

# 7 OFFSHORE OIL AND GAS INDUSTRY



Oil discharges with produced water have fallen on average by 20% in the OSPAR area and most countries have met the OSPAR 15% reduction target, but volumes of produced water are expected to increase. Pollution from drilling fluids and cuttings piles has been considerably reduced. Impacts of offshore oil and gas activities have reduced around some installations, but the evidence base for environmental impacts is limited.

## OSPAR Contracting Parties should cooperate

- to continue efforts to phase out discharges of hazardous substances and reduce discharges of oil through a risk-based approach to management of produced water;
- to consider the suitability of existing measures to manage oil and gas activities in Region I;
- to continue monitoring and assessment and improve the evidence base for evaluating the impacts of the offshore industry on marine ecosystems.

## Key OSPAR assessments

- Overall impacts of offshore oil and gas activities
- Environmental effects of releases of oil and chemicals from cuttings piles
- Environmental monitoring of impacts from offshore oil and gas activities

Offshore oil and gas activities have developed in the OSPAR area over the past 40 years. Environmental impacts occur throughout the lifecycle of these activities, including during the exploration, production and decommissioning phases. Exploration includes seismic surveys and the drilling of exploratory wells. Production includes the drilling of production wells, and the construction, placement and operation of infrastructure (e.g. platforms, pipelines). Decommissioning, the final phase of an oil and gas field development, involves activities such as the plugging of wells and removal of infrastructure. The transportation of oil and gas by pipeline or tanker has the potential to cause impacts outside the area of production.

OSPAR works under the Offshore Oil and Gas Industry Strategy to establish environmental goals and measures to prevent pollution and protect the marine environment, consistent with the objectives set by OSPAR, especially those for hazardous substances → CHAPTER 5 and for radioactive substances → CHAPTER 6.

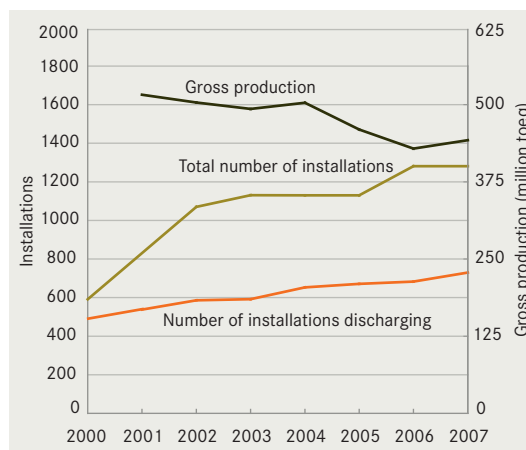
## What are the problems?

### Pressures are greatest in the North Sea and expected to increase in the Arctic

The total amount of oil and gas produced within the OSPAR area has decreased by about 14% since 2001 to around 442 million tonnes of oil equivalents (toeq) in 2007, while the number of offshore installations has increased → FIGURE 7.1. This indicates a trend towards the development of smaller fields. In 2007, around 60% of all operational installations reported air emissions and discharges to the sea as a result of oil and gas extraction.

## OSPAR Strategy objectives for the offshore oil and gas industry

- Prevent and eliminate pollution and take the necessary measures to protect the maritime area against the adverse effects of offshore activities.
- Safeguard human health and conserve marine ecosystems and, when practicable, restore marine areas which have been adversely affected.



**FIGURE 7.1** Numbers of offshore installations and total production of oil and gas (2000–2007). The increase in the number of installations between 2001 and 2002 is mainly due to a change in the way of counting installations. Offshore installations are any man-made structures, plants or vessel or parts thereof, whether floating or fixed to the seabed, that are placed within the OSPAR area for the purpose of offshore activities.

A network of pipelines connects the oil and gas fields with the onshore distribution network → FIGURE 7.2. The OSPAR area has more than 50 000 km of pipelines transporting oil and gas products from around 1300 installations.

