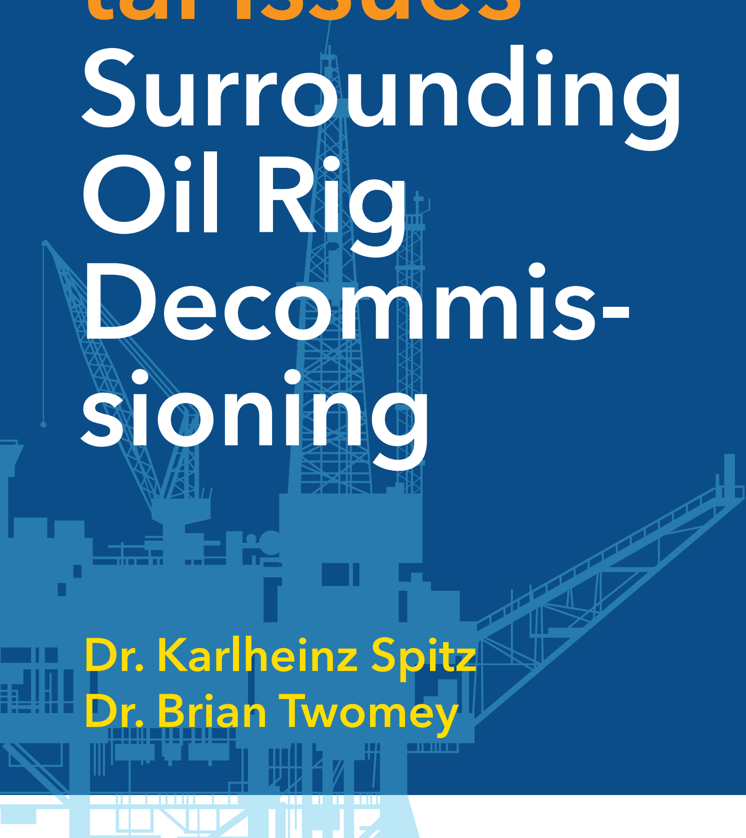
REVERSE ENGINEERING

Environmental Issues Surrounding Oil Rig Decommissioning



Dr. Karlheinz Spitz
Dr. Brian Twomey

Often Imitated Never Duplicated

REVERSE ENGINEERING

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Environmental Issues Surrounding The Decommissioning of an Oil Rig
By Dr. Karlheinz Spitz and Dr. Brian Twomey

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Contents

Preamble

There are two types of decommissioning in the oil and gas industry - onshore and offshore decommissioning.

Onshore decommissioning is largely uncontroversial and well covered by most national legislation. It involves well plugging and abandonment to protect groundwater, and removal of wellheads, flow lines, storage tanks, waste handling pits, and processing equipment. Most national legislation also covers site remediation requirements, if soil and groundwater contamination are present.

By contrast, decommissioning of offshore installations is a relatively new challenge to most oil and gas producing countries. It is natural to expect that industry's experience in building platforms is much greater than in dismantling them.

Decommissioning of offshore oil and gas installations, however, presents unavoidable future issues as installed platforms reach the end of their useful production lifetimes. A number of different decommissioning options exist and each will result in an array of environmental and socioeconomic impacts, some positive and some negative. These impacts are perceived and valued differently by stakeholders with differing perspectives.

This booklet provides an overview of potential environmental issues surrounding decommissioning of an offshore oil and gas installation (colloquially ‘oil rigs’ to oil and gas professionals); many aspects are equally relevant for onshore decommissioning projects.

This booklet does not replace the need for expert advice. Decommissioning differs widely from installation to installation as the complexity of oil rigs varies widely. A ‘One Size Fits All’ approach does not apply. That said, at a minimum, decommissioning needs to comply with national and international legislation.

“Our only business is decommissioning, all day every day for over 24 years.”

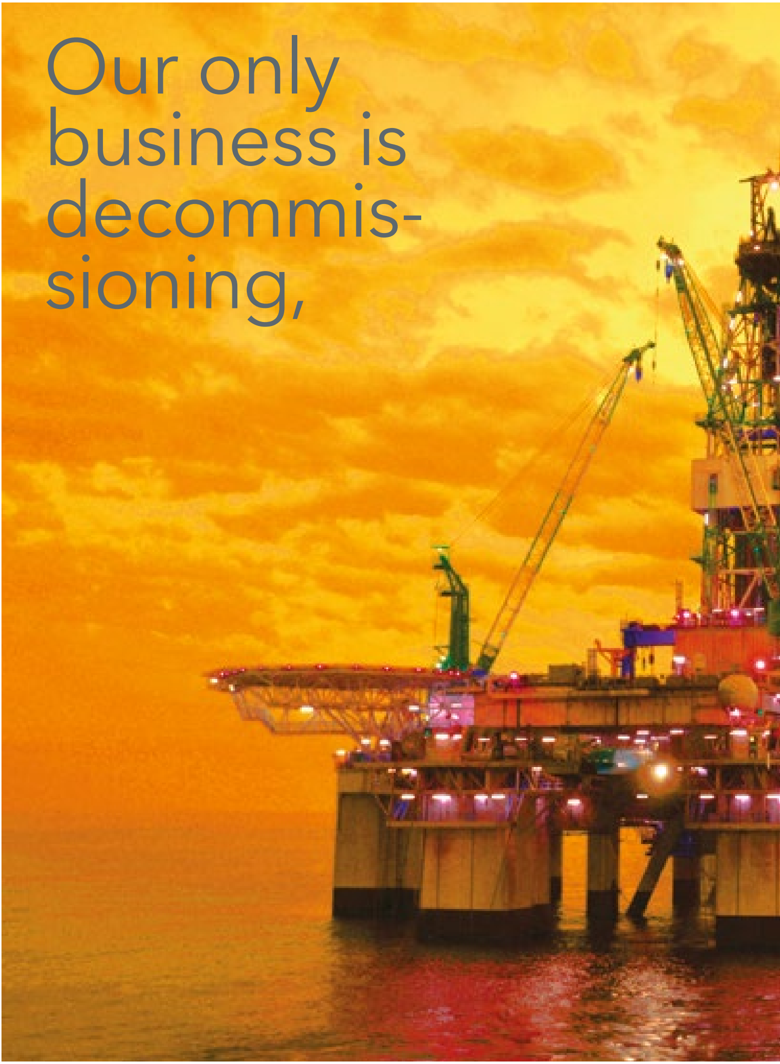
This catch phrase captures both our commitment to the oil and gas industry and our unrivalled experience. We can support your decommissioning project through every stage, helping to manage risk and to improve performance. Our experience is reflected in the choice of consultants and engineers we employ--all enjoy a high standing in the industry. Simply speaking we believe that in providing services to our clients, substance is more important than systems and platitudes.

