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Evaluation of the Methods for the Oil Spill Response in the Offshore Arctic Region

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Abstract

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The purpose of this thesis was to screen and analyze existing technologies for the oil spill responses, focusing on the Arctic region.

This thesis relates to the Joint Industry Project 2, run by the major oil companies, the reason of which is to determine the efficient and reliable methods for the worst possible scenarios of the oil spillages in harsh conditions of the Arctic seas. The contingency plan for the oil spill response is vital for establishing oil and gas exploration and production in the mentioned region.

The main topics discussed are the methods and technologies applied for the oil spill liquidation; however the work also describes the monitoring principles of the spills, the oil properties and the largest oil spill accidents in the Arctic seas. It also mentions regulations applied for the oil exploration in the Arctic region and the distribution of the offshore zones. All these topics are essential to understand the total picture of the upstream operations of oil and gas in the Arctic region and possible consequences of the accidents.

The evaluation of the technologies is based on many parameters, presented further in the work. One of the criteria besides the specific weather conditions, costs and limitations of the technologies is the ability to handle large inflow volumes. The volumes were calculated according to the three worst case scenarios, also presented in this thesis.

In the conclusion there is given a brief comparison between the remediation methods and technologies described.

In the end of the work it is concluded that the most reliable and promising method for the oil spill cleanup in this case is the mechanical recovery, based on the essential parameters taken into account when choosing the technology. Namely on this method the emphasis is given for the further investigations and development in this JIP2 project.

Keywords	Oil spill response, Arctic region, mechanical remediation, bioremediation, sorbents, spill monitoring, regulations, comparison of technologies, major oil accidents, Lamor, JIP2, offshore

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Table of Contents

1 Introduction

This work is based on the participation of the Lamor Corporation in the high-level Joint Industry Project 2 (JIP2). The project is sponsored by the nine oil companies (British Petroleum, Chevron, Conoco-Phillips, Eni, ExxonMobil, North Caspian Operating Company, Shell, Statoil, and Total). The programme is managed by the International Association of Oil and Gas Producers (OGP) and coordinated by an Executive Steering Committee, which includes representatives from the funding companies. [1]

The main goal of the project is to improve the technologies and methodologies for the Arctic spill responses. Many experts from industries, governmental agencies and academic and independent research organizations from different parts of the World are involved in this project. The research includes deep analytical studies, various laboratory tests and field experiments. The Arctic Oil Response JIP2 has established nine research projects over a four-year period in the areas of dispersant, environmental effects, trajectory modeling, remote sensing, mechanical recovery, and in-situ burning.

The research project, which this thesis is based for, is the mechanical recovery for the oil spill response. This part of the JIP2 large research is managed by three Finnish organizations – Lamor Corporation, Aker Arctic and SYKE, the Finnish Environmental Institute. Each of the parties is focused on its own part of the project, for example while Aker Arctic is developing and testing the new vessel designs, Lamor is responsible for the investigation of the on-board separation technologies. The project involves regular meetings of the company's representatives involved, as well as conferences with the main Steering Group, during which the following tasks and steps are being discussed. Even though Lamor Corporation is already the world's most unique company in terms of the equipment capable of combating oil spills in the Arctic conditions, there is still a huge gap for the development of new technologies that could be efficient in handling large oil spillages, especially in severe weather conditions.

This work gives a short review on the existing and developing technologies for the oil spill liquidation and gives a brief assessment on their effectiveness. Moreover, it introduces the overall picture of the oil and gas industry in the offshore Arctic region to the reader.

What makes the projects of this topic an extremely important issue internationally are the unique and untouched lands of the Arctic region, which carry so much importance for the Earth's environment and climate system. The global warming, contributing to the ice melting in the Arctic, and the oil peak consumption and need for new areas for oil production are making the North Region especially attractive for the oil companies. And although there is no detailed scientific data on what exactly and how much lies under the Arctic Ocean, mineral deposits in the Arctic seabed are estimated to hold 25% of the world's current oil and natural gas reserves. However, in order for the oil companies to get permission for the upstream operations, they are obligated to present clear and reliable emergency response plans in case of the oil spill, taking into account numerous parameters, such as weather conditions, oil type, accessibility to the area and many others, discussed further. While the Arctic environment is particularly vulnerable, the low population and infrastructure density make emergency response management extremely difficult in such remote region.

2 Properties of Oil

Oil, also referred to as "black gold" can be defined as neutral, nonpolar naturally occurring chemical substance, which is found in form of viscous liquid at ambient temperatures. Oil is immiscible with water, but soluble in alcohols or ethers. Oils have a high carbon and hydrogen content and are usually flammable and slippery. Crude oil has ranging viscosity and can vary in color to various shades of black and yellow depending on its hydrocarbon composition. Before oil is transported, re-injected or stored anywhere, it is gone through the field handling procedure, or oil processing on the production site. Crude oil can be refined to produce usable products such as gasoline, diesel and various forms of petrochemicals.

MARPOL 73/78 defines oil as petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined products (other than petrochemicals which are subject to the provisions of the Annex II of the Convention for the Prevention of Pollution from Ships). [2]

2.1 Chemical and Physical Properties of Oil

What makes oil an extremely dangerous pollutant is its composition and properties. In the oil there can be present thousands of compounds. Every crude oil type contains 200 – 300 different compounds. 50- 98% of the oil composition is hydrocarbons. The main are:

- Alkanes (paraffins), which are contained in the oil depositions in form of gases, liquids or solids. Alkanes possess relatively low toxicity and are biodegradable.
- Cycloalkanes (naphthenes) – compounds having 5-6 atoms of carbon arranged in a ring structures, are stable and very poorly biodegradable. 30 – 60% of oil composition arenaphthenes.
- Aromatic compounds constitute 20 – 40% of the oil. Among them there are volatile compounds (Benzene, toluene, xylene), bicyclic compounds (naphthalene), tricyclic compounds (anthracene, phenanthrene) and polycyclic compounds (pyrene).

Some microorganisms are able to decompose namely these aromatics. [15], [16]

In addition to hydrocarbons there are other important substances in the oil structure, such as sulfur compounds. The amount of sulfur in the oil can reach 10%. It was observed that after contact with the oil fishes and invertebrates acquire a kerosene taste, namely due to the sulfur content. Furthermore, oil contains fatty acids and nitrogen compounds. Vanadium and nickel can be present. [11]

Crude oil is separated into two fractions in the oil refineries. The gasoline fraction is sublimated at a temperature of up to 200 °C. More heavy compounds (such as kerosene, diesel and gas turbine fuels) boil out at the temperature range of 169-375 °C. At higher temperatures gas oil, fuel oil, tar and lubricants are evaporated. Asphalt remains as the precipitate. [15]

2.2 States of Oil in Water

Oil products entering the aquatic environment very soon change their initial state. In the sea oil can be present in different migration forms, such as surface films (slicks), water-in-oil and oil-in-water emulsions, oil aggregates and lumps, in dissolved forms, sorbed by suspensions and bottom sediments, or accumulated by the aquatic organisms. The ratio of these oil states of presence in the sea is determined by many factors, depending on the composition and properties of the oil, hydrological conditions and the circumstances of the oil spill. Change of states of the oil in water is called "weathering". [46]

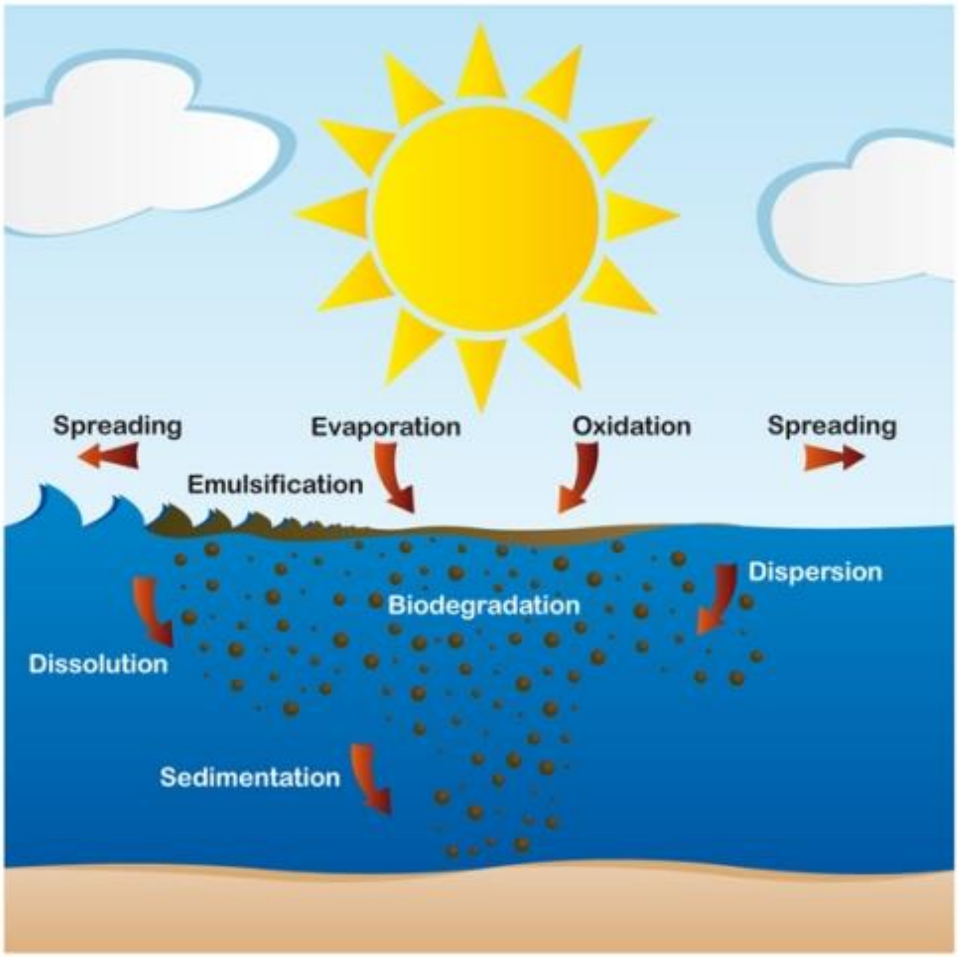

Figure 1. Weathering process of oil [46]

The oil slicks are the original form of the oil occurrence due to the spills or the oil/water emulsions breakdown. During the first hours after the oil spill mostly physical and chemical processes take place, - evaporation and dissolution. Then the decomposition of the oil by various microorganisms starts. The research done by the Shirshov Institute of Oceanology (Moscow, Russia) revealed that the formation of the uniform films is determined by the content of high-molecular compounds (resins and asphaltenes) that are poorly transformed into other states under the influence of the external factors. When the content of the asphaltens is larger than 1%, the oil hardly spreads over the sea surface area. [54]

Oil weathering in the cold environment, especially evaporation, dissolution and biodegradation, is extremely slow. Cold water affects highly the oil viscosity, making it very thick and sticky. It also contributes to forming of the oil lumps. From one hand, ice can serve as a natural containment, preventing oil from spreading and allowing more time for the response operations. However, if the oil migrates under ice or gets trapped inside the ice blocks, it makes the cleaning process extremely difficult. [54]