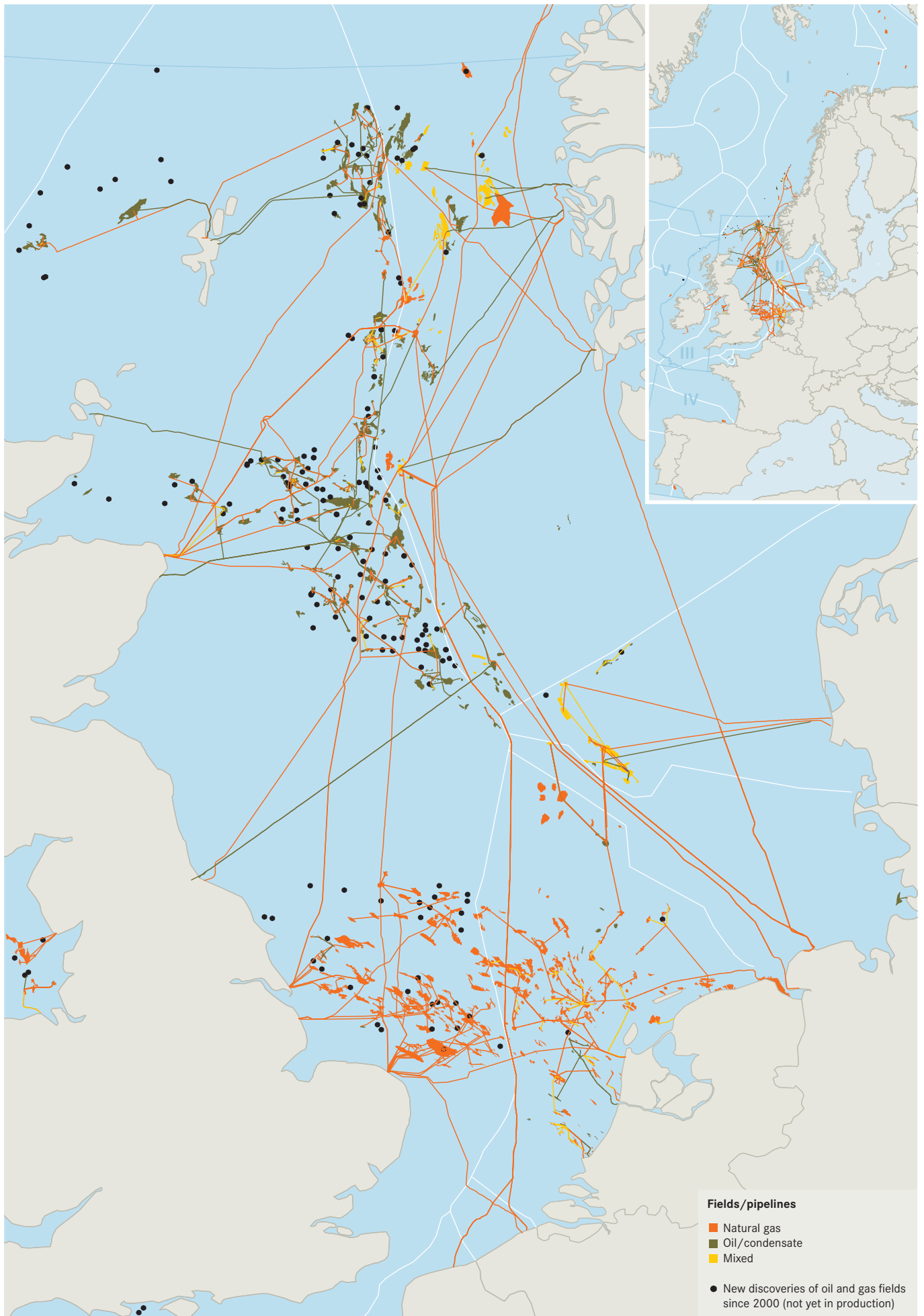


FIGURE 7.2 Offshore oil and gas fields under exploitation, new discoveries not yet in production and pipelines in 2009.

