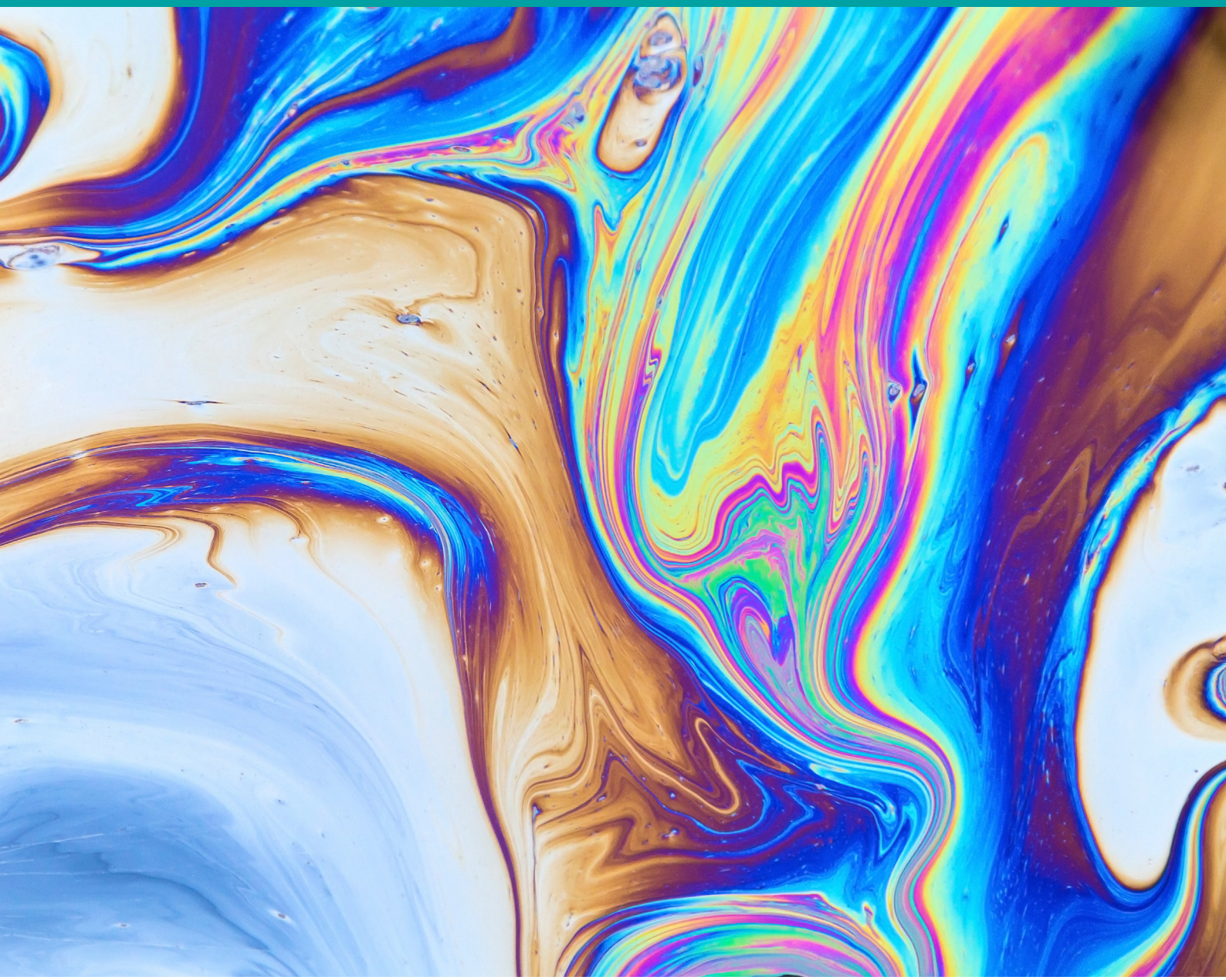
National Assembly for Wales
Senedd Research

The impact of oil spills
Research Briefing

April 2019



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April 2019

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Paper Overview:
This Research Briefing provides a brief background to oil, and aims to answer questions on the processes involved in and the potential impacts of an oil spillage on the marine environment.