Yours sincerely,

Dr. Karlheinz Spitz
Greencorp
May, 2014

Dr. Brian Twomey
RESL

Our only business is decommis-sioning,



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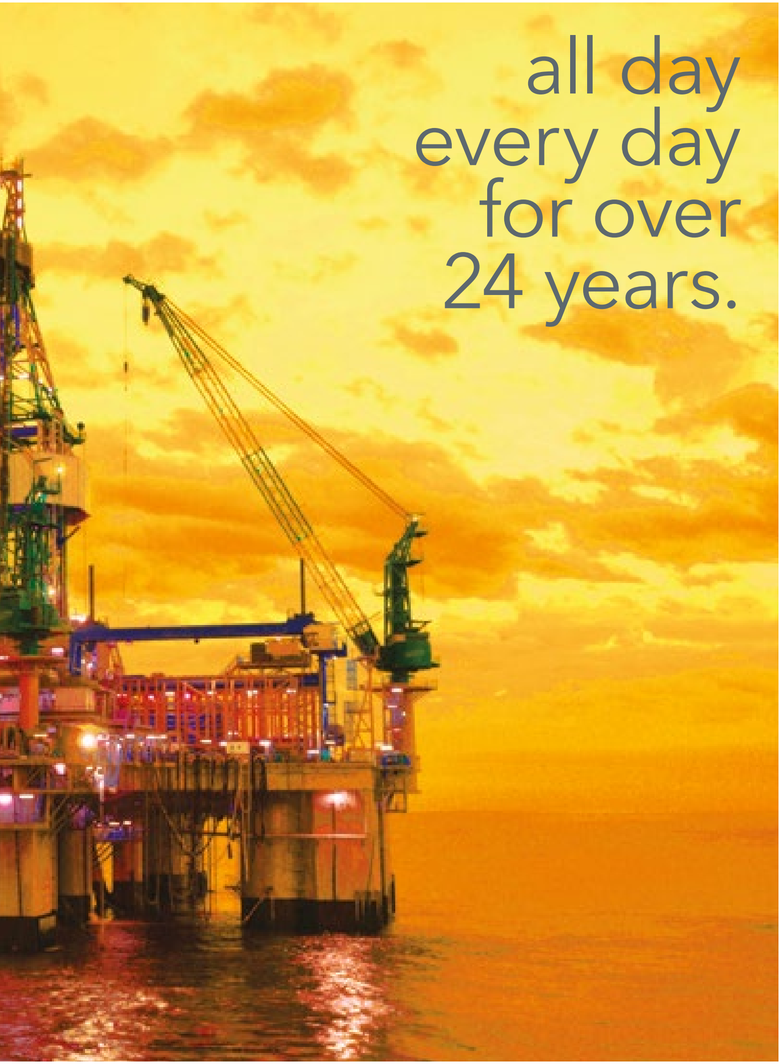
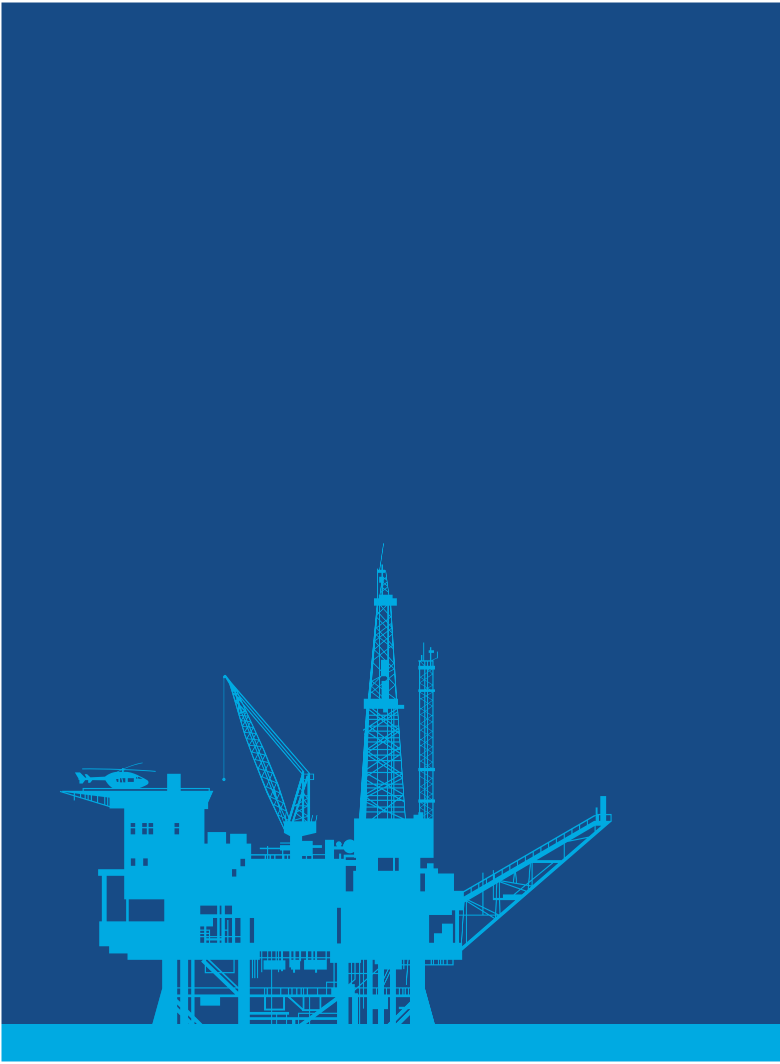

all day
every day
for over
24 years.

Acronym

CoC	Contaminant of Concern
CoP	Cessation of Production
DECC	Department for Energy and Climate Change (UK)
DEMP	Decommissioning Environmental Management Plan
GPS	Global Positioning System
EIA	Environmental Impact Assessment
EAP	Environmental Action Plan
EIS	Environmental Impact Statement
EP	Equator Principles
GHG	Greenhouse Gas
HDPE	High Density Polyethylene
IFC	International Finance Corporation
IMCO	Inter-Governmental Maritime Consultative Organization
IMO	International Maritime Organization
LSA	Low Specific Activity
LC	London Convention
LME	Liquid Metal Embrittlement
MMP	Mercury Management Plan
mwd	meters water depth

NOAA	National Oceanic and Atmospheric Administration
NGO	Non Government Organization
NORM	Naturally Occurring Radioactive Material
OSPAR	Oslo/Paris
PAHs	Polycyclic Aromatic Hydrocarbons
PPE	Personal Protective Equipment
ppb	parts per billion
PSC	Production Sharing Contract
P&A	Plug and Abandonment
RESL	Reverse Engineering Services Ltd.
ROV	Remotely Operated Vehicle
RTR	Rigs-to-Reefs
SE Asia	South East Asia
SRB	Sulfate Reducing Bacteria
UNCLOS	United Nations Convention on the Law of the Sea
WEEE	Waste Electrical and Electronic Equipment



Scale of the Challenge

Scale of the Challenge

In the coming years, with an increasing number of producing oil and gas fields nearing depletion or the economic limits of extractability, decommissioning activities are expected to increase.

Offshore installations consist mainly of production platforms (coined ‘decks’ or ‘topsides’) supported by gravity-based concrete foundations or steel frames (or ’jackets’ in short), and smaller structures either floating on the surface or positioned on the seabed, together with interconnecting subsea pipework and wells (Figure 1).

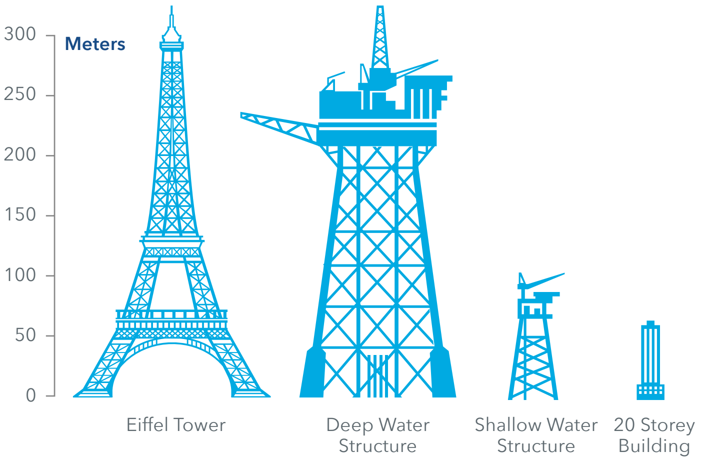
Nothing is Designed to Last Forever

Today offshore oil and gas infrastructure consists of more than 7,000 installations located on the continental shelves of more than 50 countries. About 3,500 are in the Gulf of Mexico, 1,300 in Asia, 750 in the Middle East, 500 in Africa, 350 in South America, and 630 in Europe

(Figure 2). In the coming years, with an increasing number of producing oil and gas fields nearing depletion or the economic limits of extractability, decommissioning activities are expected to increase.