The major offshore oil and gas developments within the OSPAR area are in the North Sea and Norwegian Sea; oil and gas in the northern North Sea and Norwegian Sea and mostly gas in the southern North Sea. Some production also takes place in the Irish Sea and Celtic Sea (gas only), the Bay of Biscay, the Gulf of Cadiz (gas only), and the Barents Sea → **TABLE 7.1**. There is exploration for oil and gas in Region V, but as yet no production.

Environmental pressures from offshore oil and gas operations are greatest in Region II. However, oil and gas production has peaked in the North Sea and is now declining. For other parts of the OSPAR area, such as the Barents Sea, production is expected to increase. This is due to rising global demand and increased access to Arctic resources as sea ice retreats following the rise in global temperature. Some large projects are already underway, for example, the development of the *Shtokman* field in the Russian Barents Sea. A significant proportion of the world's known oil and gas reserves are in the Arctic, with offshore areas of Greenland, the Faroe Islands, Iceland, northern Norway and Arctic Russia of particular interest. Increased production in Region I will bring an increase in environmental pressure. Marine ecosystems in the Arctic are considered to be particularly sensitive to impacts from offshore activities and effective management of oil spills and other impacts is important.

### Different pressures on the marine environment

Routine operation of production platforms leads to the release of oil, chemicals and naturally occurring radioactive materials to the sea, especially through discharges of produced water and partly from drill cuttings → **FIGURE 7.3**. Accidental oil spills can arise from different sources during operation.

The main source of oil discharge from routine production is produced water. This is the water that comes from the reservoir along with the oil. Produced water contains hazardous substances occurring naturally in the reservoir, such as heavy metals, aromatic hydrocarbons, alkyl phenols and radionuclides. Produced water also contains residues of chemicals used in the production process, including corrosion inhibitors and demulsifiers (chemicals that increase the separation of oil from water).

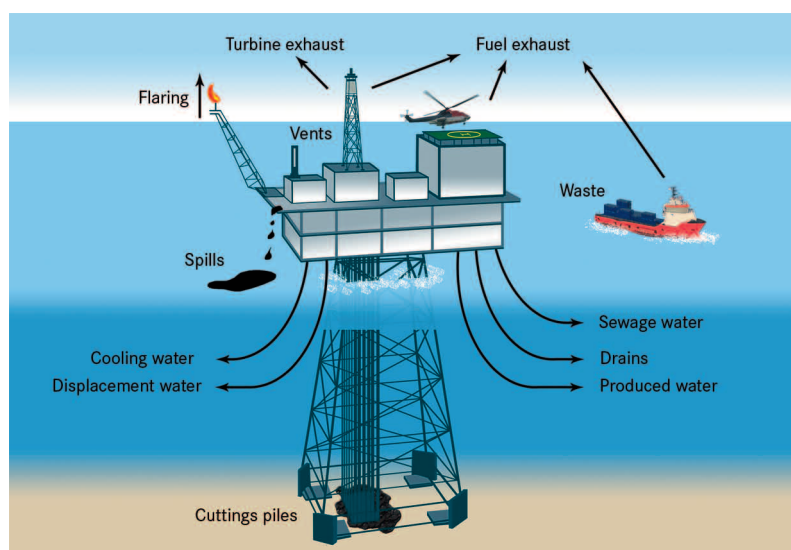
Drilling requires the use of fluids that may contain a range of chemicals. These chemicals may be water-based or based on organic-phase fluids (e.g. lighter oil fractions and synthetic fluids). Drilling fluids are generally recycled and are only disposed of once spent, but a small amount binds to rock fragments (cuttings) and is disposed of with the rest of the solid material removed from drilled rock. These cuttings can accumulate in piles at drilling sites. Old cuttings piles may contain oil (drilling

**TABLE 7.1** Oil and gas production in OSPAR countries in 2007.

Region	Oil production (million toeq)	Gas production (million toeq)
Region I	24.3	31.1
Region II	205.4	172.8
Region III	0.9	7.2
Region IV	0.007	0.0
Region V	0.0	0.0
Total	230.6	211.1

fluids used to be mainly oil-based) and other contaminants and these are released into the sea over time. This is especially the case if these old cuttings piles get physically disturbed, for example by work around platforms or trawling. At some sites, cuttings are re-injected into the seabed to reduce their environmental impact, but there is some concern that this contaminated material could break through to the seabed.