Senedd Research acknowledges the parliamentary fellowship provided to Robert Byrne by the Engineering and Physical Sciences Research Council (EPSRC) which enabled this Research Briefing to be completed.

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How important is oil?

Oil has been vital to the growth of modern economies due to its multifaceted use in energy, transport and manufacturing. Worldwide **energy use has doubled** over the past 35 years, contributing to a **7-fold increase in Gross Domestic Product (GDP)** in that time. During this period, crude oil has dominated world energy supply, constituting **34 per cent of total primary energy supply in 2017** – a greater share than other energy sources. As a result, global oil production has increased 40-fold over the past century, with **95 million tonnes** produced annually in 1920 and an average of **over 4 billion tonnes** produced per annum since 2010.

Today, global oil consumption is approximately **100 million barrels per day** (~15.9 billion litres) and despite pressures to mitigate climate change, global demand is growing by **up to 1.5 per cent per year**. This **is largely attributed to** increasing demand from the petrochemicals sector and rising numbers of Sports Utility Vehicles (SUVs) and light trucks in major economies. The International Energy Agency (IEA) **states that there is no consensus** on when world oil demand will peak and that this depends on government responses to global warming. Figure 1 shows **global oil production and consumption from 1992 to 2017**.

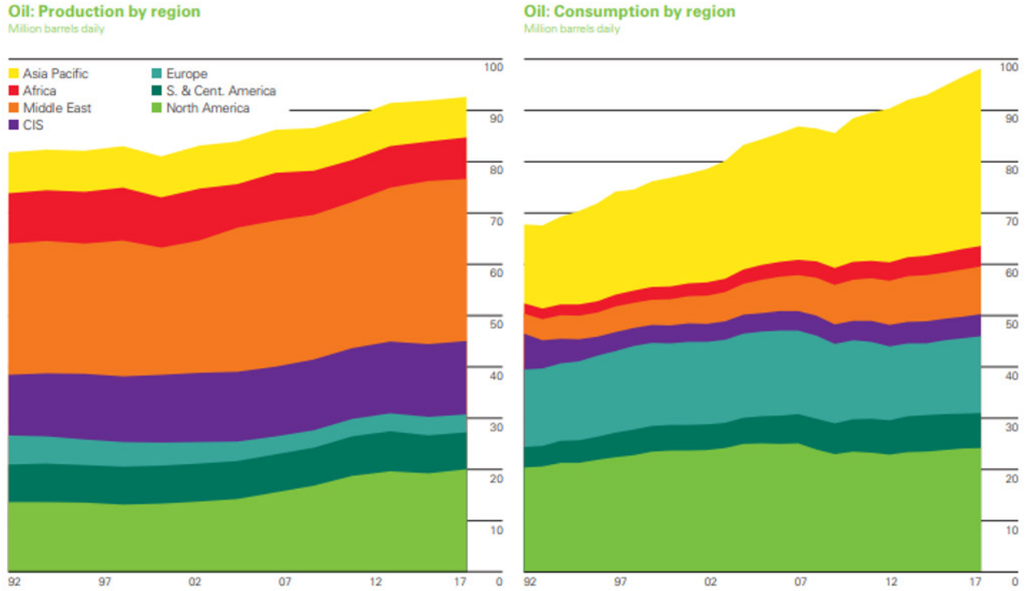

Figure 1: World oil production and consumption by region in from 1992 to 2017 (Source: **BP**)

The UK and oil

The UK Continental Shelf (UKCS) is a mature oil producing area which has produced **55 billion barrels of oil equivalent (boe)** since 1967 and has **515 million tonnes** of reported proven and probable reserves remaining. After being a significant oil exporter in the 1980s and 1990s, UK oil production peaked at **2.9 million barrels per day** in 1999 and declined to around **1.4 million boe per day** in 2014. Despite a **rise in oil and gas production** since 2014, the UK has been a net oil importer since 2005 and consumed around **1.6 million boe per day** in 2017. The UK oil and gas industry supports **over 300,000 jobs**, substantially contributing to energy security and the economy, despite **50 per cent of UKCS oil fields** operating at a loss in 2016.