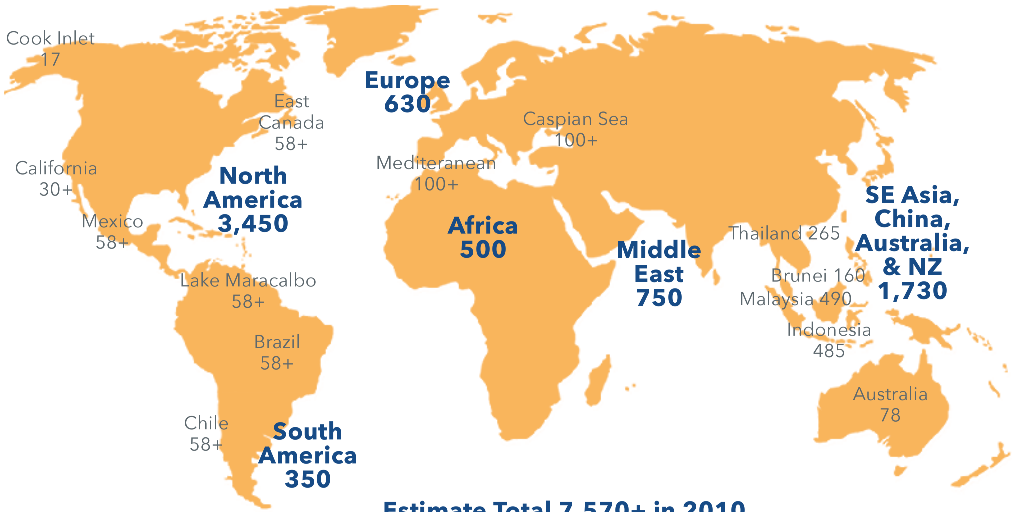
The offshore installations in SE Asia are a case in point. The primary drivers for decommissioning of an offshore installation are economics (e.g., reservoir is depleted), age (e.g., installation is well beyond its useful design age), and regulatory considerations (e.g., contractual arrangement of foreign oil company with host country comes to an end). Decommissioning options will then

Figure 1 Size Comparison of Offshore Installations



Source: Modified from W. Griffin, 1997

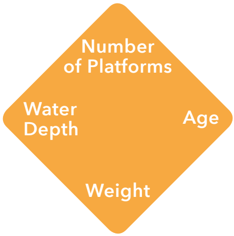
Figure 2 Worldwide Distribution of Offshore Structures in 2010



Source: Reverse Engineering Services Ltd.

Figure 3 Decomissioning Needs in South East Asia

Country	Platforms
Indonesia	485
Thailand	265
Malaysia	490
Brunei	160
Others	75
SE Asia	1,315



Depth (m)	% Platform
<75	85
>75	15

Age (y)	% Platform
<30	50
>30	50

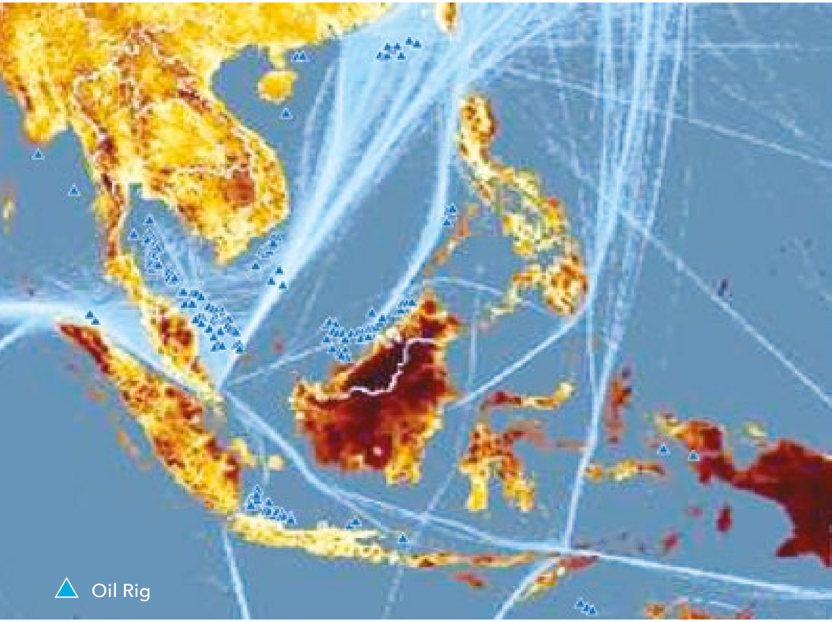
Jacket Weight (t)	% Platform
<4,000	80
>4,000	20

Source:
www.cil.nus.sg
Youna Lyons,
CIL Singapore

largely depend on water depth, age and type of installation, and weight (Figure 3). Safety of navigation is a final consideration (Figure 4). These drivers suggest that in South East Asia alone more than 400 offshore facilities are due for decommissioning in coming years.

Decommissioning (often used interchangeably with terms like 'abandonment' and 're-commissioning')

Figure 4 Shipping Traffic in the Seas of SE Asia



Source: National Center for Ecological Analysis and Synthesis from UC Santa Barabara
Youna Lyons, CIL Singapore

is the process by which options for the physical removal and reuse or disposal of offshore installations at the end of their working life are assessed and implemented at Cessation of Production (CoP). For new installations, the decommissioning process begins long before CoP; initial work is in fact part of project design phase. For older installations effective preplanning should commence at least two years before decommissioning.

UK's DECC suggests that decommissioning should be consistent with national and international obligations, taking into consideration:

- The Precautionary Principle;
- Best Available Techniques and best environmental practice;
- Waste hierarchy principles;
- Other users of the sea;
- Health and Safety laws;
- Proportionality; and
- Cost effectiveness.

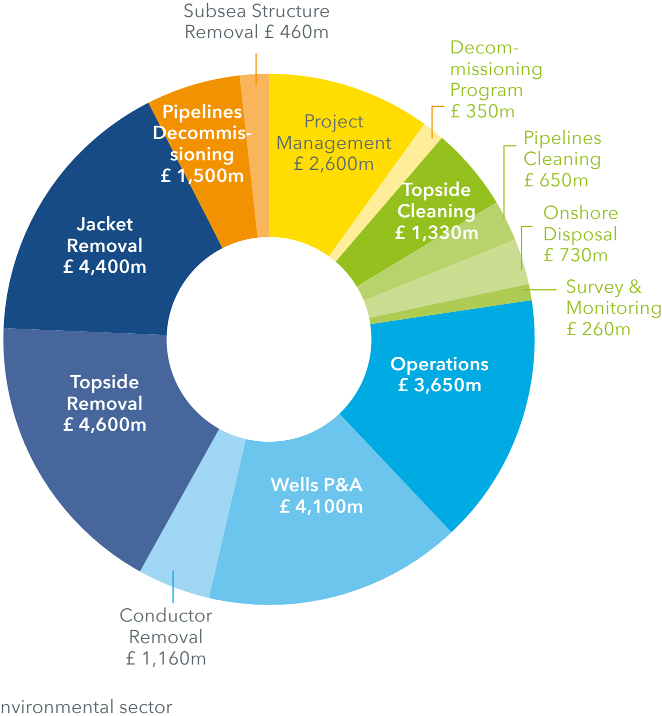
Figure 5 indicates that decommissioning of oil and gas installations can be a costly business; it comprises the following activities:

- Decommissioning planning and management;
- Physical dismantling and removal of structures;
- Remedial measures to manage environmental and social issues remaining from operations or resulting from Cessation of Production and decommissioning activities; and
- Restoration of the site to an agreed-upon use and quality in line with expectations of government authorities and relevant stakeholders.