Other pressures from oil and gas activities include emissions of volatile organic compounds, methane, sulphur dioxide, nitrogen oxides and carbon dioxide to the atmosphere. Chemicals can leak, for example, from pipeline valves and leach from coatings and anodes of pipelines and subsea structures. The seabed is physically disturbed when pipelines, cables, subsea structures and platforms are installed. Construction of offshore installations, drilling and seismic surveys during exploration are also sources of underwater noise → **CHAPTER 9**. Carbon dioxide storage in sub-seabed geological formations such as abandoned oil and gas wells is an emerging offshore activity and will for example involve drilling of injection wells and placement of offshore installations → **CHAPTER 3**.



**FIGURE 7.3** Substances are released from a range of sources during routine offshore oil and gas production.

TABLE 7.2 OSPAR measures to manage pressures from the offshore oil and gas industry.

Discharges of chemicals and oil
Decision 2000/3: Restriction of use and discharges of organic-phase drilling fluids and contaminated cuttings Recommendation 2006/5: Management of offshore cuttings piles Recommendation 2001/1: Management of produced water and 15% reduction target for oil discharged with produced water
Use of chemicals offshore
Decision 2000/2: Harmonised Mandatory Control System to manage use and discharges of chemicals offshore Recommendation 2000/4: Harmonised chemical pre-screening scheme Recommendation 2000/5: Harmonised chemical notification Recommendation 2005/2: Phase out of OSPAR priority chemicals Recommendation 2006/3: Phase out of candidate substances for substitution
Decommissioning
Decision 98/3: Ban of disposal of disused offshore installations
Environmental management
Recommendation 2003/5: Promotion of use and implementation of environmental management systems



Parts of Brent Spar being brought ashore for disposal

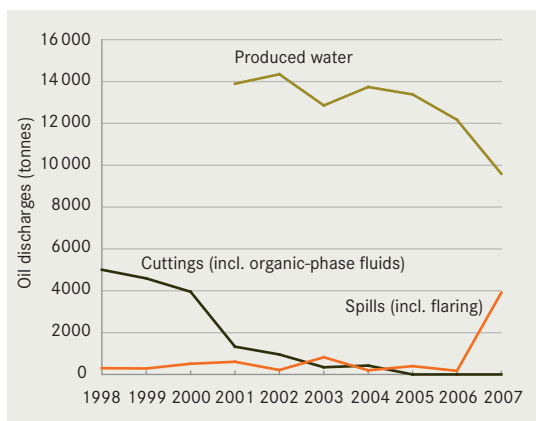


FIGURE 7.4 Annual discharges of oil from the different sources within the offshore oil and gas industry (1998–2007). A new OSPAR reference method for the analysis of dispersed oil in produced water has been implemented since 2007. This partly explains the reduction between 2006 and 2007 in discharges of oil in produced water. A single large oil spill in Norway in 2007 accounts for the steep increase in oil spills compared to previous years.

## What has been done?

### Potentially polluting activities are subject to a wide range of measures

Although international organisations such as the EU and the International Maritime Organization have developed environmental measures relevant to the offshore industry, OSPAR is the key international organisation addressing environmental aspects of offshore oil and gas activities in the North-East Atlantic.

OSPAR has adopted a wide range of programmes and measures to reduce pollution from all phases of offshore activities → TABLE 7.2. These include the reduction of oil in produced water, substantial restrictions on the use and discharge of organic-phase drilling fluids, and the banning of dumping or leaving in place disused offshore installations, subject to derogation in certain specified cases. Nearly all offshore operators have now followed OSPAR's promotion of environmental management systems for offshore installations to support the objectives of the Offshore Oil and Gas Industry Strategy and have adopted comparable schemes.