There are **6 major oil refineries in the UK** which process various crude oil types to meet **growing demand for** complex, more environmentally friendly fuels and by-products (e.g. petrochemical feedstocks). In 2016, **71 per cent of UK refinery crude** throughput was from the North Sea; 53 per cent from Norway and 18 per cent from the UKCS (Figure 2a). The **majority (62 per cent)** of oil products from UK refineries are consumed domestically (Figure 2b).

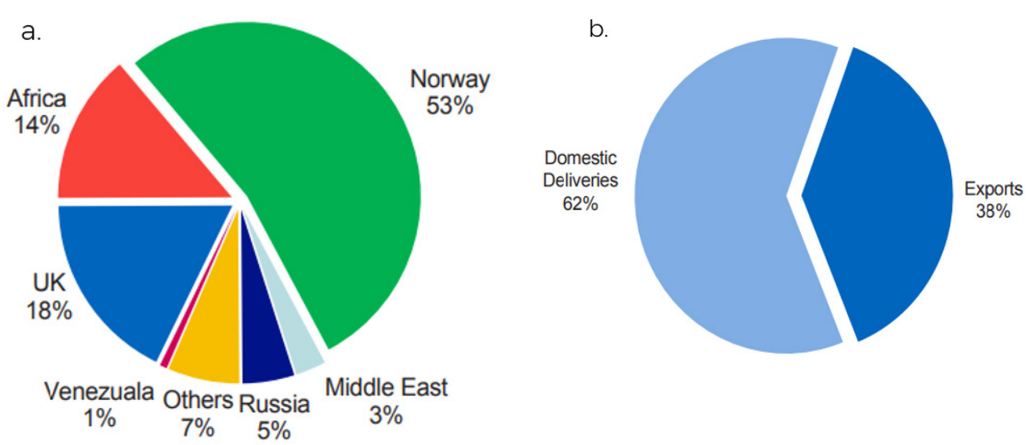

Figure 2: a) Sources of crude oil in the UK in 2016, b) destination of UK oil products in 2017 (Source: **UKPIA**)

UK refineries **are located with** connections to deep-water shipping channels capable of harbouring large tankers and pipelines (Figure 3). About **69 million tonnes of petroleum products** (from UK refineries and imported products) are transported around the UK per annum; over 30 million tonnes via pipeline.

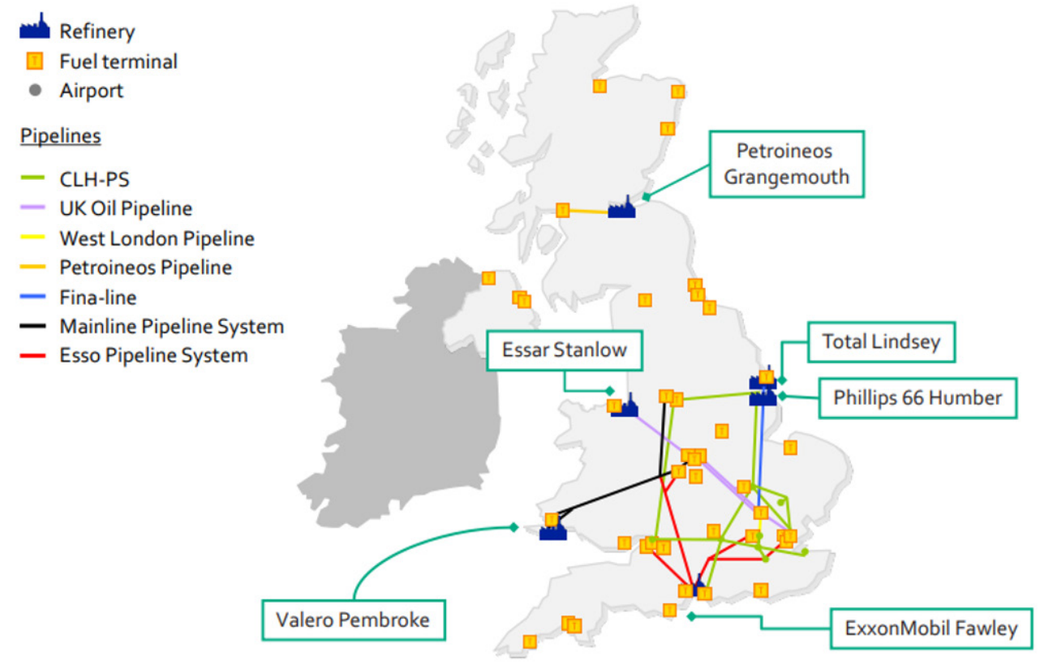

Figure 3: UK refineries and key product distribution terminals (Source: **UKPIA**)

