. When water contents of the recovered liquid oils was estimated as 50% by volume and percentage of oil in the recovered solid waste was assumed as 1% by weight, the total recovered oil was roughly calculated as 20% of the spilled oil.

## 11 Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:

| AT SEA RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Aerial Surveillance | Effective |
| **Containment and Recovery** | Booms<br>Vessels with booms, skimmers and sorbents | Effective |
| **Dispersant Delivery** | Helicopters with dispersant pods<br>Vessels with spray systems | Effective |
| PROTECTION AND SHORELINE CLEAN UP | | |
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Protective Measures** | Booms | Effective |
| **Manual Recovery** | Manual wiping of rocks and pebbles using sorbent materials and other textiles | Secondary clean up |
| **Mechanical Recovery** | Vacuum trucks, skimmers and mechanical means<br>Surf washing, flushing and pressure washing | Primary clean up<br><br>Secondary clean up |

**12 Environmental Sensitivities:** The spill occurred near Mallipo Beach (in Taean County), considered one of South Korea's most beautiful and popular beaches. The region is home to one of Asia's largest wetland areas, used by migratory birds, and contains a national maritime park and 445 sea farms. The linear coast comprised rocky areas, sandy and pebble beaches and mud flats. The drifting oil slicks soiled over 300 km of shoreline.

## 13 References:

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http://www.koreatimes.co.kr/www/news/nation/2007/12/113_15224.html
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## 9.6 MONTARA

1 **Date of Incident:** 21 August 2009.

**2** **Location:** Montara Oil Field in the Timor Sea located 224 km offshore from the northwest Australian coast.

**3** **Description of Incident:** On 21 August, the Montara Wellhead Platform had an uncontrolled release of hydrocarbons from one of the platform wells. Consequently oil escaped to the surface and gaseous hydrocarbons escaped into the atmosphere. The uncontrolled release continued until 3 November and response operations continued until 3 December.

4 **Type of Incident:** Wellhead blowout

**5** **Quantity and Type(s) of Oil Spilt:** 4,800 t crude oil. A light crude oil; with a wax content of up to 11% and a pour point of up to 27°C.

**6** **Weather Conditions over the period of the Response:** The calm conditions experienced during most of this period permitted offshore containment and recovery operations; however to some extent these conditions also hampered the natural breakup of the oil as there was little agitation

**7** **At Sea Response:**

**7.1** **Monitoring:** Over 130 surveillance flights were conducted throughout the duration of the operation, commencing on the first day of the incident. These flights gathered oil spill intelligence, environmental data, and directed the dispersant spraying aircraft and then subsequently the surface vessels undertaking dispersant spraying and offshore containment and recovery operations, to heavy concentrations of oil.

The drift of the slick was monitored using marker buoys released from an aircraft.

Confirmation (by sampling from a helicopter) was sometimes necessary to differentiate oil slicks from the natural phenomenon of algal bloom.

**7.2** **Containment and Recovery:** Offshore containment and recovery operations commenced on 5 September and continued until 30 November, although no recoverable oil was located after 15 November. These operations involved two vessels working together joined by a 300 metre containment boom, with a skimmer operating in the boom "pocket" to recover the oil. For much of the response, two pairs of vessels undertook these operations. In total, 844 $m^3$ of emulsion was recovered; of which 493 $m^3$ (58%) was crude oil.

**7.3** **Dispersant Spraying:** Dispersant spraying operations commenced on 23 August and continued until 1 November: a Hercules C-130 sprayed a total of 12 $m^3$ of dispersant on 23 and 24 August. Aircraft continued spraying operations until 2 September, spraying 32 $m^3$ of dispersant.

Vessel spraying operations were carried out from 30 August to 1 November, with 118$m^3$ of dispersant sprayed.

The six types of dispersant used, Slickgone NS, Slickgone LTSW, Ardrox 6120, Tergo R40, Corexit 9500 and Corexit 9527 were all prior approved for use within Australian waters, having passed laboratory acute toxicity testing requirements applied under the National Plan arrangements.