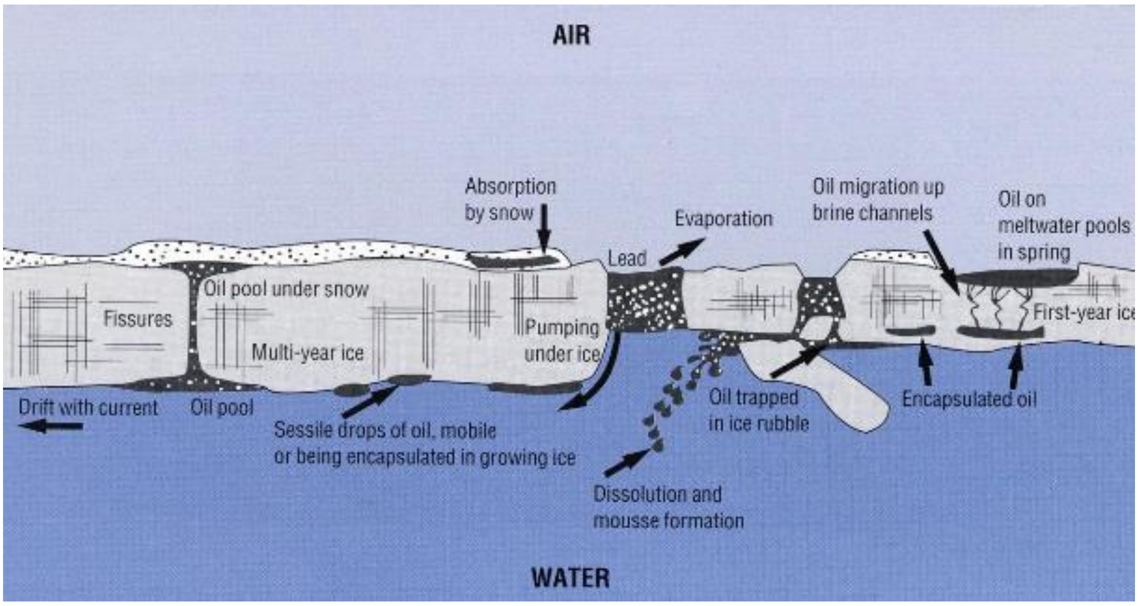

Figure 1.2 Oil and ice interaction [47]

Oil moves together with surface water with the speed of 60% of the flow rate and 2-4% of the wind speed. However, its migration becomes ten times faster due to the pressure, if being under ice. [11]

3 Risks and Probabilities of the Oil Spillages in the Arctic Region

The world consumes 14 million m^3 of oil per day, or 162 m^3 per second, and the demand is growing exponentially. In the spotlight of the global production peak, the oil companies are looking for new places of the oil and gas deposits. The main oil producers are heading now to the unexplored Arctic shelves in pursuit of the untappedoil and gas fields. However, the polar region is an extremely vulnerable area and oil production industry in these latitudes is associated with huge risks for the environment, the extent of which is difficult to assess.

Due to the severe climatic conditions the oil spillages are more likely to take place there, than in any other part of the oil extraction regions. The consequences of the pollution are more difficult to eliminate due to the lack of natural light, very low temperatures, drifting ice, high winds and the variety of other factors. The continuous series of oil spills that have been occurring in numerous countries in recent decades are only proving the fact that even in milder climatic conditions and simpler-to-reach places the response services are not effective enough in the liquidation of the oil spill consequences, especially in remote regions, such as Arctic.

One of the facts making the Arctic region prone to an ecological disaster is the slowness of the biochemical processes. The water exhibits weak mineralization (50-200 mg/L) and predominantly neutral reactions rate (pH = 6.8 – 7.2), which explains the poor ability of the microbes to digest the hydrocarbons. Moreover, the cold temperatures slow down dramatically the oil evaporation, whereas in warmer climate conditions around 50% of the spilled oil fraction is being evaporated during the first 24 hours. [11]

The Arctic Ocean is a region where the salinity of water fluctuates greatly depending on the depth and location. In most of the cases oil is lighter than water; however it can happen that the crude oil density is greater than that of the freshening Arctic water. Such phenomena can happen in the areas where the fresh rivers flow into the sea. As a result, oil entering the water environment will not necessarily float on the surface, but can emerge in the depths until it faces denser bottom water layers. The simulation results have shown that in many areas of the Arctic, especially in areas close to the large rivers, such as Siberian Rivers, the water does not hold the oil pollution on the surface. [12]

The following picture (Figure 2) shows the behavior of oil stains in various regions of the Arctic Ocean depending on the density properties:

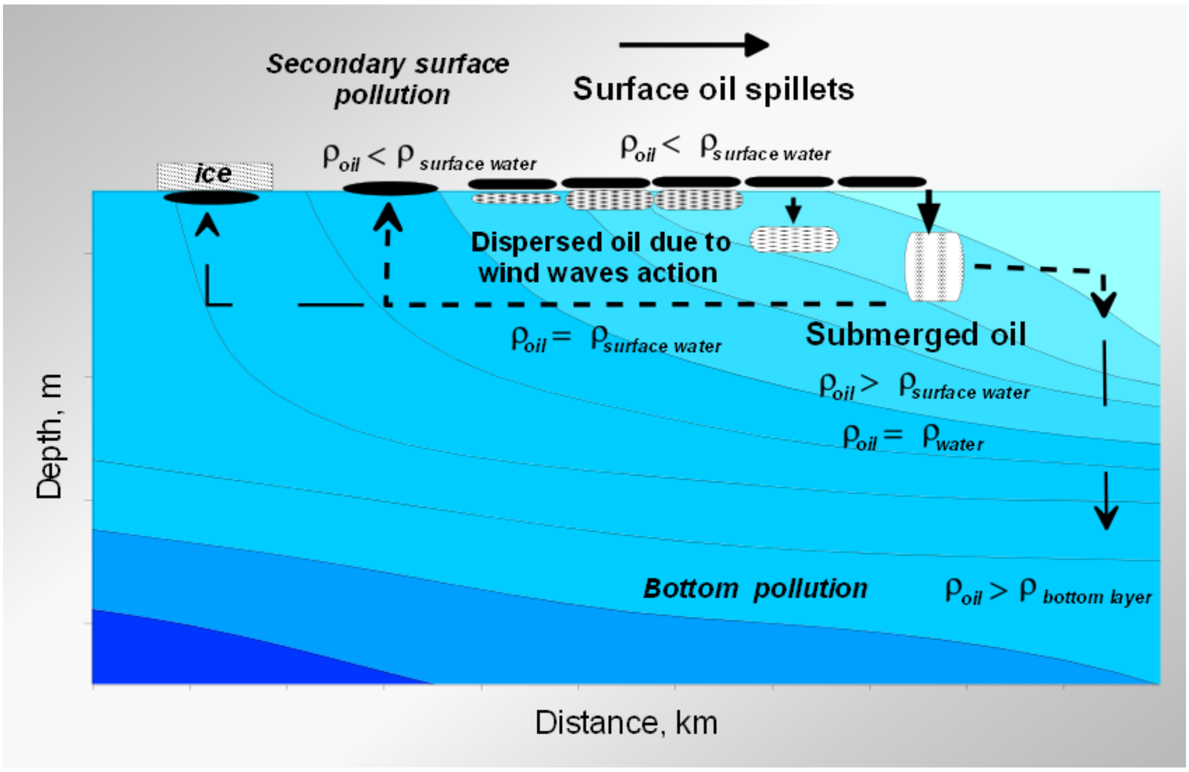

Figure 2.Virtual Oil position in the water depending on the densities of both liquids [10]

The risks of the oil spills are increased due to the wear of the old pipeline systems (up to 65% of deterioration can happen) and high accidental rate of the industrial facilities. In the Western Siberia, for instance, there are recorded over 300 accidents annually during which there is emitted more than 10 000 tons of oil each time. [11]

The newly built pipelines can also cause accidents, if not properly constructed due to, for example, improperly managed projects. This case was the reason of an oil spill in the pipeline "BCTO" on 19th of January 2010 (Transneft). The accident took place 30 km far from the Lensk city (Russia) during the works carried on to eliminate the construction defects and resulted in the spillage of 450 m^3 of oil. [3]

Figure 3.The oil spill in Lensk region, 2010. [3]

On February 3rd of the same year there happened another accident involving an oil spill in the Skovorodinsk Region which ended up in the river Bolshoy Never (a tributary of the Amur River). The ecologists claimed that the fact that both spillages happened during the winter time prevented the oil from penetrating through the snow deeply into the soil, as the oil density increases with the cold environment and its flowability correspondingly decreases. [3]

4 Largest Oil Spill Accidents in the Arctic Region

One of the largest oil pollutions in the North region was the shipwreck of the tanker "Exxon Valdez", which happened in March 1989 close to the coast of Alaska (Prince William Sound). The vessel carrying 140 000 tons of crude oil onboard hit a reef 23 km away from the port Valdez (the final destination of the Trans-Alaskan oil pipeline). The accident resulted in the spillage of over 40 tons of oil which covered 161 km^2 of water area and contaminated over 2 400 km of the coastline. The full environmental impact of this accident has not been completely evaluated by now, but it was a significant ecological disaster, as the southern shore of Alaska is a home to one of America's richest concentrations of wildlife. [13]

According to the statistical data, there were killed more than 35 thousand water birds and significant amount of sea otters; the fishing industry was severely affected. Moreover, the pollution was enhanced with the seepage of the oil into the local groundwater sources.