Pembroke Refinery, situated in the Milford Haven waterway, is the only major refinery in Wales. It was acquired by **Valero** in 2011 and is one of the most complex refineries in Western Europe; producing gasoline, diesel fuels, liquefied petroleum gas and petrochemical feedstock. The refinery has total throughput capacity of **270,000 barrels per day** and its products are distributed **by sea (90 per cent), road and pipelines** which connect to the Midlands and Manchester. The refinery is a major employer with **over 500 employees and hundreds of contractors**.

How is oil transported?

Crude oil is typically transported in vast quantities over huge (often intercontinental) distances. Due to economies of scale, such international transportation (Figure 4) only accounts for **a small fraction** of the oil price. Typically, **10-15 transfers between transport modes** occur between the source, refinery and consumer.

Tankers and **pipelines** are the most cost-effective and safe modes of transporting large quantities oversea and overland, respectively. Tankers transported approximately **62 per cent of all oil and gas products (2.9 billion tonnes)** in 2015, while pipelines transport billions of barrels per year, forming complex networks across most countries (**including the UK**). Rail and road are flexible modes for transporting small quantities **to the final consumer**.

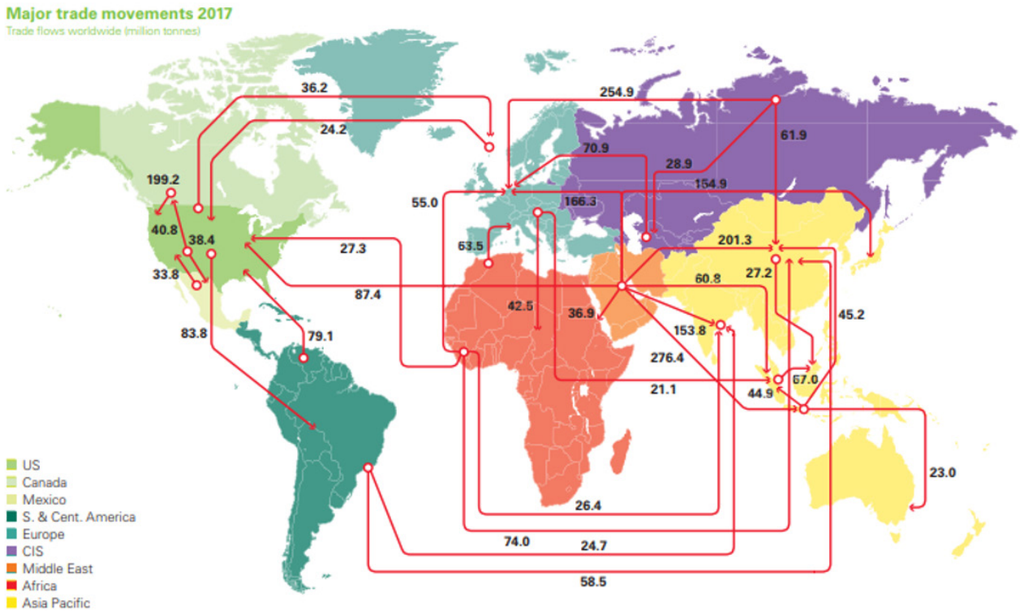

Figure 4: Worldwide major trade flows of oil around the globe in 2017 (million tonnes) (Source: **BP**)

Why do oil spills occur?

Despite increasing oil production, transportation and consumption, improvements in technology, **preventative measures** and **regulations** have **reduced accidental oil pollution** over recent decades. The quantity of oil spilled from tankers has **decreased by 90 per cent** since 1991. Figure 5 **shows seaborne oil trade and the number of oil spills (>7 tonnes) from tankers** between 1970 and 2016.