Decommissioning Planning and Management

In our environmentally concerned society, recycling of industrial installations and materials is the preferred

Figure 5 UKCS Decommissioning Spend by Sector (2009 money).



Source: Oil and Gas, UK.

Note: Figure 5 suggests that environmentally related costs amount to about 10 % of total decommissioning costs.

option. However, in the oil and gas industry, many components are likely contaminated with substances that do not allow unrestricted recycling. For example, the scale in pipelines may be contaminated with radium and thorium including all decay products. Depending upon origin and particularly for natural gas production facilities, mercury contamination must also be taken into consideration. As mercury completely evaporates at high melting temperatures, only furnaces at metal recycling plants equipped with an effective combined exhaust and air filter system are suitable to receive mercury contaminated steel.

Environmental issues in decommissioning, as detailed in the following sections, relate primarily to removal of hazardous materials such as NORM scale, cleaning and disposal of hydrocarbons and other residues in situ and at the disposal site, potential for pollution at the final destination, and to the energy use (including greenhouse gas emissions, given that energy consumption can be high for topside removal, particularly where heavy lift vessels are required for an extended period of time).

Note: While the technology for removal of hazardous materials and cleaning of hydrocarbons and other residues is generally well proven, managing environmental issues surrounding decommissioning remains a specialized and relatively new discipline.

Decommissioning Strategies

Decommissioning Strategies

Newer generations of agreements between States and outside oil companies treat the responsibility for decommissioning more effectively; early generations normally did not.

Broad Strategies for Decommissioning Offshore Installations

Four broad strategies exist for decommissioning, with total removal being often the base case preferred by Government authorities (Figure 6). In determining which strategies to adopt for a particular installation, it is important to consider how to minimize liability in the most cost-effective manner.

Deferral

Leave in situ - The entire installation is left without any attempt to restore the site, an acceptable strategy if the installation is still in good condition. Leave in situ is an option that is only to be practiced for deferral cases and is not an option for permanent abandonment. Deferral can be justified, for example, if re-use of the installation is a possibility.

Transfer of Asset - This refers to the transfer of the offshore installation to other companies; liability for abandonment and restoration in such cases would need to be assessed and agreed with the new owner. Transfer of asset will only defer and not replace decommissioning (Box 1).

Box 1 **Early Generations of Production Sharing Contract**

In some countries, during exploration, the investments risks are partiaally or completely assumed by outside oil and gas companies rather than the State as owner of the resource. However, once hydrocarbons are identified in commercial amounts, development occurs under a different agreement (for example under a 'Production Sharing Contract' or PSC) which usually attributes an important share of the production to the State through a National Oil and Gas Company.
Upon Cessation of Production (or termination of the agreement), assets are usually 'returned' to the state/national oil and gas company, which is then also responsible for decommissioning.
Newer generations of agreements between States and outside oil companies treat the responsibility for decommissioning more effectively; early generations normally did not.

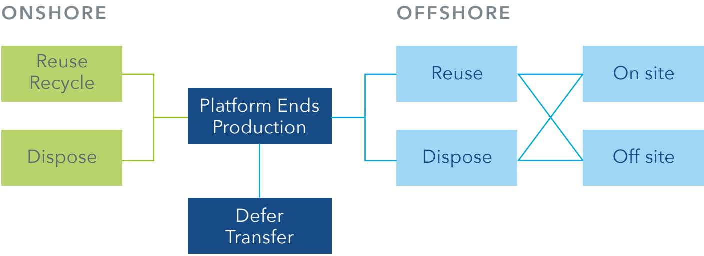
Partial Abandonment

The degree of abandonment will depend on legislative requirements and may take into account the environmental value of the area that has been impacted by operations. It is however common to strip out the topside in partial removal.

Total Removal

Every component of the installation, both above and below the water surface, is removed and the site restored to its pre-development condition to the extent practical. This option is likely to be favorable in terms of practicability and acceptability.

Figure 6 Oil and Gas Decommissioning Options



Once a platform is actually decommissioned and removed, the main options for disposing of the structure are as follow (Figure 6, after prior in situ cleaning):

- **Onshore**
  Recycling - Structural components are dismantled and removed to shore for salvage. This involves cutting up the structure into smaller pieces that can be transported to shore for recycling into scrap steel. Note that onshore recycling facilities may be limited in the host country.

  Onshore Disposal - Installation (or parts of) disposed as scrap steel into a landfill site, along with various hazardous waste fractions generated in decommissioning.

- **Offshore**
  Re-use in the Oil and Gas Industry - Re-use installation (or parts of) for oil and gas production offshore in another location. Most of the jackets and structures likely have reached the end of their design life upon decommissioning, making re-use unlikely. However, certain plant and equipment (e.g., compressors, turbine generators) may be suitable for sale and/or re-use.

  Other Uses - Installations (or parts of) are cleaned and used for other purposes, for example, as a logistic base for helicopters or boats if sufficiently near other oil fields, or as lighthouse, meteorological station, or possible site for alternative energy generation (wind or wave energy).

Toppling on Site - In this option, the topside is stripped off and the jacket is toppled to the seabed at its piled location. This process is suitable for steel but not concrete structures.

Note: The International Maritime Organization (IMO) in 1989 adopted offshore removal guidelines to clarify the obligation of coastal states with offshore installations. One requirement is that a minimum clear water depth of 55 m from the surface of the sea to the remains is required (unless designated as an artificial reef).

Disposal in Deep Water - Structure is removed, transported to a deep ocean disposal site and scuttled to settle on the sea floor at a licensed deep water site.

Artificial Reef Conversion – After cleaning, installation is placed on shallow seabed to form artificial reef to encourage marine life (Box 2). Such 'Rigs-to-Reefs' activities are found in US Gulf of Mexico, Japan, and Brunei.

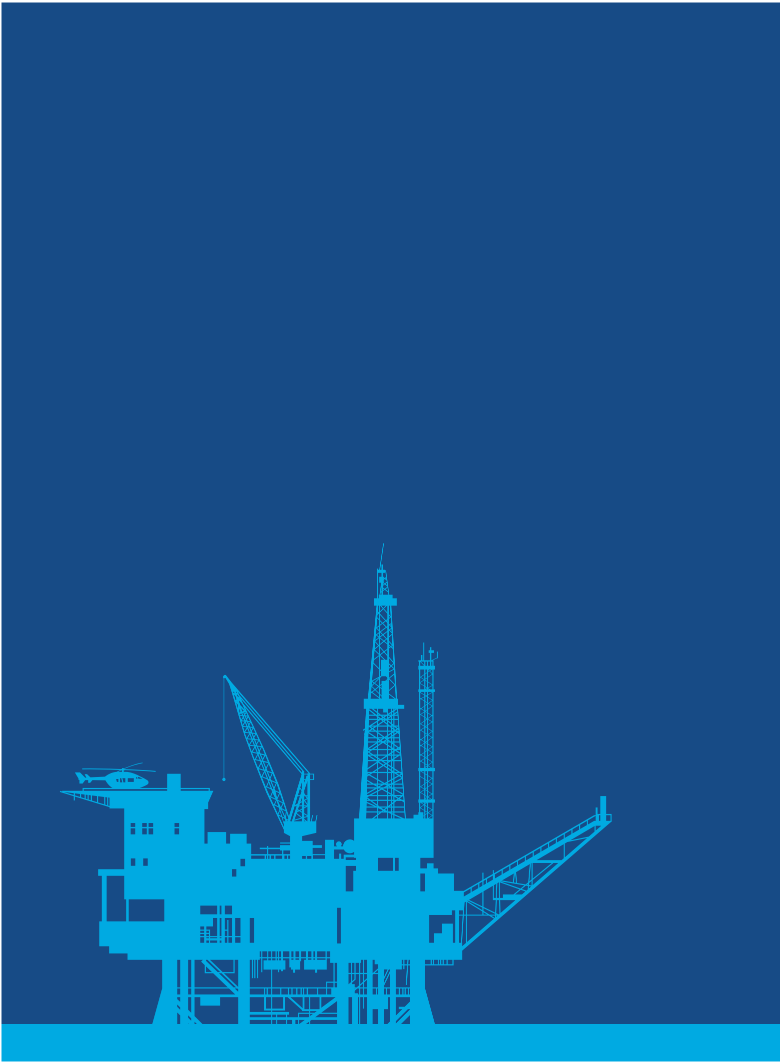
Several methods are in use to dismantle the platform:

- 'piece small': the installation is dismantled offshore and cut into small sections shipped onshore in containers;

Box 2 **Rigs-to-Reefs**

Rigs-to-Reefs (RTR) is the practice of converting off-shore oil and gas rigs after Cessation of Production into artificial reefs, based on observations that fish densities are 20 to 50 times higher around oil and gas platforms than in nearby open water. Rigs-to-Reefs, however, is somewhat of a misnomer given that marine organisms have attached themselves to the underwater portions of oil rig during production, transforming them into artificial reefs long before they are due for commissioning. This begs the question whether it is good practice to remove established artificial reefs to create new ones. In addition, to many environmentalists, any program that benefits the oil and gas industry, as by lowering decommissioning costs, is suspect. They argue that Rigs-to-Reefs is simply an excuse for ocean dumping.

- heavy lift: whole modules are removed in the reverse of the installation sequence and loaded on to flat-top barges or a crane vessel for transport to the demolition yard; and
- single lift: topside and/or jacket are removed in one piece and transported to the demolition yard (rarely used).



Environmental Concerns Vary Widely

Environmental Concerns Vary Widely

There are many environmental issues to be taken into account throughout the decommissioning process, from planning over carrying out shut down operations and cleaning to waste disposal. Environmental issues vary between installations.

The geology of the hydrocarbon reservoir, the design of the production installation, and the production history all influence the environmental issues in decommissioning a specific installation. Therefore, generalizing about the environmental issues surrounding decommissioning is questionable. That said, common environmental concerns do exist, and examples follow.

- Hydrocarbon and chemical releases;
- Scales containing Naturally Occurring Radioactive Material (NORM);
- Potential mercury contamination ;
- Presence of asbestos;
- Presence of hydrogen sulfide gas (H_2S);

- Disturbance to the seabed and accumulated drill cuttings;
- Impacts on fishing gear;
- Underwater noise; and
- Secure treatment and disposal of wastes.

Hydrocarbon and Chemical Releases

Crude oil is a complex mixture of thousands of chemical components with different toxicities, and naturally, the composition of the crude oil defines the composition of the hydrocarbon residues present in offshore installations. The PAHs (polycyclic aromatic hydrocarbons) commonly found in heavy oil fractions are among the most persistent pollutants in the environment. In general, the toxicity of PAH's increases with increasing molecular weight and substitution.

Hydrocarbon residues, together with a water phase, remaining in separators and storage compartments could further result in biological activities where bacteria use hydrocarbons as substrate. The bacterial growth based on the bioavailable hydrocarbon can cause H_2S challenges for the decommissioning project, as detailed elsewhere in this Booklet. Bioavailability and degradability vary between hydrocarbons. In general, substances with higher water solubility are more bioavailable and hence relatively quickly degraded. Compounds with high number carbons are less water soluble and hence biodegrade more slowly. Increased fractions of heavier hydrocarbons, being difficult to degrade, are thus expected to accumulate with time.

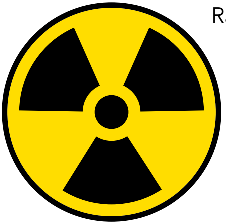
Hydrocarbon compounds with relatively low water solubility, include higher paraffins and olefins, asphalthenes, waxes, and PAH compounds. The low solubility of these compounds continues to decrease with increasing chain length. A limited concentration of these compounds is expected in the water phase of flushed enclosed systems, as these compounds have a high tendency to adsorb to particulate material. The adsorption to particles results in precipitation at the internal walls and the bottom where they accumulate. Residues of hydrocarbon sludge not removed by the flushing/cleaning process are often the main contamination in the disused installation.

Topside units can normally be manual cleaned offshore before transported to land, but non-accessible units such as subsea storages might be difficult to clean properly. Units and structures containing residues not possible to remove offshore are normally removed onshore with additional cleaning during dismantling. Any structures left in place may to a certain extent still contain hydrocarbon residues. Pipes can contain scale and hard deposits that are not feasible to remove offshore. These deposits can be both inorganic and hydrocarbon based. In storage facilities hydrocarbons can also be present as bottom sludge or as floating oil emulsion material.

The emulsion could be of environmental concern for installation units such as storage cells which are typically difficult to clean. Removal of oil and other residues from storage facilities may be difficult to accomplish as the installation normally was not designed to facilitate a cleaning operation.

In general, it is expected that the remaining oil residues consist mainly of heavy oil components as the lighter water soluble hydrocarbons are most likely removed by flushing, normally performed after Cessation of Production. Both the properties and the quantities of hydrocarbons will affect any possible environmental impacts of oil residues. High concentration of oil compounds can promote toxic effects. Heavy oil compounds can have chronic impact due the persistency in the environment, while light hydrocarbons normally have acute effect as this fraction is relatively soluble and easily dissolved and can be quite volatile. Discharged or accidental leaks/spills of the heavy oil residues can have long term effects on the environment due to the relative low degradability caused by the low solubility and thereby low bioavailability.

NORM



Radioactive trace substances are present in the formations tapped by most offshore locations. Naturally Occurring Radioactive Material (NORM) or Low Specific Activity (LSA) materials are the collective names to describe radioactive materials that exist naturally in the geological environment. Traces of these substances have been present in the formations from which oil and natural gas are extracted ever since Earth was formed. During production, they too are brought to the surface with the oil and/or natural gas, either as gas or as salts (dissolved in water or in a solid state). It is therefore possible to find gaseous radioactivity in the form of radon gas in the hydrocarbon production environment. The radioactive substances can accumulate (in sludge) in some installation components or deposit (form scale) inside pipes, tanks, and vessels (Box 3).

Box 3 **NORM Fact Sheet**

What are the characteristics of NORM?

- Invisible and odorless
- Measurable using special equipment
- Health hazard
- Environmental hazard.

Where, when, and how can you come into contact with NORM?

- When a closed system or installation leaks liquids and/or gases
- When a closed system or installation is opened

Physical forms of NORM

- Gaseous as radon
- Liquid form as (watery) sludge
- Solid form as scale

Radiation risks

The radiation dose you are likely to receive due to NORM is low and not harmful. However, radiation caused by NORM can pose a health risk in cases of:

- Regular and long-term exposure to relatively small doses of radiation or
- Direct internal contact with NORM.