In the cleanup of the sea and coastal regions there were applied variety of technologies, from the pressurized hot water vapor and oil booms to the bacterial treatment, phosphate and nitrogen powders (which were polluting the environment themselves). At that time the recovery capacities of the technologies in the area were not sufficient. By all means, there was not collected more than 20% of the total oil spill. By the year 2005 it was revealed that the oil has slightly weathered out in the area along the coastal line. [13]

Figure 4.Exxon Valdez oil spill in Alaska, 1989. [4]

The oil spill near the town of Usinsk in Northern Russia (Komi Republic) of year 1994 has been considered as one of the most severe environmental disasters of the decade. The pipeline geographically located close to the Arctic Circle had been leaking for eight months, but the oil was contained within a dike built namely for this purpose. On October 1st, 1994, the dike collapsed. As a result, around 102 000 tons of oil were discharged into the Siberian tundra, contaminating over 18 kilometers. The pollution reached the Kolva River, a tributary of the Pechora River, which in turn falls into the

Barents Sea. The winter cold saved the rivers from the total disaster, as cold temperatures and high paraffin oil properties prevented its spreading by Pechora River. The oil began to sink down in the river, transforming into insoluble pellets. Although this prevented the massive deaths of fish species, years after the accident there was noticed abnormally high rate in the morphological divergence of some fish populations. And still, the environmental impact after the oil spillage was calculated to be worth 400 000 000 $. Experts estimate the spill to be eight times greater than the Exxon Valdez oil spill in Alaska. [14]

In year 2003 the Volga Oil Fuel Shipping Company "Volgotanker" opened a loading complex in the Onega Sea for the export of petroleum products. A storage tanker was placed in the Onega Gulf close to the Osinki Island, where small ships travel along the domestic waterways and transport oil to the large tankers. During a storm on 1st of September 2003, a storage tanker "Nefterudovoz-57" was crashed in the stern by another boat while trying to moor to the big storage tanker, and as a result there were tore several holes in it. The spill was first discovered by the local population after four days of the spillage. The contamination stretched 74 kilometers along the shoreline. The sticky oily compounds covered the territory. It resulted in the death of hundreds of birds. The reason of the spillage was claimed to be poor management and lack of coordination in the terminal. Furthermore, the cleanup of the pollution was carried on by untrained people and with unqualified equipment. [55]

The described events are only the small part of the whole system of the oil spills in the Arctic region. As was claimed by the researchers, most of the spills take place in the harbors during the loading or unloading of the vessels. The generally accepted global oil industry standard is "zero losses", which mean losses of 0.1% and below. However, most of the smaller spills are hard to monitor and regulate. According to data from "Greenpeace Russia", on average at least 15 million tons of oil leak out annually in Russia as a result of accidents, with the amount of oil entering aquatic ecosystems estimated to be around 4.5 million tons. [56]

Taking into account the fact that the Arctic region's environment has already been greatly affected, without much oil production development there yet, it is obviously seen that before the upstream operations are established deeper into the harsh North climate conditions, fixed oil spill response plans and reliable technologies for the spill liquidation and monitoring are needed for the prevention of the contamination.

5 Monitoring the Oil Spillages

Detection and tracking of oil is essential for determining the location, migration and behavior of the oil spill. There are different remote sensing applications for detection of oil spill pollutions on the sea surface. In the electromagnetic spectrum, oil gives different responses to radiation from different wavelengths.

By now there is no single sensor system which would meet all the needs of predicting the movement of oil in the Arctic environment. The process of monitoring the oil spillage depends on the integrated loop of real-time data provided from many different sources, such as satellites, various airborne sensors, underwater technologies and weather forecasting programs.

The airborne radars are claimed to be the most accurate for mapping the oil presence on water and its origin under normal circumstances. However, the severe weather conditions in the Arctic region can prevent an aircraft from flying over the contaminated areas. Darkness, fog and cloud cover can also constrain the sensors operation. Another drawback is that this technology is mostly efficient on a small fraction of an area. Mostly same disadvantages comply with the sensing systems on-board the vessels.

Some of the examples of the airborne sensors include: SLAR (Side Looking Airborne Radar), LFS (Laser Fluorosensor), MWR (Microwave radiometry), IR/UV (Infrared/ultraviolet line scanner), FLIR (Forward Looking Infrared), cameras and videos.
Example of the satellite monitoring systems is SAR (Synthetic Aperture Radar). [6]

One of the most important parameters for the oil pollution monitoring is oil-water contrast. This is usually defined as the signal from a patch of oil less the signal from surrounding water divided by the signal from the water. When the contrast is 0, oil cannot be detected. Negative or positive contrast allows the oil to be detected if the contrast is greater than the noise level of the sensors. [9]

Oil can be detected in thermal images, because its thermal emissivity is lower than that of water, as well as the oil temperature almost always differs from the temperature of the surrounding water. In terms of ultraviolet (UV) spectra, oil has a higher refractive index than water. This means that oil would reflect surrounding light better than surrounding water. Due to the fact that the UV and thermal infrared sensors are sensitive to different ranges of the oil thickness, reliable maps of relative oil thickness may be produced by combining the data and overlaying the images from these two sensors. [7]

For the regional ice surveillance and large scale monitoring of the sea ice conditions the satellite image data was proven to be of major benefit so far. The sea ice condition is regularly monitored using Special Sensor Microwave Imager (SSM/I) data, which has a spatial resolution of around 50 km. The sensor efficiency is independent of the weather conditions. However, it is not capable of recognizing the oil type or oil spill thickness. Another problem with this technology is that it can be difficult to distinguish on the image the oil spills from the oil slick look-alikes, natural phenomena, such as dark patches on the surface. In comparison, the infrared/optical sensor NOAA AVHRR has a higher resolution, which is about 1 km, but is seriously limited by the weather conditions (for example cloud cover). [8], [57]

Many sensor technologies are currently under development, promising to give more reliable results under specific conditions for the oil spill detection. For example, Ground Penetrating Radar (GPR) is claimed to be able to detect oil under snow, ice and within ice. Although already available commercially, it is not yet an operational tool.

Statistical information about ice conditions, in particular total ice concentration, for example in the Barents Sea and Pechora Sea is provided by the Ice Services of the Arctic and Antarctic Research Institute (AARI), St. Petersburg, Russia and the National Ice Center (NIC), Washington D.C., USA. [10]

The oil spill modeling procedure follows the path "Monitoring – Predicting – Long-term forecasting". Firstly, in the monitoring stage, the data about pollution is being collected by the means of satellite systems and/or various sensors, located and where possible, identified in terms of pollutant. The next predicting stage involves the evaluation of the capability of current programs and sea-ice models to predict the oil spill trajectories. The pollution is quantified and qualified. And finally, daily to weekly forecasts for spill response and planning are set up and the response operations for the following days are prepared. The modeled oil-spill trajectories are calculated based on the main (worst-case) spill scenarios for the Environmental Impact Assessment (EIA) and Risk Assessment. [5]

6 Methods and Technologies for the Oil Spill Liquidation

Oil spill responses should be based on assessments using the best available knowledge and technologies and deep understanding of the processes affecting the Arctic. Prior to giving the companies the permits for hydrocarbon exploration or development, governmental regulatory authorities of the Arctic coastal states require the companies to demonstrate their ability to respond to the oil spills; as well as the potential environmental impacts of industrial activities need to be evaluated. [1]

6.1 Criteria Used to Evaluate the Suitability

Oil spill response is a demanding task in many environments, and in Arctic regions it faces many different challenges from those encountered in easier-achievable regions with milder climate. A selection of the response strategy depends on a variety of factors, including the local weather and sea conditions, the presence, concentration and characteristics of ice and size and type of oil spill. For instance, the response methods can vary depending on concentration and characteristics of the ice coverage, which can be seen as a great obstacle for shipping, and at the same time as a natural containment for the oil, preventing it from spreading.

The important role in the evaluation of the oil spill response technologies play the scenarios, based on which the assumptions and calculations are made. In the case of this JIP2 project, there were taken three main worst-case scenarios as a basis for the technologies evaluation. [1]

In the first case the volume of the well blowout was estimated, which has the least probability, but having the most destructive consequences. A number used for the study was 20 000 bbls/day (3180 m3/day). The discharge and recovery rates were considered to be even, i.e. all discharged oil would be collected and treated in the same time period.

For the second case scenario there was taken a collision of two Aframax-sized crude tanks. The amount of the crude oil in two totally rapture tanks was estimated to be 188 690 bbls (30 000 m3) and the discharge in this case was considered to be instantaneous.

The third case scenario was based on the ship wreck with the release of bunker oil, which is carrying any ship. An accident of any kind to a ship could cause a bunker oil discharge. A volume of 15 725 bbls (2 500 m3) of the discharge was estimated. The mentioned volume equals 50% of the fuel tank volume of a large icebreaker. The discharge was estimated to be instantaneous.

For each of the scenarios there were estimated two cases of the inflow of oily water to be treated, having 20% of water, 75% of oil and 5% of slush ice content; and 80% of water, 10% of oil and 10% of slush content respectively.

When developing new technologies for the pollution response, one has to evaluate tens of parameters, starting from the size of the equipment and ability of it to handle desired inflow and provide sufficient degree of treatment, and ending with the realistic cost estimations.

The following is a short overview of the oil spill response technologies is presented.

6.2 Physical (Mechanical) Methods of Remediation

One of the most efficient and environmentally friendly methods of the oil spill cleanup, preferred in many countries, is mechanical recovery. It is also a largest class of the recovery techniques, which includes a broad variety of skimmers, booms and oil-collecting vessels. The mechanical methods do not involve chemicals and therefore do not require special permissions to be implemented, unlike dispersants, which use is limited or even forbidden in many regions. The mechanical oil recovery systems are provided to the oil spill location by the specially designed and equipped spill response vessels.

6.2.1 The Booms

The booms serve in water areas mainly as a technology to contain the oil spill and prevent it from spreading, which facilitates the further cleaning steps.

The main containment boom formula used for the planning equipment requirements for the response is:

B = 1.25 x H, where:

B is the amount of boom in meters required to contain the free floating oil;

H is The amount of oil spilled in m^3. [36]

The majority of booms designs fall into two categories: curtain booms and fence booms. Curtain booms consist of a sub-surface skirt supported by an air or foam-filled flotation chamber (freeboard) usually of circular cross-section. Fence booms have flat cross-section, which has a vertical position in the water by means of integral or external buoyancy. [23]

Some booms types can be defined into a category of special purpose booms, such as ice booms for light ice conditions, sorbent booms, tidal seal booms and fire booms. Fire booms, for example, are specifically constructed to withstand very high temperatures generated by burning oil. The fire booms can be of either fence or curtain design. [23]

Figure 5.Lamor Inflatable Light Boom (ILB), a curtain boom type [48]

6.2.1.1 StructureoftheBoom

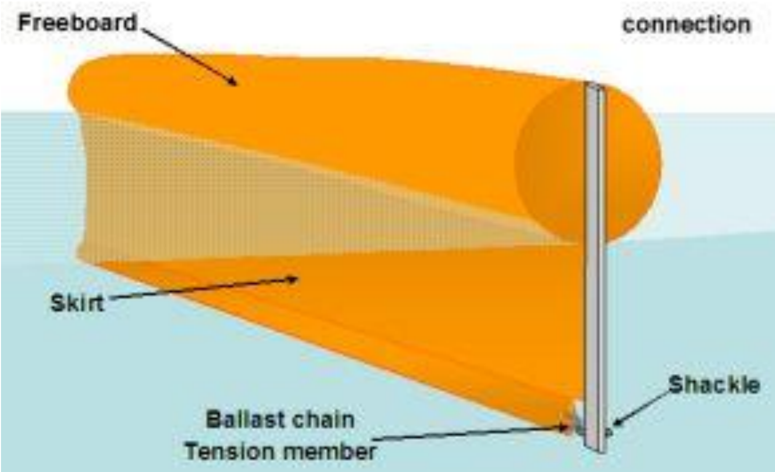

Figure 6.Structure of the most typical boom. [36]