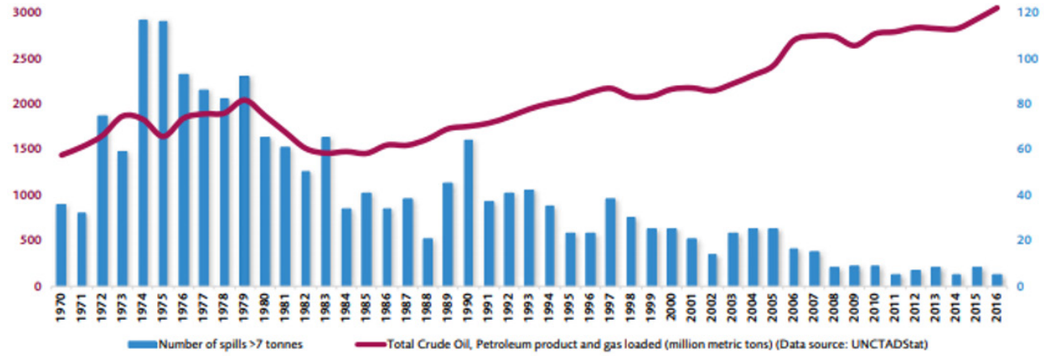

Figure 5: Total oil spills > 7 tonnes from tankers per year versus seaborne oil trade (Source: **ITOPF**)

However, with such widespread oil usage and transportation, spills or leaks are inevitable. Every day, **hundreds to thousands of spills and leaks** will likely occur worldwide. Human error is estimated to cause **30 to 50 per cent** of all spills while equipment failure causes **20 to 40 per cent**. **Emerging spill risks include** maritime activity in the Arctic, deep-water exploration and increasing rail transport of oil.

What happens to oil in the marine environment?

When entering the marine environment, oil spreads and moves with wind and currents while undergoing chemical and physical changes. These natural processes, collectively known as **weathering**, quickly and progressively change the properties of oil and the location and magnitude of its environmental impact.

The eight main weathering processes (Figure 6) **can be split** into two chronological categories of when their effect is most significant:

- **Early stage of spill:** spreading, evaporation, dispersion, emulsification, dissolution; and
- **Late stage of spill:** oxidation, sedimentation and biodegradation.