While the job is underway

- Prevent sludge spills - use spill basins
- Prevent the dispersal of radioactive dust particles - no dry grinding or brushing
- Make sure that, wherever possible, the surfaces to be treated are kept wet
- Store and dispose of NORM- contaminated components in accordance with applicable instructions

What personal protective equipment?

- Basic PPE
- Non-porous gloves
- Disposable overalls and rubber safety boots
- If dust is produced--full-face masks with independent breathing protection
- During welding (evaporation product)--pressurized welding mask with breathing air supply

Source: Modified from GDF Suez 2012, Information Material NORM/LSA

Note: NORM builds up within the pipes and components in much the same way as natural lime scale develops in a kettle over time.

Scale is composed primarily of insoluble barium, calcium, and strontium compounds that precipitate from produced water due to changes in temperature and pressure (see Table 1 and Figure 7). Radium is chemically similar to these elements and as a result is incorporated into scales.

In the context of decommissioning, the radioactive substances of primary relevance are radium isotopes (Ra 226 and Ra 228), lead isotope (Pb 210), and polonium isotope Po 210. Concentrations of Ra 226 are generally higher than those of Ra228. The average radium concentration in scale has been estimated to be 480 pCi/g. It can be much higher (as high as 400,000 pCi/g) or lower depending on regional geology.

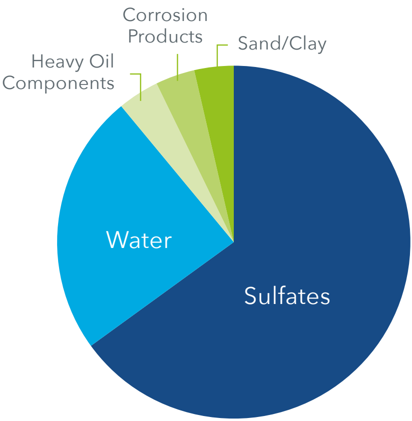
Note: Since radioactive scale is often deposited together with barium sulfate originating from produced water, larger quantities of NORM material in installations from oil fields are expected compared to those from gas fields.

Table 1 Scale Types

Scale Type	Main Constituent	Main Radionuclides	Production Type
Sulfate scale	Ba/Sr Sulfate	^{226}Ra, ^{228}Ra	Oil
Carbonate scale	Ca Carbonate	^{226}Ra, ^{228}Ra	Oil
Lead scale	Steel	^{210}Pb	Gas
Sulfide scale	Iron Sulfide	^{226}Ra, ^{228}Ra, ^{210}Pb	Oil and Gas

Source: Norway's disposal site for oil industry NORM, Per Varskog, Norse Decom AS, Norway

Figure 7 Scale Composition Illustrated



Source: Norway's disposal site for oil industry NORM, Per Varskog, Norse Decom AS, Norway

Scales are normally found on the inside of piping and tubing. The highest concentrations of radioactivity are commonly in the scale in wellhead piping and in production piping near the wellhead. The largest volumes of scale occur in three areas:

- water lines associated with separators (separate gas from oil and water);
- heater treaters (divide oil and water phases); and
- gas dehydrators, where scale deposits as thick as four inches may accumulate.

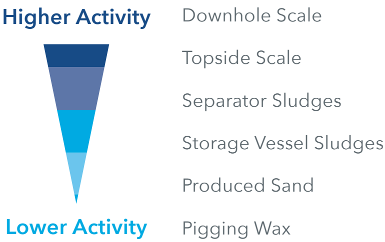
More specifically scale is found in production tubulars, christmas trees, risers, oil-water separators, topside tubes before oil-water separation, and water discharge system. As the oil in a reservoir dwindles and more water is pumped out with the oil, the amount of scale increases.

Note: Approximately 100 tons of scale per oil well are generated annually in the United States.

The activity levels of the NORM deposits produced in the various steps in the oil and gas production differ among different types of activities. Figure 8 broadly ranks the activity level in NORM depending on type of activity. In gas production, NORM is found anywhere in the system, from the risers to the flares.

The environmental concern of NORM is the ionizing radiation that can cause radiation damage, primarily if

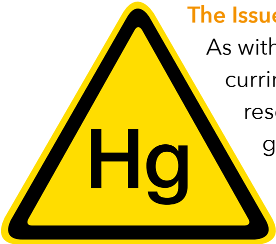
Figure 8 Ranking of Radioactivity Level in NORM from Different Types of Activities



inhaled/swallowed or in direct contact with the surface of organisms. This is also an important aspect regarding safe working environment during decommissioning. Workers can be exposed by internal radiation through NORM dust if swallowed or inhaled, as well as through skin contact. When assessing the environmental fate and impact of NORM, it is important to take the affinity toward particulate matter into consideration.

NORM scale is handled according to the same principles as all other waste in the industry, i.e., in a 'cradle-to-grave' perspective with focus on highest possible degree of reuse and recycling. Therefore, NORM scale contaminated components are typically cleaned by high-pressure water jetting, facilitating recycling of the component steel and minimization of NORM waste.

Dangers of Mercury in the Oil and Gas Industry



The Issue

As with NORM, mercury (Hg) is a naturally occurring trace contaminant in hydrocarbon reservoirs that is distributed in all phases (oil, gas, and water). The presence of mercury poses a hazard in the oil and gas industry in a number of areas including damage to and contamination of production facilities and processing plant, contamination by Hg in hydrocarbon products, environmental emissions, and waste disposal. At a minimum, it poses environmental and health hazards by its simple presence (Box 4).

Box 4 **Mercury – a Slippery Metal**

The term 'native mercury' is used for natural mercury associated with the mineral cinnabar. Mercury was named after the Roman god, Mercury. Mercury is also known as quicksilver, because this silvery mineral occurs at room temperature as a liquid. The symbol for mercury, Hg, was derived from the name, *hydrargyrum*, from the Greek words, *hydros* meaning water and *argyros* meaning silver. Mercury is a peculiar metal, being liquid at room temperature, and naturally occurring in its pure form.

- Mercury may be found in crude oil and natural gas condensate and follows the production flow in different chemical forms
- Elemental mercury is the most common form
- Reservoirs with sweet crude oil (low content of H_2S/ CO_2) and high temperature or pressure seem to experi-ence the highest content of mercury
- Elementary mercury has been detected in particular in the light fraction of hydrocarbons (C3-C5) and in oil sludge
- Gas and liquids processing can cause mercury species transformation from one chemical form to another. One example of this is the mixing or commingling of sour and sweet gas streams where elemental mercury can react with elemental sulfur to form mercuric sulfide

Mercury is typically associated with:

- Process equipment with C3 – C5 flows
- Flows that are chilled (e.g., in heat exchangers)
- Equipment made of carbon steel or aluminum. All surfaces inside process equipment that has been in contact with a process stream with elemental mercury should be treated as contaminated even though mercury is not observed
- Equipment coated with a protective material or cement (e.g. drums)
- Mercury may partly be absorbed by steel pipingv
- Mercury-contaminated process vessels and piping will begin to desorb mercu-ry at ambient temperatures long after the equipment has been purged and cleaned of hydrocarbons. This phenomenon is

multiplied when welding or cutting occurs, releasing large amounts of mercury vapor from the heated surface area.

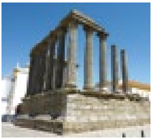
Mercury is a trace contaminant in crude oil and petroleum products in concentrations at the part per billion levels (Figure 9). These concentrations are generally considered too low to produce any observable effect. To put the average mercury content of 3.5 µg/kg in crude oil in perspective, the concentration in people is about the same. However even low concentrations of mercury can be significant because of the large quantities of oil and gas processed. Over time, mercury tends to accumulate in production facilities due to settling, amalgamation, or other forms of concentration.

