**Oil appearance and film thickness**

Aerial surveys are the primary method of detecting or supervising oil slicks on the sea surface. To enable surveyors to make practical use of aerial observations, knowledge about oil appearance is very important. The film thickness is necessary information for the estimation of the total volume of the oil spilled and for the evaluations during combat operations. For thin slicks (<50-200 µm) appearance codes applicable and common for all oils are established to estimate film thickness through the oil films appearance on the sea surface (BAOAC, News no.1 2002). For thicker slicks (>200 µm), knowledge about the specific oil is necessary to fully utilise observations from the air because different oils properties will yield different development in oil appearance and film thickness.

**Colour variations of emulsions with weathering**

As evaporation and emulsification take place in the thicker part of the oil slick, the colour of the slick will change. The colour of the emulsion is oil-specific. A selection of emulsions in the meso-scale flume is depicted below. The pictures show significant differences in appearance – both the colour and the “state” - for the different oils at the same weathering times. These differences are due to differences in oil properties. The emulsion colour can in some spill situations give additional information about the weathering of the emulsion.

**Terminal film thickness**

To enable evaluation of the volume of the combatable part of the slick, estimations of the film thickness of the oil/emulsion is necessary. Experience from field experiments has shown that emulsified oils will not spread to infinity. The spreading will retard and stop, and the slick will obtain a “terminal” film thickness. The thickness of the slick is oil-specific, and dependent highly on the rheological properties of the oil/emulsion. Typically, emulsified crude oils may have a “terminal” film thickness of few millimetres, while experiences from recent incidents with very heavy fuel oils (e.g. Baltic Carrier, Erika and Prestige), oil thickness’ of 20-50 cm was observed at sea.

To be continued on the next page.
Environmental monitoring

SINTEF Applied Chemistry delivers a range of services in environmental monitoring of soil, sediment, water and biota. We aim at performing state-of-the-art services for:

- Using statistical and modelling tools for planning environmental monitoring
- Sampling methodology, including long-term exposure of caged organisms and use of adsorbents
- Low-level trace analysis of metals and organic compounds, covering all major pollutants
- Remedial investigation and feasibility studies for heavily polluted areas
- In-situ monitoring methodology - a cost-effective way of obtaining screening data with high resolution
- Natural resource damage assessments
- Environmental forensics, e.g. oil spill identification

Assessment of environmental effects is based on reliable tools for determination of the environmental load of the different oil components. For regular discharges of pollutants, it is important to monitor potential adverse effects in the vicinity of the discharge points. This is a challenging task due to the low concentrations of the target compounds in different environmental compartments.

Acute spills (e.g. blowouts or ship accidents) require extensive monitoring of the environmental load in water, sediment and biota in addition to monitoring the direct effects on biota in the influence area. Preparation of a quality plan, monitoring plan and use of state-of-the-art sampling methods for water, sediment, and biota, sample handling and sample storage are important key features for a successful monitoring program.

Marine Environmental Technology is a major contributor to environmental monitoring of discharges from the Norwegian oil industry, and has also operated internationally in monitoring programs following acute oil spills.

Chemical analysis

The department of Marine Environmental Technology has as a result of re-organisation in SINTEF Applied Chemistry strengthened its analytical chemical services. The group of analytical chemistry now counts 8 people, and delivers a wide range of analyses covering low-level trace analysis of metals, anions, organic compounds, in addition to a high number of specialised analyses.

Our strength is the near coupling to research and monitoring activities, resulting in updated analytical procedures of all relevant parameters. After 50 years of close contact with both national and international industry, SINTEF have a good understanding of the needs and challenges of the industry with respect to environmental issues.

We offer a whole range of services in analytical chemistry:

- Simple and standardised analysis on commercial basis
- Tailored analysis on difficult parameters / matrixes
- Larger analysis programs
- Lab-partner contracts
- Field activities, including planning, modelling, sampling, analysis and environmental management advisory services

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Appearance code continued

A non-emulsifying light crude oil or a condensate will spread fast and have a thin film thickness. Work is ongoing at SINTEF to assess the possibilities of predicting the film thickness of oil slicks.

A spreading test is being developed, and the “terminal” film thickness of different crude oils will be studied in order to establish oil film thickness for different categories of oils.