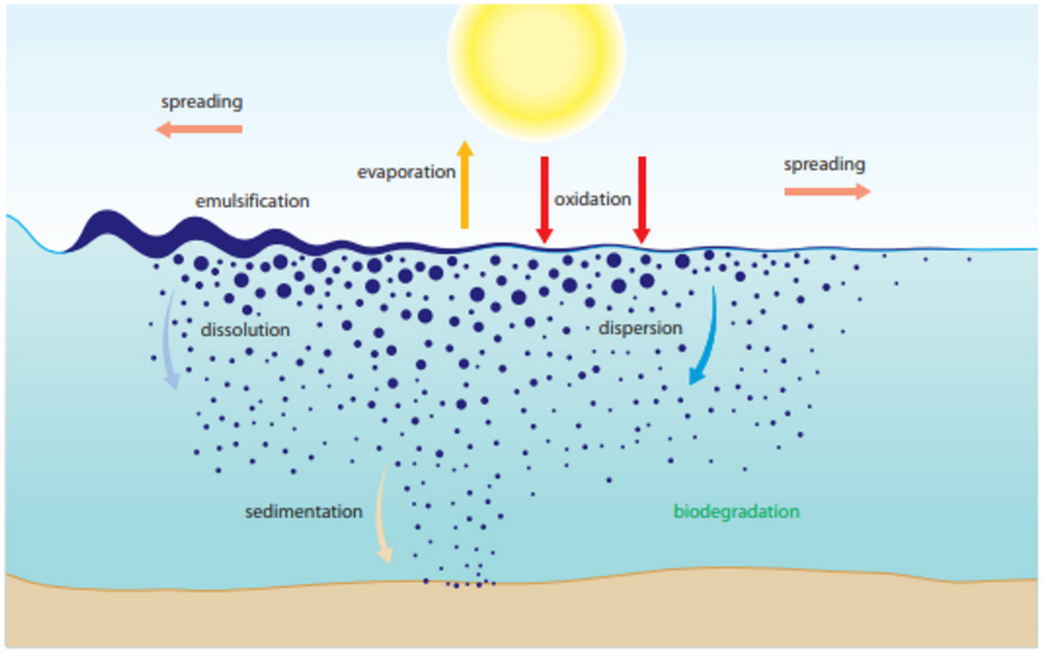

Figure 6: Diagram showing the eight main weathering processes (Source: **IPIECA and IAOGP**)

Processes like natural dispersion into water and evaporation **remove oil from the sea surface** and promote its natural breakdown. These dominate in light, non-persistent oils – gasoline, light diesel oil and kerosene. **Other processes** like the formation of water-in-oil emulsions cause oil to remain in environments for extended periods. These **dominate in** heavy, persistent oils - crude, fuel and heavier diesel oils.

The importance of each process **depends on various factors**, such as; the physical and chemical oil characteristics, oil quantity and spill rate, weather and water conditions, proximity to the shore and the type of shoreline - no two oil spills are the same.

Ultimately, the marine **environment removes spilled oil through long-term biodegradation** but this is not without impact on marine ecosystems and habitats. A good understanding of the physical and chemical properties of oils, its short term and long term behaviour after being spilled and the effectiveness and risks of different clean-up responses are essential for an oil spill contingency plan.

How are oil spills cleaned up?

The **University of Delaware Sea Grant Program** outlines key spill response methods:

- **Leave the oil to break down by natural means**. If there is no risk of polluting coastal regions, habitats or marine industries, this may be the best method for light oils;
- **Contain oil with booms** (floating oil containment devices) and collect it from water surfaces with skimmer equipment. Spilt oil initially floats and forms slicks a few millimetres thick on water surfaces. Skimmer equipment floats across boom contained slicks and sucks or scoops oil into storage tanks. This is less effective in volatile winds and seas;
- **Use dispersants to break up the oil and accelerate natural biodegradation**. Dispersants reduce surface tension which prevents oil and water from mixing. This enables oil droplets to form, promoting dilution with water movements, natural evaporation and bacterial action by increasing oil surface area. Dispersants are most effective within a few hours of the initial spill and are not appropriate for all oils or locations. When passing through the water column, dispersants and dispersed oil particles can be toxic to marine organisms like deep-water corals and can result in oil being accumulated by subtidal seafood; and
- **Use biological agents to accelerate biodegradation of oil** deposited along a shoreline. Microorganisms (bacteria) can break down oil into less harmful fatty acids and carbon dioxide. This is accelerated by fertilising nutrients like nitrogen and phosphorous, which stimulate growth of microorganisms. The effectiveness of this depends on the ground type (e.g. sand or pebbles) and whether the fertiliser is soluble or applied in pellet or liquid form.

The appropriate response depends on each individual case. **Aerial surveillance is an important tool** to guide, monitor and evaluate the effectiveness of response.

What are the impacts of oil spills?

Environmental

Oil spills have wide ranging environmental impacts of varying long-term significance. They can have **severe short-term impacts** on habitats and wildlife, reported in the media with images of oil-smothered birds. Long-term impacts **depend on a variety of factors**; the quantity and type of oil, weathering processes and interaction with the marine environment. This interaction depends on the biological and ecological properties of the marine environment; the ecological significance of species, their sensitivity to oil and the time of year.

Persistent, heavier oils **pose larger potential threats** to natural resources and wildlife by smothering habitats and contaminating beaches. Non-persistent oils at high concentrations **may be toxic** to marine organisms. Different clean-up methods also alter impacts.

Key **environmental impacts of oil spills** include:

- **Ecological alteration:** Loss of organisms with critical functions within an ecosystem. Replacement by similarly functioning organisms may reduce the severity of ecological alteration but replacement by dissimilarly functioning organisms may increase ecological alteration;
- **Physical smothering of organisms:** Often caused by persistent, heavy oils. This reduces the ability of an organism to perform critical functions (respiration, feeding, thermoregulation);
- **Chemical toxicity:** Typically caused by lighter chemical components which are absorbed into organs, tissues and cells with sub-lethal or lethal toxic results; and
- **Indirect effect:** Loss of habitats or shelter through clean-up processes.