The large wax percentage of the crude oil, which tends to solidify the slicks depending on temperature variations, had an impact on the window of opportunity for applying dispersant (more efficient in the afternoon).

Observations made by experienced personnel during the response indicated that the use of dispersant was highly effective in assisting the natural process of biodegradation and minimising the risk of oil impacts on reefs or shorelines.

8 **Protection and Shoreline Clean Up:** Throughout the incident, the majority of observed oil remained within 19 nautical miles of the platform with patches of sheen and weathered oil reported at various distances in different directions from the platform as wind, currents and seas and air temperatures varied. The calm conditions experienced during most of this period permitted offshore containment and recovery operations; however to some extent these conditions also hampered the natural breakup of the oil. Sheen was reported at Ashmore, Cartier and Hibernia Reefs by observers on board aircraft on several occasions, the only reports of potential impact on any reef were observations of wax pieces floating in the Ashmore Reef lagoon between 26 – 30 October 2009, sheen sightings at Ashmore, Cartier and Hibernia Reef towards the end of the incident. During the Montara response there was only one confirmed shoreline impact; a single sample of wax residue was identified on 30 October 2009 during a shoreline survey.

9 **Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:**

| AT SEA RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Dedicated Surveillance Aircraft | Effective |
| **Containment and Recovery** | Vessels with standard recovery booms etc. | Effective in calm conditions. |
| **Dispersant Delivery** | Aircraft + Dispersant Delivery Systems | Highly effective. |

10 **Environmental Impact:** One confirmed report of an oil affected sea snake and 29 oil affected birds found in the region affected by the oil spill. Of these, 21 birds died as a consequence of being oiled. No confirmed reports of affected whales or other cetaceans were received. No other confirmed reports of affected wildlife were received despite extensive aerial and water-based patrols in the area.

11 **Comment:** Based on information available to the Incident Analysis Team, overall the response operations appear to have been successful in achieving the objective to prevent oil from impacting on sensitive marine resources, in particular the marine parks of Cartier and Ashmore Reefs, and the northwest coast of Western Australia.

12 **References:**

http://www.amsa.gov.au - Response to the Montara Wellhead Platform Incident Report of the Incident Analysis Team March 2010
http://www.amsa.gov.au/environment/major-historical-incidents/Montara_Wellhead/index.asp
http://www.cedre.fr – Montara Oil Spill

### 9.7 EAGLE OTOME

1 **Date of Incident:** 23 January 2010.

2 **Location:** Sabine-Neches Waterway at Port Arthur (Texas, USA).

3 **Description of Incident:** **T**he Singapore-registered oil tanker Eagle Otome, carrying 13,000 $m^3$ of oil, collided with a barge. One of the oil tanker's tanks was damaged.

The oil spread along the Sabine Neches Waterway, moving back and forth across the waterway with changes in predominant wind direction. The majority of the spilled oil was contained within a 12 km length of the waterway. Relatively small quantities of oil extended to the south into Sabine Pass, into the wetland reserve of Keith Lake and the eastern section of the Inter-Coastal waterway, which connects Port Arthur to Galveston.

4 **Type of Incident**: Collision

5 **Quantity and Type(s) of Oil Spilt**: 1,800 t Olmeca crude oil. Olmeca it is considered a light, sour crude oil, with an API gravity of 38-39°, and 0.73% to 0.95% sulfur content by weight.

6 **On Water Response**:

6.1 **Monitoring**: U.S. Coast Guard Helicopter + Ground Teams

6.2 **Containment and Recovery**: 17 km of floating boom were deployed and up to 60 vessels (including 27 skimmer vessels) were sent onsite. The oil contained within booms was recovered with vacuum trucks.

7 **Protection and Shoreline Clean Up:** Following the on water response, Shoreline Clean-up Assessment Teams were engaged to both survey and recommend shoreline clean-up techniques to be undertaken. Shoreline clean-up commenced on 30 January and completed by 24 February.

