

Degradation of oil in relation to the Barents Sea

J. H. Pedersen¹, T. Kristiansen², D. A. Karlsen¹, J. E. Lie³ & H. Brunstad³

¹Department of Geosciences, University of Oslo, P.O. Box 1047 Blindern, N-0316 Oslo, Norway

²Department of Biology, University of Bergen, P. O. Box 7800, N-5020 Bergen, Norway

³RWE Dea Norge AS, P.O. Box 243 Skøyen, N-0213 Oslo, Norway

Introduction

Since 1965, over 900 petroleum exploration wells have been drilled in the Norwegian North Sea, while around 70 exploration wells has been drilled in the Barents Sea since 1980. New attention to the Barents Sea as a potential oil and gas province may result in several new exploration wells to be drilled in the near future.

Major oil spills in the past have been related to transportation of oil, rather than from oil exploration activities. The biggest risk for oil spills in the Barents Sea is therefore probably leakage from oil tankers.

Oil spilled on the sea surface will within hours change composition and properties due to physical and chemical processes, such as spreading, dispersion, evaporation,

weathering, emulsification, water washing and oxidation. Wave action and temperature are key factors.

Long term biological processes include break-down of oil by bacterial oxidation of petroleum. These processes altogether increase the viscosity and gravity of the spilled oil, due to removal of the light components in the oil.

In this study we demonstrate how degradation alters the composition and properties of oil, and that some identifiable specific organic molecules are still contained in the oil residue even long time after the spill. These molecules may be used to identify the source of an oil spill.

Oil spill

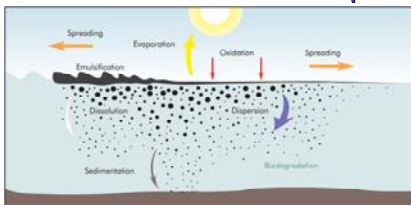


Fig. 3. Processes acting on an oil spill. Within hours and days after an oil spill much of the oil slick is lost due to spreading, evaporation and dissolution. Biodegradation and sedimentation of degraded oil residue are long term processes, going on for years after the spill. Figure from ITOFF (2005).



Fig. 4. Three different occurrences of heavily degraded spill oil along the south coast of Norway. Note matchbox for scale.

Study area

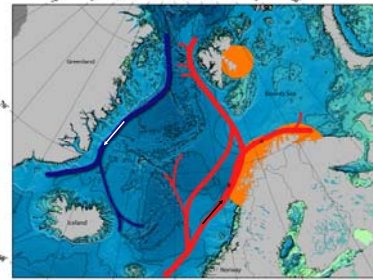


Fig. 1. Simplified map of the current system in the Norwegian and the Barents Sea. Warm, saline, Atlantic water flowing northwards is indicated with red lines, while cold, less saline water flows southwards from the Arctic Ocean. The currents system of the North Sea is characterized by strong currents and tides, that enables a quick turnover rate of the water masses compared to the Barents Sea, where water mass movements are in general slower. Important spawning, and nursery areas for cod and herring larvae are shown in orange. Two potentially important oil positions; A - Goliath and Snetthv, and B - Nordland VII, are situated in the orange areas.

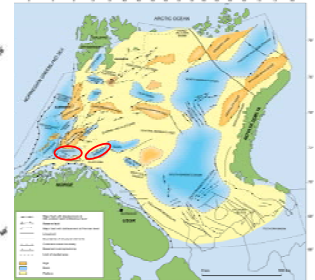


Fig. 2. Geological structural map of the Barents Sea. The red circles designates known oil and gas regions of the Norwegian Barents Sea. Modified from Johansen et al. (1992).

Samples and methods

In this study, two spill oils from the south coast of Norway were analysed, together with two oils taken from onshore natural oil seeps in Sweden. A set of non-degraded oils (fresh oil) from reservoirs in the North Sea and Barents Sea were included in the study for comparison.

The degraded spill oils were carefully scraped off the rock surface where they were found (Fig. 4), and subsequently dissolved in dichloromethane. All samples then underwent the following analytical procedures: GC-FID, GC-MS, TLC-FID chromatographic analysis and carbon 13 (¹³C) isotope analysis.

Results

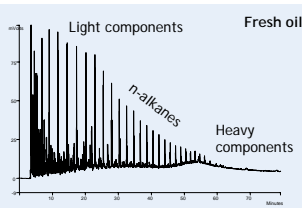


Fig. 5. GC-FID chromatogram of fresh, unaltered oil from the Oseberg oil field, Norwegian North Sea. Note the abundance of saturated compounds (n-alkanes).

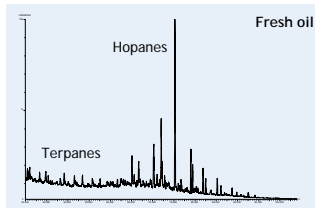


Fig. 7. GC-MS (m/z=191) fragmentogram of fresh, unaltered oil from the Oseberg oil field, Norwegian North Sea. Fossil organic molecules (terpanes and hopanes) are plentiful. The distribution of such molecules are used for characterising the oil, i.e. they act as the oils "fingerprint".