Marine ecosystems **have high natural variability** and regularly change with time of year and environmental phenomena. It is **difficult to know** exact pre-spill conditions or identify definite post-spill points of recovery. Each marine ecosystem and spill location is different, making comparison between incidents difficult.

Economic

A common feature of marine oil spills is contamination of coastal areas. In addition to clean-up costs, this may **cause serious economic losses** for industries dependent on coastal resources. Disruption of recreational activities (swimming, boating, wildlife watching etc.) can damage tourism and interconnected industries, such as national parks and transport. Negative publicity and resulting public perceptions may have lasting detrimental impacts for tourism.

Other coastal industries such as shipyards, ports, harbours and heavy industries (e.g. power generation) which use sea or river water to operate could also experience negative impacts, which may be far-reaching if they provide national services. For fishing industries, contaminated stocks, fouled gear and impeded access to fishing sites **can have immediate impacts**. In some cases, fishing bans may be imposed to preserve longer term market confidence. To seek compensation, damages **should be recorded with evidence** but comparisons of pre- and post-spill status may be necessary to differentiate between spill effects and other factors, such as industrial pollution.

Economic and associated societal impacts are highly dependent **on a variety of factors**, such as the characteristics of the oil, the circumstances and location, the marine life and the type of local businesses. Consequently, **it is difficult to predict** their severity or longevity - an effective clean-up strategy should ensure that these impacts are minimised.

What is UK Government policy related to oil spills?

Due to the myriad of potential oil pollution sources, **UK and EU legislation** exists to prevent pollution and determine responsibilities in the event of an incident. Ports, harbours, oil handlers, local authorities, environmental groups and regulatory or licensing authorities (e.g. **Natural Resources Wales (NRW)**) typically provide contingency plans and work together in multi-agency responses. **UK clean-up operations must comply** with the **EU Directive on Waste**, which prioritises waste prevention and encourages reuse and recovery.

Regarding response to marine pollution from shipping and offshore installations, the UK Government's **National Contingency Plan (NCP)** provides a strategic and operational overview for use by all emergency response bodies. The **Maritime and Coastguard Agency (MCA)** is the custodian of the NCP and its Counter Pollution and Salvage branch **is responsible for** pollution preparedness, response at sea and management of equipment and dispersal stockpiles. **The NCP** highlights that different environmental agencies and groups and commercial contractors often engage with response, clean-up and post-spill monitoring.

To plan resources for each magnitude of incident, the NCP adopts **a three-tiered approach** which considers factors such as the type and location of pollution, environmental conditions, the potential scale and long-term impact. These tiers are:

- Tier 1: Local spills managed within the capability and resource of local and harbour authorities with the MCA available to monitor and support with technical and environmental advice:
- Tier 2: Regional spills beyond one local authority. The MCA may deploy aerial surveillance to assess extent and consider deploying national pollution response (tier 3) resources; and
- Tier 3: A national response. The MCA establishes a Marine Response Centre at an appropriate location to lead the response. Other coastal states, the European Community and European Maritime Safety Agency would be alerted if there was a chance of pollution extending beyond UK waters.

The lead for ensuring responsibility for clean-up is the:

- **Harbour authority** for pollution on the water, jetties, wharves, structures, beach or shoreline owned by the harbour authority and within the port area;
- **Local Authority / Northern Ireland Environment Agency** for shoreline pollution;
- **Owner of property / land** for pollution of privately owned jetties, wharves, structures, beach or shoreline; and
- **MCA** for all other areas

In Wales, **NRW works with** the Welsh Government to **provide the regulatory regime** for waste handling, marine licensing, water discharges and fisheries. In the event of a pollution incident, **NRW carries out** advisory, monitoring and management roles to ensure an effective response and has the power to issue enforcement notices to prevent pollution. **NRW also acts on behalf** of the Welsh Government to approve the use of oil spill treatment products in Welsh waters.