OSPAR countries are also committed to phasing out discharges of certain chemicals used offshore and to do so by 2010 for OSPAR priority chemicals and by 2017 for substances identified by OSPAR as candidates for substitution. OSPAR has continued to promote a shift towards the use of less hazardous substances, or preferably non-hazardous substances, in the offshore industry through its harmonised mandatory control system. Using harmonised notification formats and harmonised pre-screening procedures for offshore chemicals, decisions on the regulation of offshore discharges have become more transparent and more predictable. There is a need to bring the harmonised mandatory control system further in line with the EU REACH Regulation.

## Did it work?

### Oil discharges have been reduced

Produced water has been the major source of oil discharges from the offshore oil and gas industry over recent years, with the small remainder mostly from accidental oil spills → FIGURE 7.4. Although the overall volume of produced water generated has increased with the increasing age of the fields, the amount of produced water discharged has remained reasonably constant since 2000 as more produced water is injected into sub-surface formations. Most countries have met and partly exceeded the OSPAR target of a 15% reduction in the total amount of oil in produced water, leading to an overall decrease of more than 20% in the OSPAR area between 2000 and 2006 → FIGURE 7.5. This has been achieved through injection of produced water and the considerable efforts of the offshore industry to optimise processes and introduce new water treatment technology.

## Most oil spills are small

Accidental oil spills arise from several sources, including pipelines, valves and broken hoses, and during offloading and filling of tanks. More than 95% of all spills are less than one tonne in volume → **TABLE 7.3**. As infrastructure ages, the risk of accidents (e.g. leakage from older pipelines) may increase, resulting in more spills of oil and chemicals in future.

The frequency of small oil spills has progressively declined since 2000 while the number of larger spills has remained relatively stable. The volume of oil spilled varies widely from year to year. In 2006, around 170 tonnes of oil were spilled, whereas almost 4000 tonnes were spilled in 2007. The total for 2007 is dominated by a single large oil spill off Norway in which the amount of oil spilled was almost as much as the total discharged in produced and displacement water for the whole OSPAR area in 2007. The time and place of a spill are important; a relatively small spill can have a greater impact for example during the spawning season than a much larger spill at a different time.

## Discharges of contaminated cuttings have largely stopped

Cuttings from wells drilled with water-based drilling fluids are discharged to sea in most OSPAR areas, whereas cuttings from wells drilled with organic-phase drilling fluids (which are still used in lower sections of wells) are re-injected into sub-surface formations in line with OSPAR measures or transported onshore for treatment and disposal. Discharges of drill cuttings contaminated with oil and organic-phase drilling fluids largely ceased in 2005. Cuttings contaminated by oil at levels below 1% can still be discharged to sea. Technologies which can clean cuttings to below 1% oil are now available for offshore facilities. Recent assessments of the potential for pollution from old cuttings piles through leaching or as a result of disturbance (e.g. decommissioning, trawling, dredging) indicate no significant impacts and that their management could be addressed by OSPAR countries as part of the decommissioning plan for the installation.

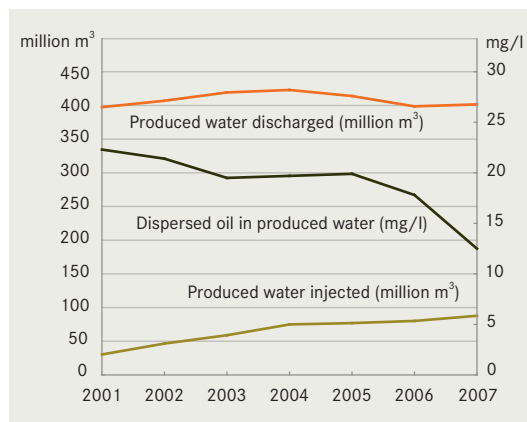
## Discharges of priority chemicals are 90% lower than in 2003

Comprehensive data on the use and discharge of chemicals are only available for 2003 onward. Since then, the amount of chemicals used offshore has increased, but there has been a slight decrease in the amount discharged → **FIGURE 7.6**.