A boom consists of several main component parts. Freeboard is the part of the boom which stays above the water surface. Its function is to prevent oil from being washed over the boom. Freeboard can be filled with air, or rigid. The skirt is the continuous portion below the water, which has the purpose of containing the oil. It is often considered that the skirt's effectiveness depends on its depth. However there is a optimum skirt depth for different applications. Ballast is the weight added to the skirt to maintain the barrier in a position perpendicular to the surface of the water. It can be water, or steel and lead weights. The connection is a device that links together the necessary amount of the booms. It can have many different shapes and can be made of various materials. [23]

6.2.1.2 Limitations

The use of the booms is strongly limited with the rapid water currents. The way, in which the oil escapes, i.e. the oil relationship to water velocity is as much a function of oil type as of boom design. The following pictures represent the typical boom failure modes. The arrows indicate the current direction. [23]

Figure 7.Entrainment [23];

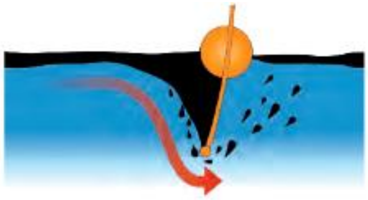

Figure 8.Drainage failure [23];

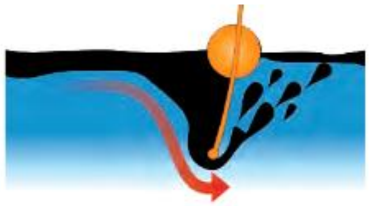

Figure 9.Critical accumulation [23]

Figure 10.Splash-over [23];

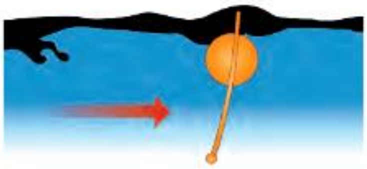

Figure 11.Submergence [23];

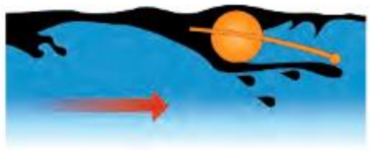

Figure 12.Planing [23]

Entrainment (Figure 7) happens with viscous oils. It is caused by the turbulence, when the droplets of the oil are carried down under the boom. Low viscosity oils are prone to the drainage failure (Figure 8), during which the oil particles separate from the accumulated oil and flow under the skirt of the boom. The oil may migrate under the boom also when the critical thickness of it reaches the limit (Figure 9).

A typical situation in case of the high winds is the splash-over (Figure 10), when the oil migrates with the water movement over the boom. The case of the submergence and planing of the boom (Figure 11 and Figure 12 respectively) may be caused either by wind, or by insufficient buoyancy provided. [36]

Even though the booms are constantly developing, and there is a wide variety of designs invented, there are no booms that could be efficient in the conditions of the concentrated ice and high storms. During storms the oil does not float on the surface, but becomes mixed or emulsified with water due to the turbulence and submerged down the water column. [23]

6.2.2 The Skimmers

Usually, skimmers are used together with the booms. The skimmers remove oil from the water surface without causing changes in its physical or chemical properties and transfer it to the storage tanks onboard the vessel. In case of the winter conditions with presence of the ice on water, often there is no need to use the booms, because the ice serves as a barrier against oil spreading.

A variety of skimmer designs have been optimized to operate efficiently in different weather conditions, as well as in the Arctic sea with high concentration of ice. Although designs vary, all skimmers rely on specific gravity; surface tension and a moving medium to remove floating oil from the water surface.

The skimmers can be classified according to many different parameters. For example, if classify them by the design characteristics, skimmers can be divided in two classes: oleophilic and non-oleophilic. [23]

Oleophilic skimmers employ such materials that have strong affinity for oils rather than water. The oil adheres to the surface of the material, which lifts the oil from the water surface as it rotates. Once separated from the water surface, the oil is scraped or squeezed off the oleophilic material and allowed to drop into a sump from where it is pumped to the storage. Oleophilic materials are usually made from various forms of polymers, although metal surfaces have also been shown to be effective. They can be of different shapes, such as disc, drum, belt, brush or rope-mop. [22], [24]

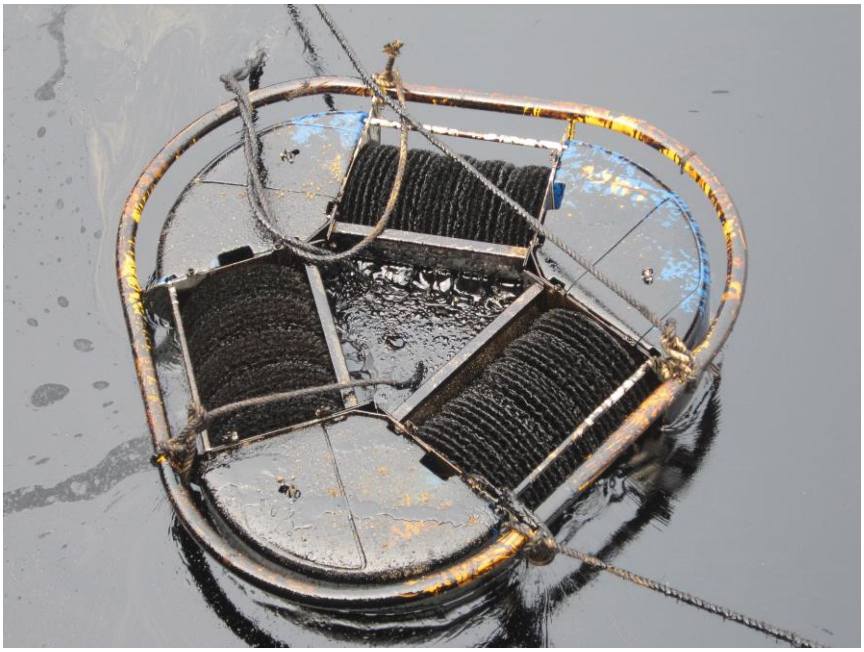

Figure 13.Lamor Multi Skimmer (LMS), designed with interchangable brush, disc and drum modules, free-floating [37]

Figure 14.Lamor LFF100 free floating skimmer, using brushes [37]

Among the non-oleophilic skimmers the suction skimmer has the simplest design, although its performance is mostly inefficient, especially in the sea waters, as even small waves would result in collection of large amounts of excessive waters. Greater efficiency of oil separation can sometimes be achieved by integrating a weir device to the suction hose. Weir skimmers use gravity to separate oil from the surface. By positioning the lip of the weir part at about the same level as the oil-water interface (this can be adjusted on-the-run), the oil flows over the weir to be pumped out with minimal amounts of water. The weir skimmers are well-suitable for oil having low viscosities. However, there are no weir skimmers which could be effective in steep waves. [24]

Figure 15.Lamor Weir Skimmer (LWS) 1300. [37]

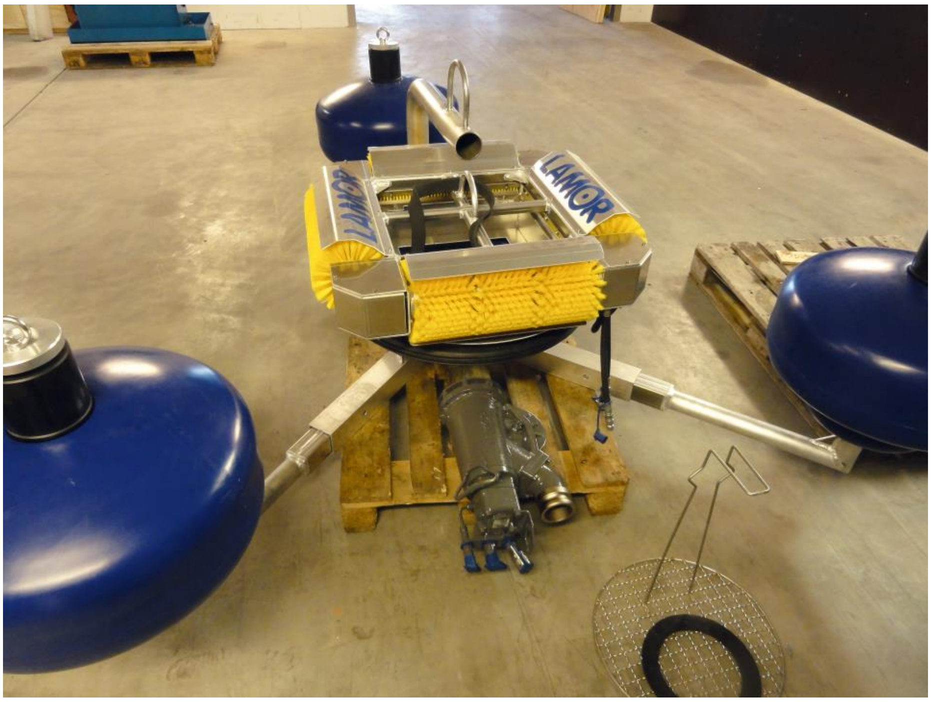

Figure 16.Lamor Weir Skimmer in combination with a Lamor Brush Adapter, designed to fit to it for better performance. [37]

Many skimmer designs have been adapted to cope better with waves and rougher seas. The rotating belts technique, for example, can be partially lowered beneath the oil-water interface to reduce the influence of the waves.

Figure 17.Lamor Bow Collector (LBC), using a chain brush. [37]

The skimmers can also be classified by the operation principle. They can be self-floating (stationary and self-propelled), crane-operated or vessel-integrated. In the conditions of high ice concentration, like in the Arctic Ocean, more attention is given to the crane-operated and vessel-integrated types of the skimmers, as ice can prevent the devices from free-floating. [58]

An example is the Lamor Arctic Skimmer, which can be deployed by a crane. It includes ice deflection pipes and rotating brush wheels for the oil separation and collection in its design. The Arctic Skimmer can also be equipped with warm water steam injection system to improve recovery in extreme cold conditions. [37]

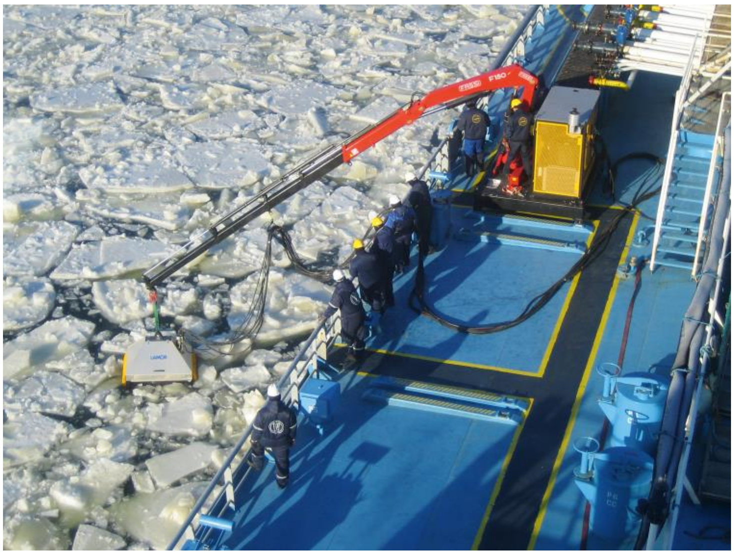

Figure 18.Lamor Arctic Skimmer. [37]

One of the most efficient skimmers, which has shown great performing characteristics in ice conditions (in recent laboratory tests in Ohmsett, 2013) is the Lamor Oil Recovery Bucket (LRB), which is also operated by a crane onboard the vessel. The skimmer uses the brush wheel technology. The recovered oil is claimed to normally contain less than 5% of water. [37]

Figure 19.Lamor Oil Recovery Bucket. [37]

One of the most important factors when selecting the skimmer type, in addition to the weather conditions and the effects of the waves, are the type (viscosity) of the spilled oil together with the levels of debris. A further limiting factor is the pump capacity (especially with high viscosities), affecting the distance over which the oil can be moved to storage. [58]

6.2.3 The Vessels

Oil-collecting vessels are motorized vessels which are integrated with some oil-recovery technologies and can perform an independent collection of the oil spill on the water. They are considered to be the most reliable possible technology in the future due to their ability to handle large volumes of the inflow to be treated with minimal negative impact on the environment, compared to other technologies. Most of the vessels combine several oil spill response technologies onboard.