Admittedly there is little readily available experience to confirm or deny adverse mercury exposure in oil and gas decommissioning work. The dilemma is that there is potentially a nasty way to find out.

The important concerns of mercury presence in decommissioning apart from market image are

- Economic/treatment liabilities;
- Toxic nature of sludge;
- Water discharge, especially from offshore platforms;
- Mercury accumulation in transportation systems such as pipelines.

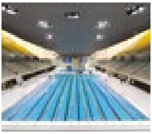
Figure 9 What is One Part per Billion?

One Minute in 2,000 Years


One Penny in $ 10,000 Dollars


One Inch in 16 Miles

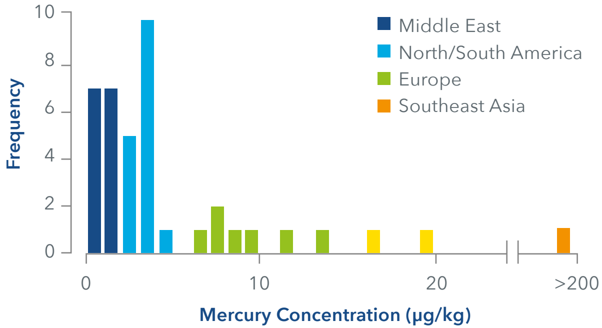



One Drop of Water in Olympic Size Swimming Pool

Mercury Levels in Crude and Gas

The concentration of mercury at the well head is highly variable, ranging from non-detectable quantities to saturated levels. Mercury levels in crude and gas vary widely, both between and within reservoirs and geographical areas. Unfortunately, the same can be said for historical laboratory data, due to the variety of mercury compounds and test methods. A histogram of the distribution of concentrations across the globe, excluding extreme outliers from SE Asia, particular Thailand, suggests that most global sources of crude oil have low (0 to 5 μg/kg) mercury concentrations (Figure 10).

Figure 10 Histogram of Crude Oil Mercury Concentrations Reported by Countries



Source: Mercury in Crude Oils
2013 MCA Spring Seminar Series
Tom Littlepage

Mercury Components in the Oil and Gas Industry

Mercury, a highly volatile transition metal, is found in the environment from elemental form to highly toxic organo-mercury compounds. Detectable mercury components of crude oils would include elemental mercury, mercuric chloride, mercuric sulfide, mercuric selenide, dimethylmercury, diethylmercury, and asphaltenes (tars) (Table 2). As stated elsewhere, these can exist in soluble, insoluble, gaseous, solid and liquid states. Of note is that this variation significantly influences sampling and test methods.

Note: Whereas crude oil contains a complex array of mercury species, most of the mercury in natural gas is elemental mercury. Mercury concentrations in natural gas are generally higher than in crude oil. For example, the difference in mercury concentrations in SE Asian gas and gas liquid is about three orders of magnitude, from approximately 1 to 1,000 µg/m3 in gas and 1 to 1,000 ppb in liquids.

Mercury in Pipelines and Equipment

Mercury is known to form amalgams with metals, particularly aluminum and magnesium (or gold; for this reason mercury is widely used in artisanal gold mining), leading to a condition known as Liquid Metal Embrittlement (LME). During operation mercury can damage pipeline welds, cryogenic components, aluminum heat exchangers, and hydrogenation catalysts. The amount of mercury adsorbed to the steel varies as the mecha-

Table 2 Mercury Compounds in The Oil and Gas Industry

Crude/Condensate		Natural Gas
Form of Mercury	**Example**	**Form of Mercury**
Dissolved Elemental Mercury	Elemental Hg	Elemental Mercury
Dissolved Organic Mercury	RHg or RHg-X where R = CH_3, C_2H_5, etc. and X = Cl	
Inorganic (Ionic) Mercury Salts	$Hg^{+2}X$ or $Hg^{+2}X_2$ where X is an iniorganic ion	
Complexed Mercury	HgK or HgK_2	
Suspend Mercury Compounds	Mercuric sulfide (HgS) and Selenide (HgSe)	
Suspend Adsorbed Mercury	Elemental and organic mercury that is not disolved but rather adsorbed on inert particles such as sand or wax.	

Source: Guidelines on Mercury Management in Oil & Gas Industry, Director General Department of Occupational Safety and Health Ministry of Human Resources, Malaysia, 2011

nism is a function of metallurgical and physical/chemical factors. The mechanism is not currently completely understood, but it is important to note that the process is reversible.

Note: Mercury adsorption to steel is reversible. Therefore, mercury adsorbed by the steel components can be re-dissolved into liquids or re-evaporated into gas, which can cause exposure of workers and can leach to the surrounding environment during decommissioning projects.

Mercury adsorbs (reversible bonds) and chemisorbs (irreversible chemical bond) to metallic surfaces. As such, piping and steel equipment that contact gas or condensates with measurable concentrations of mercury will eventually contain mercury in proportion to the concentration of mercury in the fluid or gas that contacted the piping and equipment. Said differently mercury and mercury compounds, if present, have the potential to contaminate essentially the entirety of production, processing, and petrochemical manufacturing systems.

Carbon and stainless steel are both excellent scavengers of mercury. The reaction is catalyzed by the presence of H_2S in trace quantities. Chemisorption dominates for carbon steel surfaces, while adsorption dominates for stainless steel surfaces. Both contribute to a lag effect, which can delay the appearance of mercury in downstream processing facilities for months or years. Mercury can penetrate up to 1 mm into pipeline walls. Measurements on natural gas before and after passing through a 100km pipeline showed mercury concentrations decreasing by 60 %.

Note: The presence of mercury poses challenges to scrap metal recycling. Many smelters set a 2,000 µg/kg limit on mercury in scrap metal to avoid damage to the off-gas clean-up filters--with higher concentrations requiring disposal as hazardous waste, or metal recycling in smelters with special flue gas treatment facilities to capture evaporated mercury vapor.

Distinct from mercury chemisorbed into pipeline walls is mercury-rich sludge, which can be removed from pipelines via 'pigging'; effectively rolling a large ball down the pipeline collecting the sludge that has accumulated. While the waste collected from the 'pig' is mercury rich, the quantities are small.

Understanding the nature and distribution of mercury in the production installation to be decommissioned, including depth profiles in steel process equipment and piping, is important to developing effective mercury management and decommissioning plans.

Mercury Management Plan

Mercury in hydrocarbons is a fact of life. In response, industry has developed a number of mercury safe-handling protocols for use in upstream, midstream, and downstream applications. In modern operations, mercury management includes removing mercury before it has a chance to negatively impact operators and equipment downstream. Unfortunately, while there is a wealth of information available across the industry related to safe mercury management in new production and operation facilities, this does not necessarily hold true for older installation that now approach their end-of-life.

The takeaway from this discussion is that before decommissioning work commences, especially for facilities in which hydrocarbon production has been exposed to increased mercury levels, there is the need to conduct a hazardous materials survey and a risk assessment for mercury, and to develop a site-specific Mercury Management Plan (MPP) in accordance with both legal obligations and industry best practices. The Mercury Management Plan documentation should be kept on site and communicated to all contractors who will be performing work at these facilities.

Asbestos in Older Oil and Gas Installations

The asbestos issue is restricted to decommissioning of older oil and gas production installations. Asbestos, while largely banned today, was widely used when the first offshore oil and gas installations were put in place. These are the same offshore installations that now are due for decommissioning.

Asbestos has been widely used because of its unique properties: it is hard-wearing, chemically inert (resistant to corrosion by acids and bases), and stable at high temperatures (Box 5). Asbestos can be present in j4m3z (www.jmxphoto.com), Istockphoto.

many parts of older offshore structures, e.g., insulation, gaskets, cables for emergency systems, and hardwall/drywall plates.