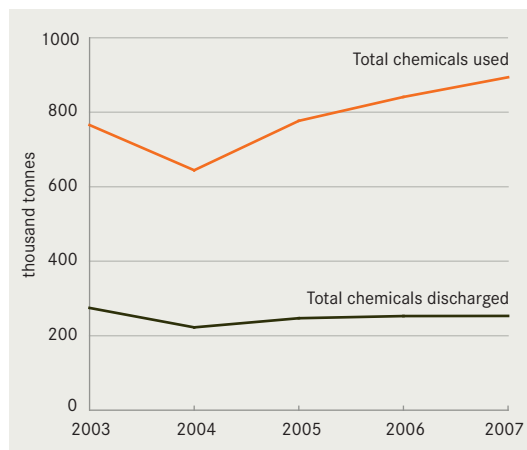
Around 900 000 tonnes of chemicals were used offshore in 2007 of which 250 000 tonnes were discharged to sea. Most substances used and discharged offshore pose little or no risk (PLONOR) to the marine environment; in 2007 almost 87% of chemicals discharged were PLONOR substances. This includes substances such as barite (barium sulphate) used in large volumes as a weighting agent in water-based drilling muds, methanol used as gas hydrate inhibitor or potassium chloride



Fluorescence imaging of cuttings piles



**FIGURE 7.5** Annual amounts of produced water discharged and injected (2001-2007).



**FIGURE 7.6** Total use and discharge of chemicals offshore (2003-2007).

**TABLE 7.3** Number and total quantities of oil spilled in small ( $\leq 1$  tonne) and large oil spills in the OSPAR area.

Spills		2000	2001	2002	2003	2004	2005	2006	2007
Small ( $\leq 1$ tonne)	Number	22	25	27	19	24	17	15	22
	Quantity, tonnes	454	537	158	744	157	345	135	3882
Large (> 1 tonne)	Number	700	743	774	602	654	638	494	493
	Quantity, tonnes	60	68	56	80	42	54	38	25

used in brine solutions in drilling and completion of wells. About 2500 tonnes of the chemicals discharged in 2007 were substances identified by OSPAR for priority action or substances that should be substituted by less hazardous substances. Discharges of substances identified by OSPAR for priority action have been reduced by around 90% since 2003. This is mostly due to their substitution by less hazardous alternatives. Also, concentrations of naturally occurring heavy metals in produced water are generally low.

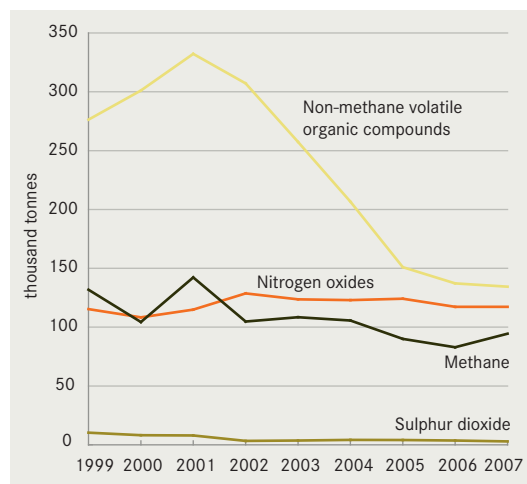
### Most offshore structures are brought ashore for disposal

Since the ban on dumping of, or leaving in place, disused offshore installations in 1999, 122 offshore installations have been brought ashore for disposal. In this period, permits have been issued for four concrete sub-structures and the footings of one large steel structure being left in place. The decommissioning of the *Frigg* field is one example → **BOX 7.1**. Derogations from the dumping ban may be considered for 59 steel installations with a sub-structure of more than 10 000 tonnes, and 22 gravity-based concrete installations.

### Some emissions to air are decreasing

Carbon dioxide accounts for the greatest proportion of emissions to air from offshore installations with around 32 million tonnes emitted in the OSPAR area in 2007. Emissions of carbon dioxide and nitrogen oxides have been relatively stable since 1999, while sulphur dioxide and methane emissions have been substantially reduced. Emissions of non-methane volatile organic compounds have halved. Measures taken by operators to reduce fugitive emissions (gas escapes, for example, from leaks or processes) and the use of vapour recovery systems at off-loading facilities have helped reduce emissions of methane and other volatile organic compounds → **FIGURE 7.7**.