What are the largest oil spill incidents?

While large spills receive media attention and can have severe effects, they are infrequent. From 2010-18, large maritime spills (>700 tonnes) **occurred just 1.9 times per year on average** (compared to 24.5 times per year from 1970-79).

Over **3 million tonnes of oil** are estimated to be released into the environment from all sources. The vast majority released **is due to general shipping and industrial activities**, not major spills. Natural discharges and runoff from land-based sources are responsible for around **48 and 38 per cent** of oil in the oceans, respectively. Only **13 per cent derives** from transportation and **3 per cent** from extraction.

The UK

The Torrey Canyon tanker released around **119,000 tonnes** of crude oil over 12 days after running aground off Cornwall in 1967. The oil contaminated approximately **120 miles of UK coastline** and 80km of French coastline, killing around 15,000 birds and countless marine organisms. The UK Government **gave orders to aerially bomb** the wreckage in an effort to sink it and burn off the slick. The spill is the largest in UK history and was the first major tanker incident. It **triggered international conventions** which now form the basis of compensation for tanker spills.

On 15 February 1996, the Sea Empress struck rocks entering the Milford Haven waterway and released **72,000 tonnes of a light crude oil** over 7 days, contaminating **200km of coastline.** It became the UK's third largest oil spill and the largest in Wales. Although impacts were far-reaching, they were significantly reduced **by a combination of factors**. The UK Government appointed an independent committee; the Sea Empress Environmental Evaluation Committee (SEEEC) to assess the impact - its findings were published in the **SEEEC report.**

Worldwide

The deliberate release of approximately **6 million barrels of oil** during the 1991 Gulf War is the largest oil spill in history. Despite immediate environmental impacts, a **UNESCO Intergovernmental Oceanographic Commission report** concluded that there was little permanent damage to coral ecosystems and fisheries. **This was due to** over half of the oil evaporating, one-eighth being recovered, one quarter washing ashore and the remainder dispersing into the water column.

In 2010, an explosion **at 1522m depth** of Deepwater Horizon, which drilled on the BP-operated Macondo Prospect in the Gulf of Mexico, released **3 to 5 million barrels of crude oil** over 87 days and caused 11 worker fatalities. This is the largest accidental oil spill in history. **Over 650 miles**, of coastline was contaminated. The clean-up involved **7000m3 of dispersants deposited** from over 400 flights and over 400 fires to burn surface oils at an estimated total cost **of $44bn** to BP. The total environmental and economic impacts have not yet been fully assessed.

Key Sources

UK Government

The **UK Government website** provides a significant amount of information related to oil and related pollution, including:

- **guidance on** environmental management of oil spills, including reporting and clean-up;
- **key statistics** relating to oil in the UK;
- **statutory guidance on** the National Contingency Plan;
- **statutory guidance on** the UK National Standard for Marine Oil Spill Response Organisations; and
- **statutory guidance on** the Marine Management Organisation's role in marine pollution response.

Natural Resources Wales (NRW)

The **Natural Resources Wales (NRW)** website provides **guidance on** NRW's role in regulating onshore oil and gas and **a list of NRW website pages** relating to oil, in particular reports on NRW action to combat recent leaks or spills.

International Tanker Owners Pollution Federation (ITOPF)

The International Tanker Owners Pollution Federation (ITOPF) is a not-for-profit organisation which promotes an effective response to marine spills of oil and other hazardous substances. ITOPF's website provides informative resources, including:

- **an explanatory report** on the fate of oil spills, covering effects, response and technical papers;
- **a summary of** oil spill response arrangements and resources in the UK; and
- **data and statistics** related to worldwide marine oil spills.

Other Sources

- **A list of related UK and EU legislation and guidance** on the **Oil and Gas UK Environmental Legislation website; and**
- **An International Association of Oil and Gas Producers report** on the impacts of oil spills on marine ecology.

Senedd Research

Other briefings produced by Senedd Research are available on the **Senedd Research website**, and on our blog: **InBrief/environment** and **InBrief/marineandfisheries**

- **Our blog on an oil leak in Milford Haven** provides a brief background to oil spills, particularly in Wales.