6.2.3.1 LORS

An example is the Lamor Built-In Recovery System (LORS), which consists of fixed jib arms, sweeping booms, oil transfer pumps and control panel with or without radio remote control. Most of the latest deliveries of the system are fully hydraulic operated, which eliminates the need of manual assembly and disassembly, making deployment and retrieval of the technology faster and safer.

Figure 20.LamorBuil-In Oil Recovery System. [37]

The oil is carried by the flow through the recovery channel, where the oil is efficiently separated and removed from the flow with the brush skimmer. The system is highly deployed worldwide; however it is not applicable in the conditions with concentrated ice. [37]

6.2.3.2 The LOIS recoveryvessel

Another example of integrated system is the vessel with an ice vibrating unit Lamor Oil-Ice Separator, commonly called LOIS.

The working principle is that the vibration caused by the device installed on side of the vessel causes the ice blocks to submerge under its body, where they are moved upside down or rotated by the grid movements. Due to gravity force the oil particles are then release from under the ice and floated on the water surface, where they can be collected. The oil is pumped through the brush system to the response vessel, where it is separated from the water. The pieces of the ice entering the system are transferred back to the sea by conveyor. [37]

Figure 21.Lamor Oil-Ice Separator unit installed to fairway service vessel Letto (SYKE) [49]

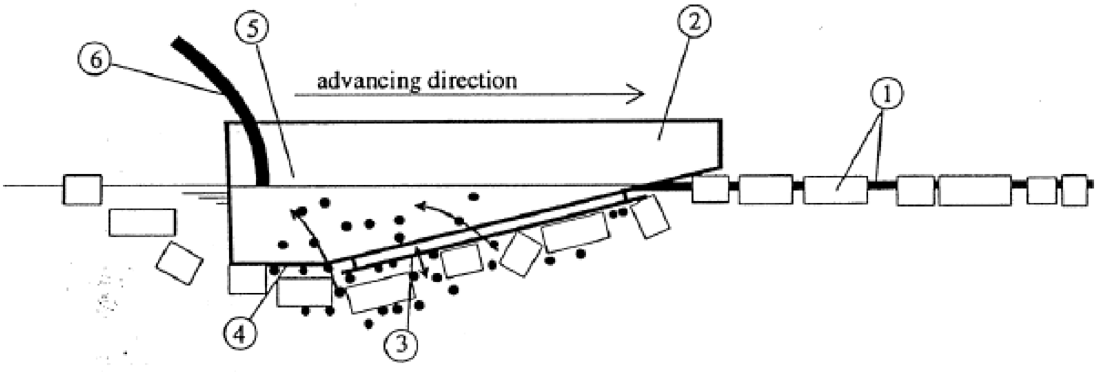

Figure 22. LOIS unit [49]

The working principle of the device can be observed from the picture above (Figure 22). When oil is captured between the ice blocks (1), the recovery unit (2) can separate oil from the ice pieces with the help of the vibrating perforated plate or grid (3). The grid makes the ice blocks vibrate and rotate, which allows the il particles to flow on the surface, namely to the space inside the recovery unit where oil enriches on the water surface. Then, the skimmers can be used to collect oil inside the recovery unit (6). [49]

The device has been developed by the Lamor Corporation together with the Finnish Environmental Institute, SYKE. According to the tests carried out with this technology, it operated quite efficiently, however there were some problems encountered, for example with the ice cubes accumulation. [37]

6.2.3.3 An Oil/Water/Ice Separation Unit

A technology having similar working principle to the previous one was developed by Pauli Immonen; and the owner of the patent is the company Mobimar. The big difference is that this technology has not been built in the real scale, neither tested, unlike the previous two cases.

The ship consisting of three units (Figure 24) is equipped with the separation device (Figure 23), which forces the ice blocks to move between the middle part (SH1) and the side parts (SH2, SH3). The separation device can be, for example, a grid situated alongst the vessel. Density of the oil which needs to be collected is less than density of water. This makes the oil products, separated from the ice, float through the separation unit's grid to the surface of the water. The oil can then be collected in the container and treated further onboard the vessel. [38]

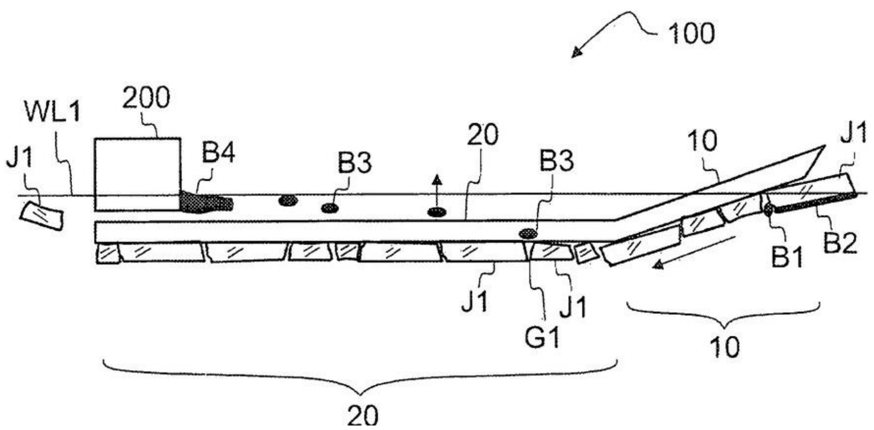

Figure 23. Side view of the separation unit [50]

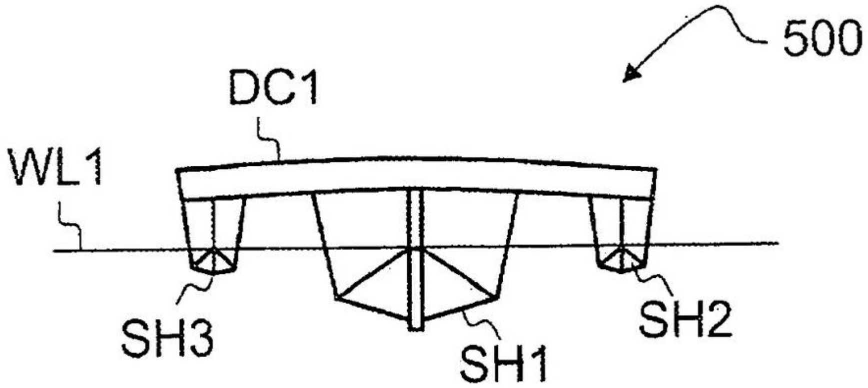

Figure 24. Front view [50]

6.2.3.4 A New Generation Ice Breaker NB508

Arctech Helsinki Shipyard is currently constructing the world's most advanced and innovative ice-breaking multipurpose emergency and rescue vessel for the Russian Ministry of Transport. The special asymmetric design allows the vessel to maneuver efficiently in all directions. The vessel has the Lamor in-built recovery system (LORS) onboard, suitable for operations in heavy weather conditions. It is also equipped with a deck for the helicopter, an off-shore crane to move the loads and a boat that is designed to handle the booms. [51]

Figure 25. The icebreaker NB508, ARC 100 concept [51]

The ice-breaker is capable of moving easily in various directions due to its special design. The vertical side of the hull is utilized as a sweep arm, and when the vessel moves forward sideways through oil spills, the oily water is guided through a hull hatch to the brush skimmers and tank compartment. [37]

6.3 Chemical Methods

The following section gives a brief description of the chemical methods for the oil spill liquidation.

6.3.1 Dispersants

The main aim of dispersants application is to break down the oil slicks into small droplets, which submerge into the depth and become rapidly diluted. This prevents oil from spreading further on the surface and reaching the shores, where the consequences are the most devastating. The small droplets of the oil in water are more easily degraded by naturally occurring micro-organisms. [52]

Each dispersant molecule contains both oleophilic (attracted by oil) and hydrophilic (attracted by water) parts. When sprayed onto oil, the solvent transports the dispersants to the oil/water interface where the molecules re-arrange so, that the oleophilic part is in the oil and the hydrophilic part is in the water. This reduces the surface tension of the oil/water interface, which together with wave energy results in droplets separating from the oil slick. To achieve the effective dispersion, oil droplets must be in range of 1μm to 70μm, with the most stable size less than 45μm. [29]

The dispersants are generally classified according to their generation and type. The first and second generations, the very first dispersants, are no longer used due to their toxicity and development of new technologies. The third generation dispersants can be divided into class 1 and 2. Both classes are concentrate dispersants and contain a mix of two or three surfactants with glycol and light petroleum distillate solvents. The most typically used surfactants are non-ionic (having neutral charge, such as fatty acid esters and ethoxylated fatty acid esters) and anionic (having negative charge, such as sodium alkyl sulphosuccinate). The difference is that the 2^{nd} class dispersants are typically diluted with sea water prior to use and require a large dosage to be effective. [52]

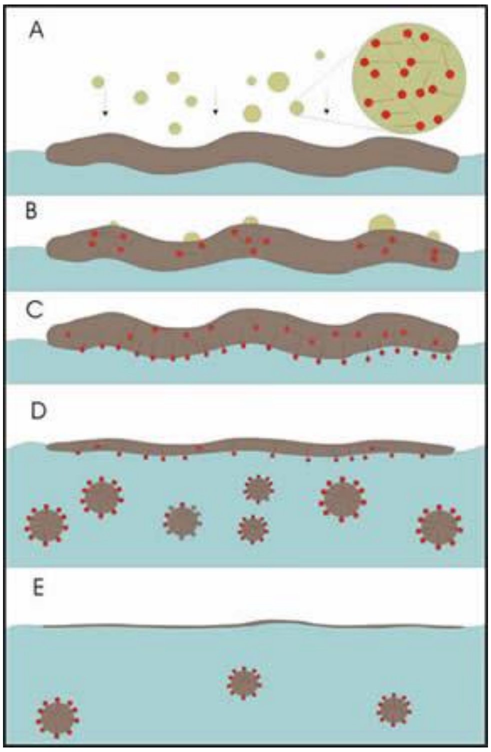

Figure 26. Schematic representation of the working principle of dispersants [52]

As can be seen in the picture above (Figure 26), the dispersant is firstly sprayed to the oil spill (A); the surfactant is then carried into the oil slick (B). The surfactant molecules penetrate to the oil/water interface (C) and the small oil droplets are separated from the slick (D). The separated droplets are then dispersed by the turbulent mixing (E).