Flaring



**FIGURE 7.7** Emissions to air from the offshore industry (1999–2007).

### How does this affect the quality status?

#### Areas affected by contaminated drill cuttings have reduced

Based on the collected evidence, environmental conditions around many installations have improved, especially in Region II. This Region had high, but very localised, impacts throughout the 1980s and 1990s. After further restrictions in use and discharge of organic-phase drilling fluids in 2001, monitoring at Danish, Netherlands', Norwegian and UK rigs has shown that sediment oil concentrations have reduced significantly and that the benthic fauna have started to recover.

The *Ekofisk* field in the Norwegian sector is an example of a mature production site which has been in operation since the early 1970s. The restrictions in use and discharge of oil-based drilling fluids and the recent decline in oil and gas activities at the site have resulted in reduced discharges and decreasing sediment concentrations of oil and barium (from barite). This has led to a clear recovery of the sediment dwelling animal communities; the area disturbed fell by 85% to less than 20 km<sup>2</sup> between 1996 and 2005. In contrast, areas impacted by oil and barium sulphate and with disturbed benthic fauna are still increasing at younger oil and gas production sites.

Areas contaminated by cuttings piles have also been reduced through natural erosion and because the oil leaching rate is now lower than when the cuttings were first deposited. Possible releases of oil and chemicals from old cuttings piles that are physically disturbed do not appear to be causing increased impacts on the environment.



*Frigg* is the largest decommissioning project ever in the OSPAR area. It is a transboundary gas field with six platforms straddling the UK and Norwegian sectors.

The UK and Norway have cooperated closely since the project began in the 1970s. A bilateral treaty allowed the field to develop and operate as a single unit, starting in 1977. Both governments approved the decommissioning of the three concrete structures on the UK shelf and the three structures (one concrete) on the Norwegian shelf following the end of exploitation in 2004. National authorities and the operator collaborated on a single cessation plan for the field, which included a comprehensive environmental impact assessment. OSPAR Decision 98/3 was followed throughout the process and OSPAR countries have been consulted.

The *Frigg* concrete sub-structures are allowed to remain in place. This was considered the most environmentally friendly option, taking into account considerations such as the potential carbon dioxide (CO<sub>2</sub>) emissions involved in the different disposal alternatives. These ranged from 265 000 tonnes CO<sub>2</sub> for refloat and disposal onshore to 14 000 tonnes for leaving concrete structures in place. External steel structures are being removed and disposed of on land. The operator must recycle as much of the equipment and material as practicable, applying most appropriate techniques and best environmental practice. The decommissioning plan includes measures to mitigate and reduce environmental impacts.

*Frigg* field in operation in 2004 (upper) and *Frigg* sub-structures after decommissioning, started in 2008 (lower)

### Water column monitoring shows mostly low biological response

Water column monitoring to determine possible effects from polycyclic aromatic hydrocarbons (PAHs) and other chemicals such as alkyl phenols discharged with produced water has been carried out to a limited extent in the OSPAR area.

Monitoring in the Netherlands' sector has shown that caged blue mussels accumulate the PAH naphthalene up to 1000 m from a platform. Water column monitoring in the Norwegian sector began in 1999 and has shown that caged blue mussels exposed to produced water discharges accumulate PAHs from the surrounding seawater. These concentrations decreased with increasing distance from the point of discharge. Levels of biological responses in caged mussels showed similar gradients to those for contaminant concentrations.

Concentrations of PAHs and alkyl phenols and measured biological responses in wild fish such as cod and haddock caught in the vicinity of offshore installations from Norwegian waters in 2002 and 2005 showed a mixed pattern mostly with no increased concentrations, but some elevated biological responses suggesting past exposure.

The results from water column monitoring are complex to interpret, particularly for wild fish for which it is not possible to link observed biological responses to a specific exposure source. Monitoring data are limited and do not yet allow conclusions to be drawn on the significance of the observed biological responses for marine life and ecosystems.