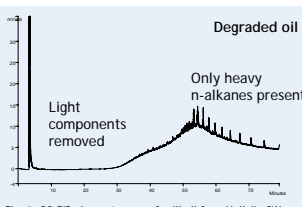


Fig. 6. GC-FID chromatogram of spill oil from Hellvik, SW coast of Norway. Saturated and aromatic hydrocarbons, like n-alkanes, benzene and toluene are removed by bacteria and water washing.

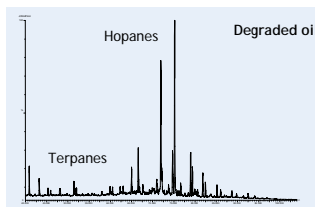


Fig. 8. GC-MS (m/z=191) fragmentogram of spill oil from Hellvik, SW coast of Norway. Specific molecules like terpanes and hopanes are abundant despite severe biodegradation and water washing, making it possible to identify the origin of the oil.

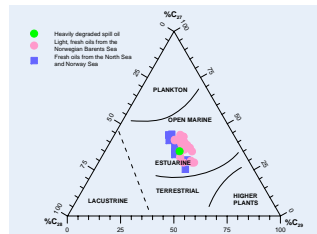


Fig. 9. The distribution of regular steranes in a crude oil indicates the organic origin of the oil. The steranes are little affected by degradation, allowing identification of spill oils.

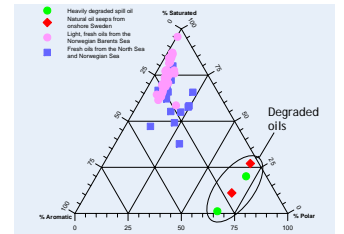


Fig. 11. A ternary diagram of the main components of crude oil shows how the degraded oils have lost saturated hydrocarbons and are enriched in the polar fraction.

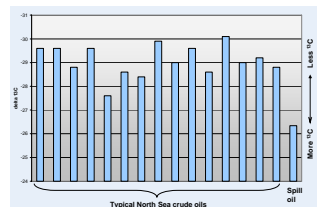


Fig. 10. Degraded oils are enriched in the ¹³C isotope, due to bacterial and chemical fractionation favoring removal of the lighter ¹²C isotope.

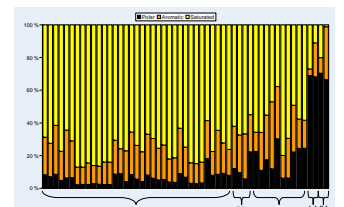


Fig. 12. The bulk composition of oils broken down into polar, aromatic and saturated compounds. The degraded oils (a and b) are severely depleted in saturated compounds.

Conclusions

- Oil residue from degraded oils are enriched in ¹³C isotopes, heavy, long chained components and polar hydrocarbons (rich in nitrogen, sulphur and oxygen) due to physical and biological removal of lighter components in the oil
- Specific organic molecules in the oil survive heavily degradation, and are easily identified
- The source of an oil spill is possible to identify by analysing the molecular composition of oils, i.e. by analysing fossil biologically derived compounds in the oils (biomarkers)
- Cod (*Gadus morhua*) and Norwegian spring spawning herring (*Clupea harengus*) drift with the Barents Sea Atlantic Current or the Norwegian Coastal Current from the spawning areas along the coast of Norway, into their nursery grounds in the Barents Sea. Capelin (*Mallotus villosus*) spawns along the northernmost coast of Norway, and is a vital prey for both cod and herring
- Due to the nature of the ocean current system in the shallow Barents sea, combined with cold water and air temperatures, oil spills in the Barents Sea are likely to survive longer than in the North Sea

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References

- Conford, C. (1998) Source rocks and hydrocarbons of the North Sea. Glennie, K. W. (ed) *Petroleum Geology of the North Sea 4th Edition*, Blackwell Science Ltd., 376-462
- Dahl, B. & Speers, G. C. (1985) Organic geochemistry of the Oseberg Field (I). *Petroleum Geochemistry in Exploration of the Norwegian shelf*, Norwegian Petroleum Society, Graham & Trotman, 185-195
- ITOPF (2005) Fate of marine oil spills. *Technical information paper*, The International Tanker Owners Pollution Federation Limited, www.itopf.com
- Johansen, S. E., Ostisby, B. K., Birkeland, D., Fedorovsky, Y. F., Martirosov, V. N., Christensen, O. B., Cheredeev, S. I., Ignatenko, E. A. & Marguliu, L. S. (1992) Hydrocarbon potential in the Barents Sea region: play distribution and potential. Warren, T. O., Bergsjø, E., Dahl-Stammes, Ø. A., Holter, E., Johansen, B., Lie, E. & Lund, T. B. (eds) *Arctic Geology and Petroleum Potential*, NPF Special Publication 2, 273-320
- Skanmagn, G. (1985) Significance of coniferous rain forests and related organic matter in generating commercial quantities of oil, Gippland Basin, Australia. *American Association of Petroleum Geologists Bulletin*, 69, p. 1241-1254
- Understanding Oil Spills and Oil Spill Response (1999) US Office of Emergency and Remedial Response
- UNEP (2004) Matshov, G., Golubeva, N., Titova, G., Sydnis, A. and B. Voegelé. Barents Sea, GWA Regional assessment 11. University of Kalmar, Kalmar, Sweden
- www.npd.no (2005) The Norwegian Petroleum Directorate