Dispersants are mostly effective in the warm regions, as their efficiency depends on the oil density, which increases with the decrease in temperature. With very high density oils the dispersants are not effective. [52]

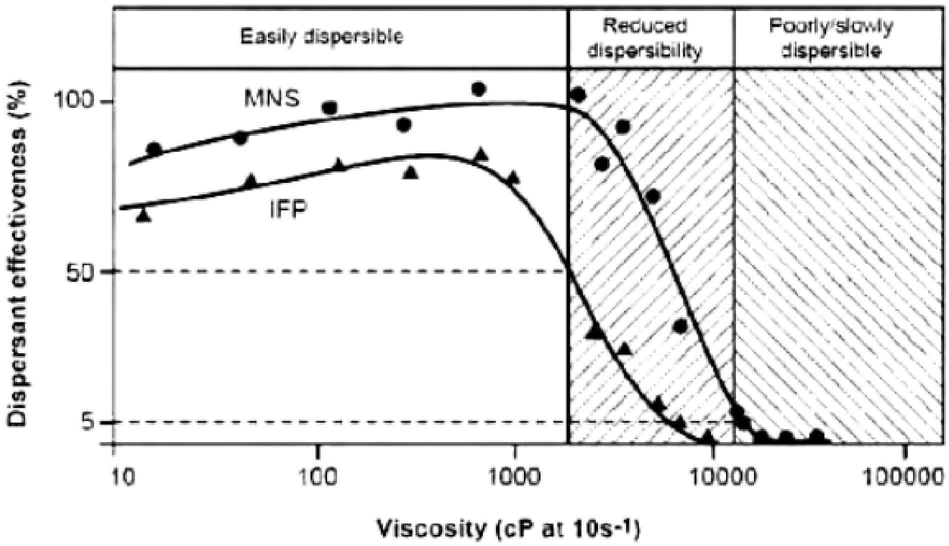

Figure 27.Dependency of the efficiency of dispersants from the oil viscosity. [27]

The waves and the wind energy is of great importance for the dispersion process, as it demands mixing energy to overcome the surface tension at the oil/water interface. Natural dispersion can occur in moderately rough seas. For example, severe storm conditions in Shetland, UK, during the grounding of the tanker Braer in 1993, caused the very low viscosity oil to be dispersed naturally, with minimal impact to nature. However, the process of natural dispersion may slow down or stop due to several factors, such as oil weathering with time (when for example evaporation takes place) or emulsification (which results in water-in-oil or oil-in-water emulsions). Dispersants can be spread to the spill from the vessels or aircrafts. [27]

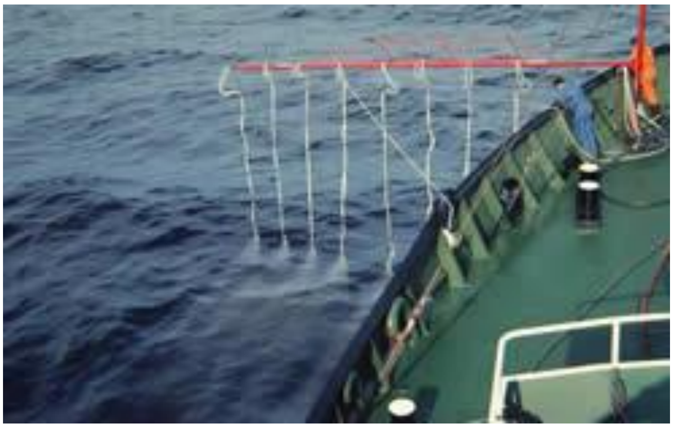

Figure 28. Application of dispersants from the vessel [52]

Figure 29. An Air Tractor spraying dispersants from the under-wing sprays [52]

Some of the disadvantages of applying dispersants is that when the oil is dispersed into the water column, it may affect some marine organisms which would not otherwise be reached by oil. Moreover, the time span between the oil leakage and the dispersants application generally should not exceed 24-72 hours due to the oil weathering. The dispersion must be very precise to avoid the negative impact on the marine environment. [29]

6.3.2 Solidifiers

Solidifiers are polymers that are oleophilic (have physical attraction to the oil), that is enhanced by Van der Waals forces, which are based on the theory that molecules are attracted to those that have similar structure. Non-polar hydrocarbon polymers are attracted to non-polar petroleum hydrocarbons. They are soluble in the excess liquid (solvent), but with continued application they increase viscosity of the oil to the point that it forms a solid mass. [30]

Solidifiers can generally be applied for the small oil spill liquidation or in the shoreline areas. The purpose of the solidifiers is to prevent the oil spillage from spreading by making it more viscous (solidifying it). The solidified oil does not sink and must be collected afterwards by, for example, mechanical methods. In case of heavy viscous oil the solidification time becomes larger and the effectiveness reduces dramatically. As a result, the solidifiers may not penetrate to the oil/water interface, but only solidify the surface of the spill, which would make the mission of cleaning more complicated. [59]

There are three types of solidifiers: polymer sorbents, cross-linking agents and polymers with cross-linking agents. The types have unique characteristics and properties. Polymer sorbents, for example, simply adsorb oil into spaces between polymers. Oil becomes held into these spaces by weak forces. Another type, the cross-linking agents and the polymers with cross-linking agents, form chemical bonds between molecules in the oil. They may react quickly and thus result in incomplete solidification if not rapidly mixed. [30]

There are certainly needed more studies regarding solidifiers, as there is not enough information regarding many aspects, such as toxicity for the environment and clear dependency of the weather conditions. Moreover, if used in large scale oil spills, solidifiers can be extremely costly. [59]

6.4 Sorbents

Sorbents are materials that soak up oil from the water. There are two types of sorbents: adsorbents and absorbents. Adsorption attracts the oil particles to the surface of the material, whereas absorption allows oil to penetrate into the material through the pores. In order to be effective, the sorbents have to also be hydrophobic (repel the water). [59]

Sorbents can be either natural organic (peat moss, feathers), natural inorganic (clay, sand) or synthetic (polyethylene, nylon). There is wide variety of materials able to serve as sorbents, but nowadays the largest use has the melt-blown polypropylene, which is able to absorb 25 times more oil than its own weight. [31]

Sorbents are generally applied as the post-cleaning technology and in the shallow regions. Most often sorbents can be reused many times, which makes them very environmentally friendly.

Figure 30. A boom filled up with polypropylene sorbent, applied to collect oil [23]

Although nowadays sorbents are of great interest for scientists and oil industry, being relatively cheap and very environmentally friendly, this technology still possess numerous limitations. Sorbents are claimed to be inappropriate technology for use in the open sea and inefficient with heavy fuel oil. Moreover, they are bulky to store and transport. [31]

6.5 Thermal Remediation

Thermal remediation means in-situ burning of the oil spill immediately after it is contained with the fire-resistant booms. Incineration allows removing oil from the water surface in a fast and economically efficient way; especially in case when there is limited access to the spill and other methods cannot be applied. In addition to the high rate of the oil removal (up to 95%), the in-situ burning minimizes the need for recovery and storage of the collected oil. [28]

Figure 31. In-situ burning test conducted with the JIP [53]

Although the method is claimed to be one of the most efficient, it is also considered as environmentally harmful. As by-products after the incineration process there are generated ashes, which submerge to the seabed and high level of greenhouse gases (carbon dioxide), released to the atmosphere. As a result, the water pollution is substituted with the air pollution. The smoke produced by the oil combustion on the sea surface is mainly composed of carbon dioxide (CO2), 95%. Particulates commonly account for about 5% to 10% of the original volume burned. About half of the particulates are soot, which is responsible for the black appearance of the smoke plume. Minor amounts of gaseous pollutants are present, such as carbon monoxide, sulphur dioxide, and nitrogen oxides. In addition, some polynuclear aromatic hydrocarbons (PAHs) are emitted, but the amount released is less than the amount in the original oil. [33],[35]

The difficulties involved with this technology are inability to be used in the harsh weather conditions, because the booms become ineffective in the oil containment. Likewise, thermal remediation cannot be easily used with weathered oil (when not immediately after the spill) and with emulsified oil. To overcome this problem, oil can be thickened with the herding agents(the oil layer is required to be at least 2 to 3 millimeters thick). The more weathered or emulsified the oil is, the greater the thickness required for ignition is.After one day from the spill, the water content of emulsified oil can be as high as 70 percent. The water can be removed from the emulsions either through the boiling of the water out, or by breaking the emulsion chemically. [28]

6.6 Bioremediation

The biological method is usually applied like a secondary treatment on-site, after the mechanical or chemical methods, when the layer thickness of the oil is not less than 0.1 mm. There are only few microorganisms capable of digesting the petroleum hydrocarbons. These are mainly bacteria of the genus Pseudomonas, and some species of fungi and yeasts. The more finely divided the oil is, the more accessible it becomes to other types of oil-eating bacteria. Bioremediation typically involves biostimulation, which means the addition of the rate-limiting nutrients in order to accelerate the biodegradation of the oil. Namely, if order for the microorganisms to digest the carbon, the significant amount of nitrogen and phosphorus, which are essential ingredients of protein and nucleic acid, is needed. Maintaining sufficient nutrigen amount is considered the biggest challenge. [25]

With sufficient oxygen saturation of water at a temperature of 15-20º C the microorganisms are capable of oxidizing oil at 2g/kv.m the surface per day. However, in the cold weather conditions the process of bioremediation becomes extremely slow and petroleum products can remain in the water for over 50 years, whereas in warm environment the process requires weeks to effect the cleanup. Therefore, in Arctic region this method is completely inefficient. [33]

6.7 Innovations

Many alternative technologies together with the old, but developed ones constantly appear in various researches associated with the oil spill response methodologies. Some of them are considered extremely promising.

6.7.1 Laser Technology in Oil Spill Response

As one of the alternative methods for the oil spill liquidation there was recently proposed laser radiation technology with a wavelength of 10.6 microns. Such radiation is hardly absorbed by the oil, however, in opposite, very well-absorbed by water. The penetration depth of this radiation's wavelength is in range of 100-300 microns for the oil, depending of its type; and 10 microns for water. [39]

The first in the world electro-ionization CO2 laser technology, operating on a steam of air, was claimed to be developed by the Russian scientists. The working principle of the CO2 laser is as follows. Laser radiation is absorbed by the thin layer of water which is in direct contact with the oil layer, so that water is heated up rapidly and turns into a stable state. The superheated water causes a gaseous explosion which leads to the breakage of the heat contact between oil and water, which prevents the burning of the oil layer in normal conditions. The oil is thrown up to the height of 30-40 cm and broken into smaller particles. When mixed with the air, it forms combustible mixtures, which leads to the instantaneous ignition of the oil. [39]

The laser radiation is not only characterized by having the heat effect on the materials, but it possesses number of unique properties, such as coherent and monochromatic properties of the high-quality optical radiation flux. Such properties lead to the possible development of the mobile applications for the oil spill liquidation by the laser technology. [39]

The laser cleaning methods can be successively used in the final stages of the oil spill response, as it is mostly effective with a thin layer of the oil.