8 **Employed Response / Remediation Techniques and Equipment Used in Tabulated Form**:

| ON WATER RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Helicopter<br>Ground Teams | Effective<br>Effective |
| **Containment and Recovery** | Numerous Vessels with recovery booms etc.<br>Vacuum Trucks | Highly Effective / 380 t recovered. |
| PROTECTION AND SHORELINE CLEAN UP | | |
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Protective Measures** | Booms | Effective |
| **Manual Recovery** | Shovels, Mops, etc. | Effective to a degree but very time consuming |

9 **Economic / Environmental Impact:** The main economic concerns were the temporary closure of the waterways, which are the main access route for barges carrying feedstock for local refineries, as well as a major import–export route for numerous petrochemical facilities that line the waterways to the northwest of Port Arthur. A rehabilitation centre for oiled wildlife was set up

due to large quantities of birds present in the area. Eight birds were captured, cleaned and successfully released.

**10** **Comment:** The volatile nature of the oil meant a significant quantity was eliminated through evaporation. After four days, 520 t had evaporated or naturally dispersed and 380 t of crude oil had been recovered. The Sabine-Neches Waterway was then partially reopened to shipping. Ecologically sensitive areas were preserved.

This incident, which was the largest oil spill Texas had known for 15 years, was in part due to heavy shipping in this area as well as to the narrowness of the channel. The waterway had not been widened or deepened since the 1960s.

**11** **References:**

http://www.cedre.fr
http://www.itopf.com
http://www.incidentnews.noaa.gov

### 9.8 DEEPWATER HORIZON

1 **Date of Incident:** 20 April 2010

2 **Location:** Gulf of Mexico; near Mississippi river delta; approx. 67 km off the coast of Louisiana. United States

3 **Description of Incident:** The Deepwater Horizon was a 9 year old, submersible, mobile, floating, dynamically positioned drilling rig**.** High-pressure methane gas from the well expanded into the drilling riser and rose into the drilling rig, where it ignited and exploded, engulfing the platform. The rig sank on the morning of 22 April. Following the explosion and sinking, a sea-floor gusher flowed for 87 days.

4 **Type of Incident:** Explosion / Well head blow out

5 **Quantity and Type(s) of Oil Spilt:** 783,800 $m^3$ crude oil +/- 10%.

The oil is a light crude oil; the model, designed to predict the behaviour of oil at sea, indicates that when spilt in the environment, 35% of this oil will evaporate, 10 to 15% will be diluted and the remaining 50% can form an emulsion containing up to 90% water.

Although it remains highly viscous, the recovered oil can be pumped. However, this requires specialised equipment specific to this type of fluid, such as appropriate pumps and a water ring injection system for pipes when the oil is not heated.

6 **At Sea Response:**

6.1 **Monitoring:** Movements of the slick were monitored using satellite imagery as well as aerial reconnaissance flights. From early May to mid-July, the aerial surveillance program carried out 297 hours of flights.

Ships, gliders below the surface and people on the ground were used to collect data.

The air, water, sediment and dispersant monitoring information were made available to the public.

6.2 **Containment and Recovery:** By the end of July, over 4,000 vessels and 540 barges had been mobilised, including a barge used to deploy over 750 skimmers of all types.
By the end of July, it was declared that they had recovered 13, 000 $m^3$ of water and oil emulsion, containing unknown quantities of water.

6.3 **Dispersant Usage:** The conditions for dispersant use very good: a continuous flow of crude oil in very deep waters, promoting wide dissemination of the dispersed oil. The treatment was applied mainly by aircraft, near where the oil rose to the surface. In early July, the volume of dispersant spread at the surface exceeded 4,000 $m^3$.

To make the most of the deep water column (1,500 m) and disperse oil where it rises to the surface, the responders innovated by injecting over 3,000 $m^3$ of dispersant into the wellhead. Meanwhile, a major system designed to measure the oil concentration in the water mass was set up to assess the effects of this technique in the environment.