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The Norwegian Ministry of Petroleum and Energy has initiated a series of studies on the possible consequences of all-year petroleum activities in the regions from Lofoten and into the Barents Sea. The main objective of the studies is to examine if year-round petroleum activities can be conducted in ways that are not harmful to other activities (fisheries) or to the environment. The findings from the various consequence studies will form the basis for a final report that will be presented to the Norwegian Parliament later this year. Marine Environmental Technology has recently been granted contracts on three of these studies. The first, related to the possible adverse effects in the water masses of accidental discharges, is conducted in co-operation with two other institutions, Det Norske Veritas (DNV) and Alpha Miljørådgivning AS. The second study deals with regular discharges from drilling operations and oil production, while the last one is a study of the potentials and limitations of oil spill counter measures in the region.

In 2002 an entire full-scale MORICE recovery system was successfully tested at Ohmsett, New Jersey. Here all the functions and components could be tested simultaneously while operating in oil and broken ice. Nearly 200 tons of ice was transported to Ohmsett and stored until it was deployed in the tank. The prepared ice field was comprised of a mix of ice sizes. The test oil was non-emulsified Hydrocal 1200.

In general the MORICE recovery system is sound, but industrialization should include a redesign of the entire system. Scaling up the concept would make it possible to increase the capacity, improve the capability to process ice and recover oil, and to work in more severe ice conditions. To encourage private industry to develop a commercialized unit, the reports from the project are open.

Further research to develop a technique for separation of the recovered mixture into oil and ice/water is highly recommended. This important issue was not addressed in the project.

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New Norwegian regulations state that the physical and chemical properties of oils in production should be measured regularly. The oils should be further characterised if the analysis shows differences in the oil of concern. The characterisation should be performed with respect to weathering properties and fate in the marine environment.

Marine Environmental Technology department do re-check studies of oils where weathering studies earlier is performed. The re-check study is a limited study and include physical and chemical properties of both the oil and a weathered samples, and also emulsion properties.

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Consequences of petroleum activities in the Barents Sea

The Norwegian Ministry of Petroleum and Energy has initiated a series of studies on the possible consequences of all-year petroleum activities in the regions from Lofoten and into the Barents Sea. The main objective of the studies is to examine if year-round petroleum activities can be conducted in ways that are not harmful to other activities (fisheries) or to the environment. The findings from the various consequence studies will form the basis for a final report that will be presented to the Norwegian Parliament later this year. Marine Environmental Technology has recently been granted contracts on three of these studies. The first, related to the possible adverse effects in the water masses of accidental discharges, is conducted in co-operation with two other institutions, Det Norske Veritas (DNV) and Alpha Miljørådgivning AS. The second study deals with regular discharges from drilling operations and oil production, while the last one is a study of the potentials and limitations of oil spill counter measures in the region.

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Oil re-check studies

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Biodegradation of oil in seawater at low temperatures

In the water column natural biodegradation of oil compounds is a major weathering process determining the fate of petroleum hydrocarbons. Weathering processes strongly influence the bioavailabilities and impacts of hydrocarbons to marine biota. Highly toxic compounds may have low or moderate impacts due to rapid degradation, while compounds with moderate toxicity may have significant impacts due to their persistence. The weathering processes, including biodegradation, in ice-free seawater, are generally temperature-dependent. However, with permanently low temperatures “cold-loving” microbes (psychrophiles) will be important for biodegradation.

We have studied the influence of seawater temperature on oil compound biodegradation. Thin films (thickness 7-10 µm) of a paraffinic oil, immobilized on hydrophobic fabrics, were submerged in normal seawater, and n-alkane depletion was measured at 20, 5, or 0°C, with oil-degrading microbes pre-cultured at homologue temperature. The separation of biodegradation and dissolution processes (another important weathering process) were measured in normal and sterilized seawater. The results showed that dissolution of n-alkanes was negligible, while biodegradation was significant at all tested temperatures, as shown in Figure 1.

Typically oil-degrading bacteria first appeared in the water phase, and then established on the oil-water interface, as shown by the arrows in Figure 2. These bacteria are currently being identified by cloning and sequencing strategies.

![Figure 1](image1.png)

**Figure 1.** Depletion of C\textsubscript{10} - C\textsubscript{36} n-alkanes from Fluoretex fabrics immobilized in seawater at 0, 5, or 20°C during an experimental period of 80 days. n-Alkanes were analysed by GC-FID.

![Figure 2](image2.png)

**Figure 2.** Polymerase chain reaction (PCR) amplification of 16S rRNA genes of bacterial communities during biodegradation in static systems with 0°C seawater temperature. The members of the communities were detected as separate bands by denaturing gradient gel electrophoresis (DGGE). The arrows show oil-degrading bacteria in seawater and on oil films (Fluoretex fabrics) during a degradation period of 8 weeks.

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