6.7.2 Microsubmarines

Nano-engineers from the University of California-San Diego have found recently a new application for micro-devices, which were previously used only in medicine. The devices were designed to collect oil drops from contaminated water and transport them into collectors. [26]

The microsubmarines have been coated with a special alkanethiol polymer chain, which makes the devices extremely water repellant, but attractive to oil. As the little robots move around in the spill, the particles of oil strongly attach to the end of the chain. By changing the type of the polymer chain used, the robots can be optimized for targeting various types and densities of the oily contaminants. To navigate the devices and make them transport oil to the collection vessel, the magnets have been used. [26]

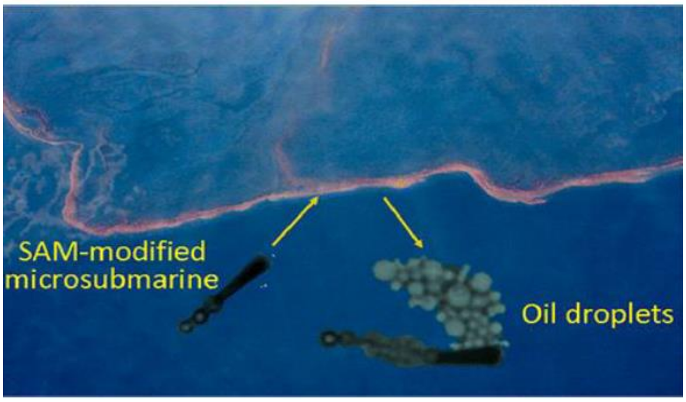

Figure 32. Modified microsubmarines capturing oil [26]

6.7.3 Magnets

Researchers from the MITUniversity (Massachusetts, USA) have developed a new technique for magnetically separating oil and water that could be used to clean up oil spills. According to the working principle of the technology, water-repellent ferrous nanoparticles would be mixed with the oil, which could then be separated from the water using magnets. The researchers envision that the process would take place aboard an oil-recovery vessel, to prevent the nanoparticles from contaminating the environment. Afterwards, the nanoparticles could be removed from the oil and reused.

The magnets are permanent magnets, and they arre cylindrical. Because a magnet's magnetic field is strongest at its edges, the tips of each cylinder attract the oil much more powerfully than its sides do. In experiments the MIT researchers conducted in the laboratory, the bottoms of the magnets were embedded in the base of a reservoir that contained a mixture of water and magnetic oil; consequently, oil could not collect around them. The tops of the magnets were above water level, and the oil attached to the sides of the magnets, forming beaded spheres around the magnets' ends. [42]

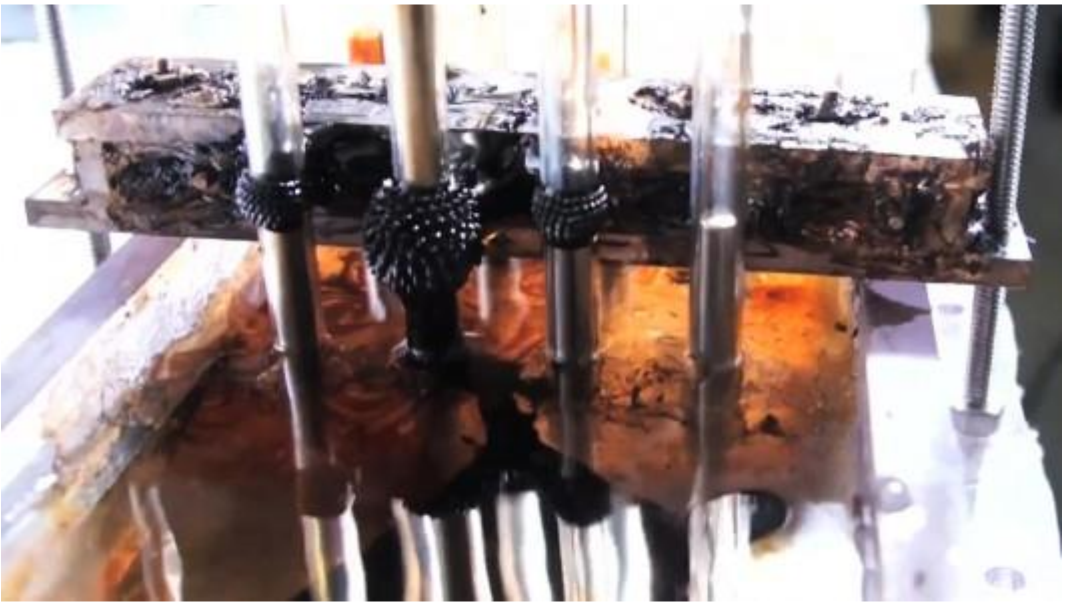

Figure 33. The oil is attracted to the tips of the magnets [42]

One of the biggest advantages of this technology (except high efficiency of separation claimed by the scientists) is very little need in electrical power and maintenance. The system can be manufactured on a large scale. It was also said that the oil/water separation takes much less time than, for example, general gravity separation technologies. However, following real-scale experiments and analysis are needed to make eliable conclusions. [42]

Another technology using magnets was presented in the Italian Institute of Technology (Center for Biomolecular Nanotechnologies). The core of the separation method is a novel composite material based on commercially available polyurethane foams functionalized with colloidal superparamagnetic iron oxide nanoparticles and submicrometerpolytetrafluoroethylene particles, which can efficiently separate oil from water. [43]

Untreated foam surfaces are inherently hydrophobic and oleophobic, but they can be rendered water-repellent and oil-absorbing by a solvent-free, electrostatic polytetrafluoroethylene particle deposition technique. It was found that combined functionalization of the polytetrafluoroethylene-treated foam surfaces with colloidal iron oxide nanoparticles significantly increases the speed of oil absorption. Detailed microscopic and wettability studies reveal that the combined effects of the surface morphology and of the chemistry of the functionalized foams greatly affect the oil-absorption dynamics. In particular, nanoparticle capping molecules are found to play a major role in this mechanism. In addition to the water-repellent and oil-absorbing capabilities, the functionalized foams exhibit also magnetic responsivity. Finally, due to their light weight, they float easily on water. Hence, by simply moving them around oil-polluted waters using a magnet, they can absorb the floating oil from the polluted regions, thereby purifying the water underneath. This low-cost process can easily be scaled up to clean large-area oil spills in water. [43]

In the Chinese Technological University here was recently introduced a fast and selective removal of oils from water surface through core-shell Fe2O3@C nanoparticles under magnetic field. These nanoparticles combined with unsinkable, highly hydrophobic (water-repelling) and superoleophilic (attracted by oil) properties, could selectively absorb oil up to 3.8 times of the particles weight while completely repelling water. The oil-absorbed nanoparticles are quickly collected in seconds by applying an external magnetic field. More importantly, the oil could be readily removed from the surfaces of nanoparticles by a simple ultrasonic treatment whereas the particles still kept highly hydrophobic and superolephilic characteristics. Experiment results showed that the highly hydrophobic Fe2O3@C nanoparticles could be reused in water-oil separation for many cycles. [40]

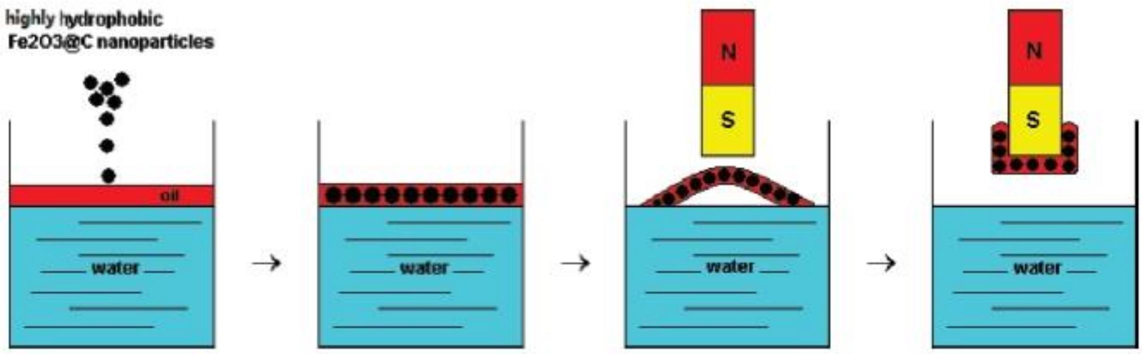

Figure 34. Removal of oil from the water surface under magnetic field [40]

This approach possess the advantages of easy production and storage, fast distribution and collection, low cost, good recyclability, high resistance to corrosion, thermal stability, and environmental friendliness. [40]

6.7.4 Paper-mill Sludge

In Slovenia scientists are testing a new material which is thought to be able to absorb extremely large amounts of oil spilled on the water. The material they are testing, inside booms, is both ecologically friendly and very efficient because it is made of paper mill sludge.It can absorb around four times its own weight, which is about the same as other existing absorbents. But what makes it different is that it's much cheaper than the alternatives. Moreover, when the calorific value of the absorbed substance is high, the material could be used as a secondary fuel source. [41]

Figure 35. Paper mill sludge [41]

Finland and several South American countries have already expressed interest in starting their own production of the paper mill sludge absorbent. Along with the paper-mill sludge there have already been used many different materials as absorbers in the booms, for example hair and manure.

6.7.5 Seaswarm

More and more technologies are developed using renewable technologies. As an example, recently the Massachusetts Institute of Technology (MIT), USA, has introduced an innovation -Seaswarm, a device for cleaning the oil spills. The Seaswarmis a robot consisting of a conveyor belt covered with a thin nanowire mesh which absorbs oil and repels water. The robot uses two square meters of solar panels for self-propulsion which makes it independent in operation.