Subsea injection of dispersant (Corexit 9500A and 9527A), which is a novel technique that was used first during the DWH incident, created controversial outcomes among society about its efficiency. Some of the researchers' support that dispersants can enhance the degradation rates of the expected side-cloud of micro-droplets which can further be biodegraded while others believe that the resulting low dispersion efficiency may exclude the use of solvents in the dispersant formulation. Additionally other research findings suggest that the injection of dispersant directly on the well may have contributed to the formation of continuous and some discontinuous plumes of dispersed oil at approximately 1000 to 1250 m depth and in which plumes dioctyl sodium sulfosuccinate (DOSS) surfactant of Corexit 9500 was reported to persist for months. Elsewhere it was reported that subsurface use of dispersants was found to increase dissolution of the oil which likely increases hydrocarbon concentration in subsurface waters. According to these results researchers support that dispersant application could be both beneficial by minimizing the amount of hydrocarbons reaching the shoreline and by increasing their bioavailability and harmful by increasing water column toxicity (Campo et al., 2013; Spier et al., 2013; Gray et al., 2014).

6.4 **In-situ Burning:** On 28 April, in-situ burning trials using fire booms were conducted. Due to strong prevailing winds, attempts had to be called off for several days.

On 5, 6, 17, 18 and 19 May, favourable weather conditions allowed responders to conduct successful controlled burning operations.

Following static, temporary burning operations conducted at the beginning of operations, a dynamic burning technique was implemented, consisting of gradually concentrating the oil to continue to fuel the fire using a fire boom towed by two vessels working together. The operation was conducted by trained fishermen but the technique remained dangerous.

At the end of July, 411 controlled burning operations enabled 42,000 $m^3$ of oil to be dispersed into the atmosphere. Observations showed that the combustion residues sank rapidly.

7 **Protection and Shoreline Clean Up:** The authorities made widespread use of booms to protect the shoreline. Over 3,000 km of containment and sorbent booms were deployed during response. A portion of these booms was regularly destroyed by high winds. To provide better resistance to the winds and currents rife in certain narrows between the islands of Louisiana, and to prevent the pollutant from penetrating highly sensitive marshlands, an original system was set up. Known as the rigid pipe boom, it consisted of assembling several km of metal pipes equipped with skirts and positioning them between a double row of metal stakes driven into the mud, using a crane.

In order to prevent shoreline erosion, geotextile socks filled with a mixture of sand and cement were deployed, as well as Tiger Booms, long double-chambered booms, similar in appearance to shore-sealing booms, but filled with sand. These two systems positioned parallel along the beaches were doubled up with sand bunds.

Manual and mechanical recovery using sand screeners was completed in places with sand washing machines. This technique consisted of mixing sand with hot water (without additives) to cause the oil to rise to the surface, before centrifuging the mixture to recover the “spun” sand.

After the well was captured, the cleanup of shore became the main task of the response works. Two main types of affected coast were sandy beaches and marshes. On beaches the main techniques were sifting sand, removing tar balls, and digging out tar mats manually or by using mechanical devices.

8 **Marsh Clean Up:** Techniques such as vacuum and pumping, low-pressure flush, vegetation cutting, and bioremediation were used.

- Vacuum/pumping – removes pooled oil on marsh sediment or on the surface of the water.
- Low-pressure flush – pushes oil towards collection points where other equipment can recover the oil.

- Vegetation cutting – selective plants are cut and removed so that other techniques may be employed.
- Bioremediation – a low-impact cleaning technique using microorganisms and their enzymes to facilitate decomposition of the oil.