### Recovery from physical impacts may be longer for sensitive species

Temporary physical impacts are caused when structures like platforms and pipelines are first put in place. These temporary physical impacts are more extensive than the long-term impacts of the structure. Disturbance from trenching and/or burying pipelines is greater than when pipelines are just laid on the seabed. Temporary impacts usually occur between 5 and 10 m from the pipeline, although this is influenced by size of the pipeline, sediment type and trenching method.

Creating hard substrates such as pipelines, platform legs and subsea templates in soft-sediment areas provides shelter for fish and other mobile marine organisms, but alters the benthic communities by providing settling areas for hard-substrate communities.

*Deployment of a net cage to expose fish and mussels for water quality monitoring at the Ekofisk oil field*



Potential environmental impacts vary across the OSPAR area, depending on differences in bottom topography, geology, water mass movement and biology. Recovery may take longer for sensitive species and in deeper and colder waters. Soft-bottom fauna can recolonise within a year or two, especially in shallow waters with a sandy/muddy seabed.

### What happens next?

#### Environmental status has improved

Cooperation between OSPAR and the offshore industry has allowed a range of issues to be addressed, including discharges of produced water and the use and discharge of chemicals. This cooperation has also supported the introduction of environmental management systems by operators.

The target of a 15% reduction in oil discharges in produced water has been achieved at the OSPAR level, set against a trend for increasing produced water generation. The increase in produced water is due to the maturing of oil reservoirs, particularly in Region II. Injection of produced water has proved technically challenging for some installations, mainly due to reservoir properties. Substitution of certain chemicals by other less hazardous chemicals has also proved technically challenging. Impacts of offshore oil and gas activities have reduced around some installations but the evidence base is limited. Concerns over impacts of the offshore industry on the marine environment continue, especially those relating to oil and chemicals discharged with produced water, impacts from historic cuttings piles and atmospheric emissions.

#### Further management efforts are needed to address all impacts

OSPAR should address the following priorities for action:









- Continue to work towards the target for ceasing discharges, emissions and losses of hazardous substances and achieving a reduction of oil in produced water discharged to the sea to a level which will ensure that the discharges will present no harm to the marine environment by 2020.
- Move towards a risk-based approach to managing produced water that embraces more substances than oil.
- Consider aligning the management of chemicals used and discharged offshore (substances covered, the data and information base, and management criteria) through OSPAR's harmonised mandatory control system with the requirements of the EU REACH Regulation.
- Continue monitoring and assessment and improve the evidence base for future assessments of the impacts of the offshore industry on marine ecosystems.

OSPAR should examine whether there are specific issues relating to ageing installations and infrastructure and, if required, develop appropriate measures, taking into account possible extensions in the life of infrastructures. OSPAR should also investigate the impact of underwater noise from the offshore oil and gas industry and, as appropriate, develop guidance on best practice for its mitigation.

Oil and gas production is at different stages and intensities in the OSPAR Regions. OSPAR should consider whether its current measures are suitable for the northern part of Region I where increasing oil and gas activity is expected.

## Delivering OSPAR Strategy objectives for the offshore oil and gas industry

→ LEGEND: BACK-COVER FOLD-OUT

OSPAR Region	Prevent/eliminate pollution	Environmental status 1998–2006	Key factors and pressures	Outlook for pressures	Action needed
Region I	Partly achieved ***	Improved *	Oil discharges and spills Input of contaminants Air emissions	↑	 OSPAR  OSPAR
Region II	Partly achieved ***	Improved *	Oil discharges and spills Input of contaminants Air emissions	↓	 OSPAR  OSPAR
Region III	Partly achieved ***	Improved *	Minor activity: Oil discharges and spills Input of contaminants Air emissions	↔	 OSPAR  OSPAR
Region IV	Mostly achieved ***	?	One non-discharging installation: Air emissions	↔	 OSPAR
Region V	Not applicable	Not applicable	Exploration activities: Oil spills Air emissions	?	 OSPAR