The fabric is claimed to be able to absorb up to twenty times its own weight. By heating up the material, the oil can be removed and burnt. After, the nanofabric can be reused. [44]

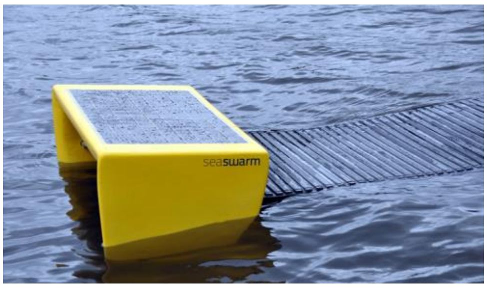

Figure. The Seaswarm [44]

Moreover, the device operates using wireless communication and GPS and can ensure an even distribution over a spill site. The MIT researchers estimated that a fleet of 5,000 Seaswarm robots would be able to clean a spill the size of the gulf in one month. [45]

7 Policies and Regulations Regarding the Offshore Hydrocarbon Activities in the Arctic area

The Arctic Council is a high-level intergovernmental forum, which consists of the eight Arctic States: Canada, Denmark (including Greenland and the Faroe Islands), Finland, Iceland, Norway, Russia, Sweden and the United States. Six international organizations representing Arctic Indigenous Peoples have permanent participant status in the Council. The Arctic Council was established in 1996 to promote sustainable development in the environmental, social and economic sectors within the Arctic Region; as well as promote cooperation, coordination and interaction among the Arctic States. [21]

7.1 Territorial Claims of the Arctic

The Arctic region can be understood as the region lying within the Arctic Circle, North of an imaginary line drawn at latitude 66° 33´North, and, therefore, consists of the Arctic Ocean and parts of Canada, Denmark (via Greenland and the Faroe Islands), Finland, Iceland, Norway, Russia, Sweden and the United States of America (U.S.).

The status of certain regions of the Arctic seas is in dispute for many reasons. Canada, Denmark, Norway, the Russian Federation and the United States all regard parts of the Arctic seas as national waters (territorial waters out to 12 nautical miles (22 km)), also called internal waters. [17]

The Third United Nations Convention on the Law of the Sea (UNCLOS), which came into force on November 1994, has introduced a number of provisions, related to the off-land waters. The convention has set the limits of various areas, as well as defined such issues, like exclusive economic zones (EEZs), continental shelf jurisdiction, deep seabed mining, the exploitation regime, protection of the marine environment and many others, very closely related to the oil operations in the Arctic seas as well. [18]

According to the UNCLOS, the exclusive economic zone of the coastal country is considered the aquatic zone of 200 nautical miles (365 kilometers) from the baseline. (The sea baseline is normally the territory of the low-water line, but when the coastline is deeply indented or is highly unstable, straight baselines may be used.) The extention of the EEZs is allowed in case, if the borders of the continental shelf (natural prolongation of the land territory) do not end in the area of 200 nautical miles. However, it may never exceed 350 nautical miles. In this territory only one country has the right of harvesting the minerals and non-living materials in the subsoil. [18]

It can happen that two countries lay up claim at the same region of the seabed. An example is an argument between Canada and the USA. The USA insists that the Arctic sea border cannot be an extension of the land, but has to lay down perpendicularly to the coastal border of the two countries. Therefore, the United States has signed, but not yet ratified the UNCLOS. [19]

Similar arguments are carried on around the islands and the ridges. In year 2001 Russia, for instance, has claimed its right over more than 1.2 millions km^2 of Arctic. In year 2007 the flag of Russian Federation was officially established on the seabed in the North Pole. However, under international law, no country currently owns the property rights of the North Pole or the region of the Arctic Ocean surrounding it. Likewise, Denmark has expressed a desire to claim ownership of the North Pole. There are also disputes regarding what passages constitute "international seaways" and rights to passage along them. [18]

7.2 Policies Regarding the Offshore Hydrocarbon Activities in the Arctic Area

Overall, nowadays there are big gaps in the coverage of the entire Arctic region regarding regulations of the offshore hydrocarbon activities. As was stated by the WWF International Arctic Programme, there are no global standards and recommended practice and procedures for the whole Arctic region apart from those discussed in the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). [17]

The OSPAR Convention and the decisions, recommendations and other agreements adopted by the OSPAR Commission only apply to part of the Arctic marine area, namely the North-East Atlantic. Likewise, the competence of the ISA (International Seabed Authority, established by the Law of the Sea Convention) and its decisions only apply to parts of the Arctic region. [17]

In my opinion, the "Arctic offshore Oil and Gas Guidelines" and other outputs of the Arctic Council are not strict enough and not compulsory in part of jurisdiction. Even though the guidelines are revised regularly, there is no proof on whether they have been followed or not.

The International Maritime Organization (IMO) has also established a list of regulations regarding the response actions, such as the global International Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC 90), which is complemented by the regional 1993 Nordic Agreement and the 1983 bilateral agreement between Canada and Denmark. [20]

According to MARPOL, Annexes 1 (Prevention of Pollution by Oil) and 5 (Prevention of Pollution by Garbage from Ships), the Arctic is not considered a special area, unlike Antarctic, which means it does not require a higher level of protection than other areas of the sea, apart from its extreme climatic conditions and vulnerability. The concentration of the bilge water or any other oily water processed by the onboard oil/water separators should not exceed 15 ppm of oil concentration before being discharged. However, MARPOL regulations are not generally applied to the oil spills liquidation technologies. In case of the oil spill any purification degree is considered as acceptable. There are no particular requirements regarding the concentration, as the main purpose is to minimize the environmental negative effects of the accident. A discharge of oily water in an oil spill response situation is considered a national decision in the area of jurisdiction of the discharge. [2]

8 Conclusion

For years, the response to major offshore oil spills has proven not adequate enough because oil often spreads rapidly to enormous areas and is deposited over broad coastal regions. Even when containment and spill response systems can be mobilized in time, they are usually insufficient to deal with the very large volumes of the spilt oil. In Arctic region, one of the most remote regions in the World with not developed enough infrastructures, is far more difficult to reach the place of an accident.

Arctic is a unique region with its climate and resources, and therefore the oil spill response technologies need to be determined for it separately and with great care taken. No single existing remediation method can be considered as a reliable and efficient enough approach for the spill liquidation in the harsh changing weather conditions including high seas, concentrated ice, extreme cold temperatures and lack of natural light.

In order to be prepared to deal with the large offshore oil spills, response planners need to investigate and evaluate in terms of Arctic conditions as many tools and techniques as it is possible to get. Mechanical removal, dispersant application, bioremediation and in-situ burning are important response techniques that have been applied and tested regularly. However, all of them have unique advantages and disadvantages, as well as potential in different situations.

For example, it is clear that in-situ burning is the fastest and most cost-effective mean of dealing with spilt oil on water; however its use becomes dangerous and highly inappropriate in some circumstances, such as in presence of high winds and waves, abundant in Arctic. Moreover, it is not the most environmentally friendly technique, which is an extremely important factor for the vulnerable Artic zone and its living organisms. For the same reason the use of chemical methods, such as dispersants, is not in favor. Even though the chemicals used today are much less toxic than those used in the past, they still possess long-term environmental effects, especially in the regions where the natural processes are slow downed.

Increased emphasis is being placed on the use of mechanical methods of oil spill response methods, particularly the specially-designed vessels, which would quickly and safely eliminate large quantities of oil efficiently, with minimal environmental impact and without the need for large temporary storage systems on location, which means involving the on-board oil/water separation technologies.

The mechanical recovery is one of the subjects where the largest room for more development is present. By now, the mechanical technologies seem to be the most reliable in terms of the ability to clean up the oil from under ice sufficiently, as well as be operated remotely without special maintenance required, which is very important in the cold climatic conditions.

Undoubtedly, there is a need for further developments and research regarding the mechanical remediation, which has to take into account all the evaluation parameters. Unless there is established a clear contingency plan with qualified remediation techniques able to handle efficiently large oil spills, the oil exploration and production in the Arctic should not be proceeded.

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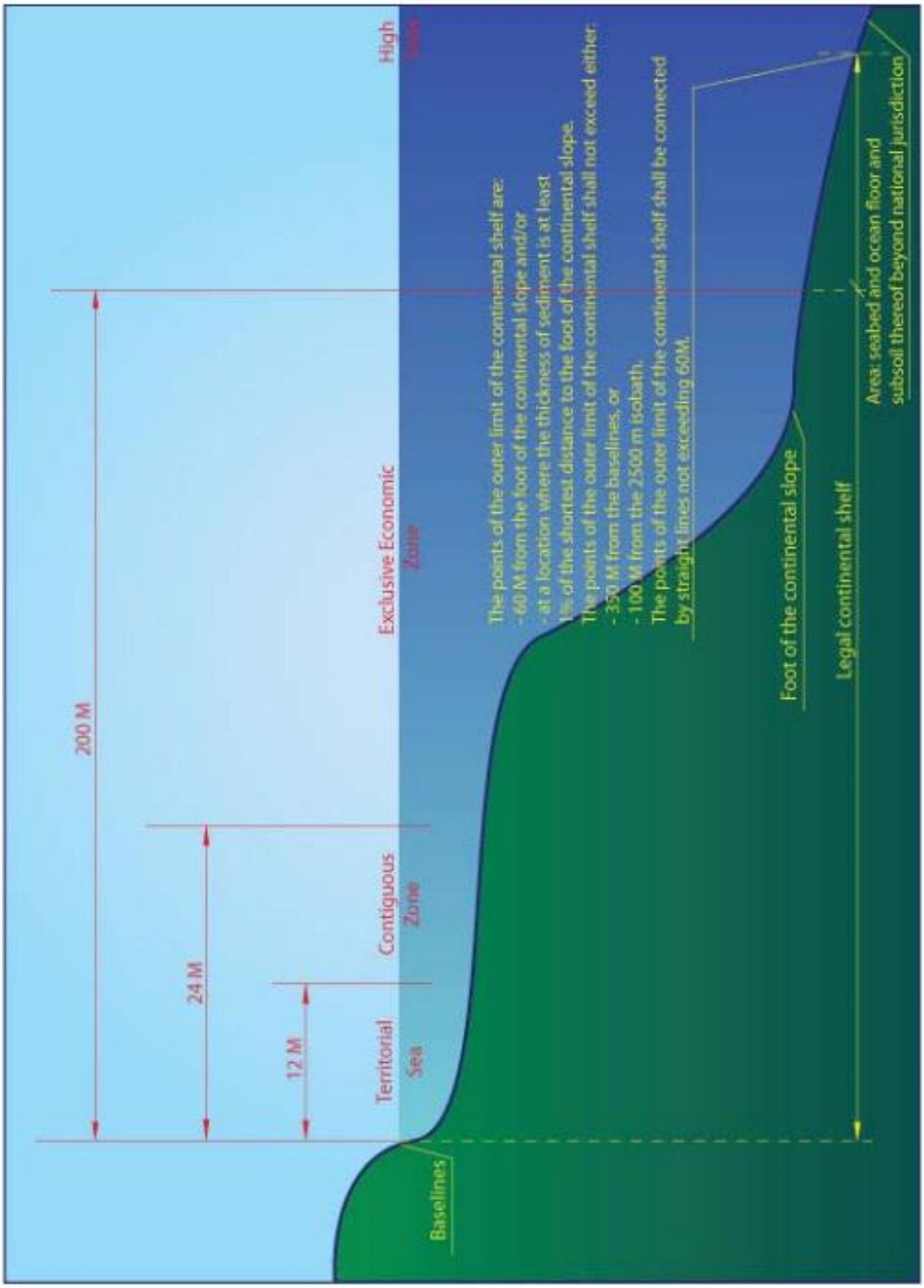
Extended Continental Shelf Constraint Lines



Map of the Arctic Region