## 9 Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:

| AT SEA RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Aircraft/Satellites/Vessels<br>All types of sampling devices | Effective<br>Effective |
| **Containment and**<br><br>**Recovery** | Booms<br><br>Booms + Skimmers | Effective – weather + sea dependant<br>Effective – weather + sea dependant<br>Oil recovered from the wellhead 132,600 $m^3$ (17%)<br>Oil skimmed from the surface 23,000 $m^3$ (3%) |
| **Dispersant Delivery** | Mainly aircraft with specialist spray systems | Moderately effective, fast tool for minimizing shoreline impact however concerns due to toxicity.<br>6% to 10% of oil chemically dispersed (62,400 $m^3$- 8%)<br>12% to 20% of oil dispersed naturally (124,800 $m^3$- 16%) |
| **In-Situ Burning** | Fire proof booms – developed during the operation. | 5% of oil burned.<br>Approx. 42,000 $m^3$ |
| PROTECTION AND SHORELINE CLEAN UP | | |
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Protective Measures** | Booms – Traditional + Sorbent<br>Sandbags + Sand Barriers + Berms<br>Floating Barriers - Barges | Mainly effective – weather + sea dependant |
| **Manual Recovery** | Hand Tools | Effective but time consuming. |
| **Mechanical Recovery** | 'Sand Sharks' + diggers + shifters | Effective. |
| **Marsh Clean-Up** | Personnel + Vacuum Pumping; low-pressure flush; vegetation cutting; bioremediation. | Mostly effective |

**10 Economic Impact:** The economic cost of the Deepwater Horizon oil spill hit the coastline industries, such as Louisiana's oyster and shrimp industry, the hardest. Tourism along the Gulf Coast has also suffered as visitors who to the coast for recreation, fishing, swimming and boating were deterred by cleanup efforts and beach closures.

**Decline in Recreation** - The Gulf Coast states rely heavily on commercial fishing and outdoor recreation to sustain their local economies. According to NOAA, commercial fisheries brought in **$659 million** in shellfish and finfish in 2008, and just over **3 million people took recreational fishing trips** in the Gulf that year. After the spill, recreational fishing from the Atchafalaya Delta to Mobile Bay was shut down from May to August, and state park closures dealt a serious blow to the parks' summer revenue.

11 **Environmental Impact:** More than 8,000 birds, sea turtles, and marine mammals were found injured or dead in the six months after the spill.

In the months following the oil spill, wildlife managers, rescue crews, scientists and researchers saw many **immediate impacts** of the oil impacting wildlife: **Oil coated birds' feathers,** causing birds to lose their buoyancy and the ability to regulate body temperature; **mammals ingested oil,** which caused ulcers and internal bleeding; **sea turtles were covered in oil**; dead and dying deep sea corals were discovered seven miles from the well.

More than 8,000 birds, sea turtles, and marine mammals were found injured or dead in the six months after the spill.

Though oil is no longer readily visible on the surface, it isn't gone. Scientists have found significant amounts on the Gulf floor, and the oil that has already washed into wetlands and beaches will likely persist for years. It is likely that the full extent of impact will not be seen for many years: **sick dolphins; sea turtles stranding at five times normal rates; unbalanced food web** and **decreased fish and wildlife populations**

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Spier C., Stringfellow W.T., Hazen T.C., Conrad M. (2013) Distribution of hydrocarbons released during the 2010 MC252 oil spill in deep offshore waters. *Environmental Pollution.* 173, 224-230

### 9.9 RENA

1 **Date of Incident:** 5 October 2011.

2 **Location:** Bay of Plenty, North Island, 19 km off the coast of Tauranga; New Zealand

3 **Description of Incident:** In the early hours of the morning the Liberian-flagged container ship grounded north of New Zealand. Immediately following the grounding light sheen was observed around the casualty, followed by reported slicks of bunker fuel stretching from the casualty.

4 **Type of Incident:** Grounding

5 **Quantity and Type(s) of Oil Spilt**: 200 - 300 t IFO 380

6 **Type(s) and Quantities of Other Substances Spilt:** The vessel was carrying 1,368 containers, 11 of which contained dangerous. Initially, 86 containers were lost overboard, including one containing dangerous goods (alkylsulphonic liquid, class 8). Oiled and non-oiled container debris washed ashore across a wide area of the Bay of Plenty to the East Cape.

7 **At Sea Response**:

7.1 **Monitoring:** Navy and Air Force helicopters conduct surveillance flights to monitor the movement of oil at sea.

Clean-up and wildlife rescue teams conducted shoreline assessments to determine the sites to be protected, identify priority areas for clean-up in the event of pollutant arrivals and define the techniques to be used.

7.2 **Containment and Recovery:** Recovery operations began at sea on 9 October, but proved to be of limited efficiency. The pollutant rapidly became very viscous, due to the temperature conditions on site.

Vessels in the harbour area worked to clean up the oil at sea

7.3 **Dispersant Spraying:** The day after the incident, dispersant spraying operations began. The dispersant Corexit 9500 was used with variable results. Sea swells of up to 4 metres make it difficult for the dispersant to work. The dispersant spraying was stopped after results proved inconclusive.

8 **Protection and Shoreline Clean Up:** Shore-sealing and sorbent boom was deployed to protect sensitive harbour and estuary sites.

Following a storm on 10 October, the first arrivals of oil were discovered on Mt Maunganui beach in the form of weathered tar balls. Clean-up teams immediately took action. On land, beaches were closed from Mt Maunganui to Maketu Point.

By the 14th, 60 km of coastline had been polluted. Beach clean-up crews collected more than 1,000t of oily waste from the coastline

## 9 Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:

| AT SEA RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Aerial Surveillance + Ground Teams | Effective |
| **Containment and Recovery** | Booms<br>Vessels with specialist equipment | Limited Effectiveness due to weather. |
| **Dispersant Delivery** | Helicopters with dispersant pods | Limited Effectiveness due to the type of oil and weather |
| PROTECTION AND SHORELINE CLEAN UP | | |
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Protective Measures** | Booms | Effective – but weather dependent |
| **Manual Recovery** | Hand Tools | Effective but time consuming |

**10 Environmental Impact:** More than 1,000 dead oiled birds and 250 live oiled birds, predominantly Little Blue Penguins, were collected, the latter treated as part of a significant wildlife response. By 22 November, the number of dead birds had reached the 2,000 mark. Pre-emptive captures of NZ fur seals and the endangered NZ dotterel were carried out by trained responders.

Scientific studies on the impact of the pollution and in particular the impact of dispersants on wildlife are underway.

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### 9.10 BONGA FIELD

1 **Date of Incident:** 20 December 2011

2 **Location:** Bonga Deepwater Oil Field in the Atlantic Ocean; about 120 km southwest of the Niger Delta, Nigeria.

3 **Vessel(s) / Installations Involved:** The Bonga floating production storage unit (FPSO) and off-loading tanker Northia

4 **Type of Incident by Primary Cause**: Leakage during oil transfer

5 **Description of Incident:** A leak in one of the transfer lines occurred during a transfer of crude oil.

6 **Type(s) and Quantities of Oil Spilt:** Around 6360 $m^3$ Bonga crude oil. Bonga is a medium gravity, low sulphur, naphthenic crude. Gravity 30.4 and Sulfur 0.23%

7 **At Sea Response**:

7.1 **Monitoring:** Aerial, satellite and vessel surveillance.

7.2 **Dispersant Spraying:** Vessel dispersant application began soon after the spill. On 23 December airborne dispersant operations commenced using a Bandeirante aircraft. The next day a C-130 aircraft flew four sorties.

8 **Employed Response / Remediation Techniques and Equipment Used in Tabulated Form:**

| AT SEA RESPONSE | | |
|---|---|---|
| **RESPONSE** | **EQUIPMENT** | **COMMENTS** |
| **Monitoring** | Aircraft, satellite and vessel surveillance | Effective |
| **Dispersant Delivery** | Vessels with spray equipment<br>Aircraft with spray systems | Effective |

9 **Comment:** On December 22, as a result of natural dissipation and evaporation (in the region's warm water and air) as well as vessel dispersant applications it was estimated that the spill had reduced in size by about 50 %.

The cleanup operation completed on 1 January 2012; satellite and aerial images confirmed that the Bonga oil spill could not have reached coastlines in the eastern Niger Delta.

10 **References:**

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