Note: Documentation and materials inventories from the construction period of the installation in question may contain useful information on the use of asbestos.

The largest challenge associated with asbestos is the working environment during removal. There are very high demands to ensure the removal is safe for the personnel involved. This includes establishment of sanitation zones and use of special personal protective equipment (PPE). Inhalation is the main way that asbestos enters the body, and even small amounts of certain types of asbestos inhaled can cause serious health problems such as asbestosis and cancer. During the demolition works, materials that contain asbestos are removed and handled as other materials classified as hazardous, including packaging and labeling in accordance with the asbestos regulations and delivery to an approved landfill.

Box 5 **Asbestos – The Miracle Material of the Past**

Since all asbestos fibers are silicates, they exhibit common properties: incombustibility (in the past, fire was occasionally used to clean fabric made out of asbestos), thermal stability, resistance to biodegradation, chemical inertia toward most chemicals, and low electrical conductivity. Its crystalline structure also allows separation of asbestos minerals into thin and strong but flexible fibers. Fibers that are at least 1 cm in length can further be spun into yarn. Because of these characteristics, asbestos found numerous industrial applications up to the mid-Twentieth Century: fireproof fabrics, yarn, cloth, paper, paint filler, gaskets, roofing composition, reinforcing agent in rubber and plastics, brake linings, tiles, electrical and heat insulation, cement reinforcing, and chemical filters. Over the centuries, asbestos was regarded as a miracle material, combining the strength of rock with the flexibility of silk.

Potential Presence of Hydrogen Sulfide Gas

Hydrogen sulfide (H_2S) is an extremely hazardous, toxic compound. It is a colorless, flammable gas that can be identified even in relatively low concentrations by a characteristic rotten egg odor. The gas can occur naturally in gas wells, but also as a product of decaying sulfur-containing organic matter, particularly under low oxygen conditions. It is therefore commonly encountered in sewage systems (not surprisingly, H_2S is often called 'sewer gas').

H_2S can accumulate in systems that are enclosed after Cessation of Production (CoP). These systems include in particular the top side separator tanks and the substructure storage cells. It is important to recognize that H_2S is a concern with respect to the working environment and is not normally an environmental issue. H_2S is very toxic and H_2S gas can be an overlooked challenge in decommissioning projects. The toxic gas may escape to the working environment during decommissioning; it can result in immediate deaths offshore when it reaches high concentrations (>700 ppm).

The H_2S is more pronounced in facilities closed for a long time after CoP. Residue hydrocarbons will act as substrate for microorganisms in the production fluids, where both water from the reservoir and seawater containing bacterial fauna enters the system. The environment within the closed system will with time shift to anaerobic, which is favorable for sulfate reducing bacteria (SRB). The SRB's will take over as the major driver in the anaerobic environment and H_2S is produced by reduction of sulfate as shown below:

$$SO_4^{2-} + \text{organic matter} \rightarrow CO_2 + H_2O + H_2S$$

Inhibition of H_2S is important to ensure a safe working environment during decommissioning work. Inhibition of H_2S can be executed by the use of H_2S scavengers, which are commonly used by the industry for pH increase during production. The chemical treatment can however be toxic and will produce residues that may require further treatment or handling. H_2Sv scavengers are of environmental concern and require appropriate handling as they can have the impact of killing microorganisms present in the surrounding environment if discharged to sea.

Air Pollution

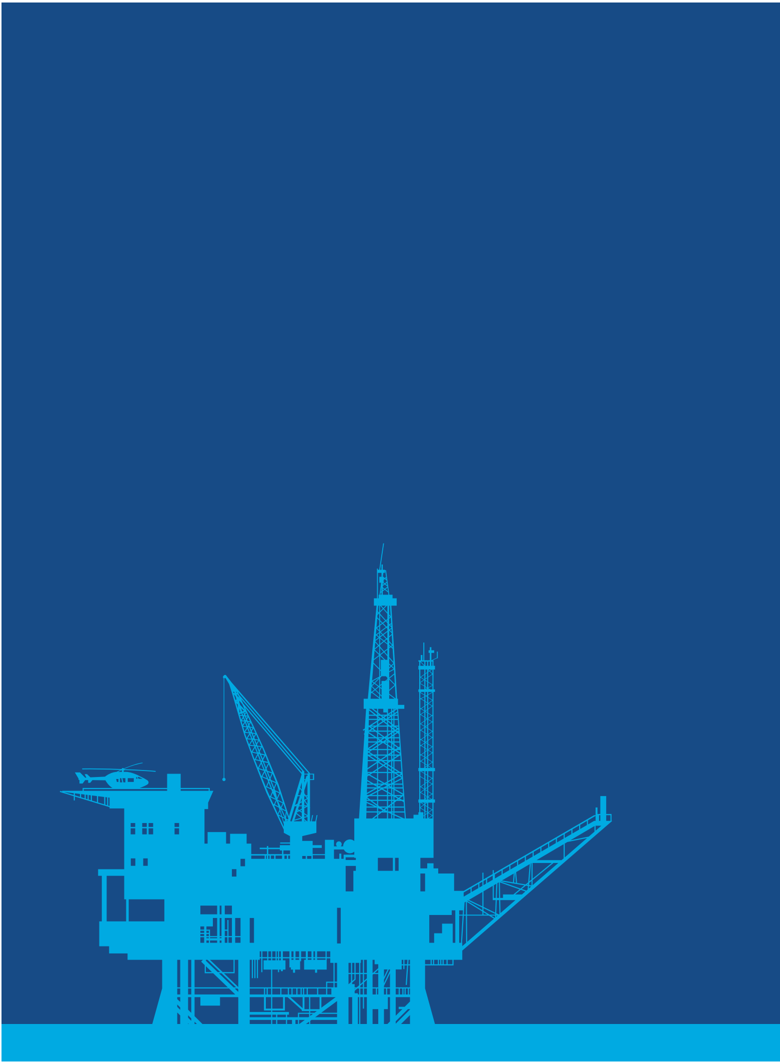
The vast majority of air pollution emissions from platform decommissioning will stem from combustion of fuel by diesel engines, which are used in virtually all phases and activities of the decommissioning process. The number of engines required is large, the engine size and likely age range are broad, the number of applications for which the engines are used is considerable, and the uses occur both offshore (e.g., at the platform itself, in its vicinity, and in transit to and from it) and onshore (e.g., in port, at offloading, salvage and recycling facilities, and in material transportation). Thus, the potential for air pollution emissions is correspondingly large, as combustion of diesel fuel produces exhaust that contains a multitude of air contaminants.

As technology has improved and the water depth of offshore leases has increased, platform support structures have necessarily grown in size, such that the sheer weight and physical bulk of a deep water platform are many times greater than for a shallow water counterpart (see also Figure 1, page15). Because platform removal will be performed with diesel engines, a simple but reliable rule of thumb is that the deeper the water in which a platform is set and the higher the percentage of the platform that is to be removed, salvaged, and disposed, the greater will be the associated air pollution emissions.

Combustion of diesel fuel produces a number of air contaminants, including CO_2, a prominent greenhouse gas. Greenhouse gas (GHG) emissions, per se, are not regulated through any enforceable permitting system as yet. But analysis and quantification of emissions, associated impacts, and potential mitigations for GHG attributable to a decommissioning project would likely still be addressed during the project's environmental impact assessment phase. Conceivably, the same issues would need to be addressed in the postoperation phase of the environmental impact assessment of a future project currently being designed and permitted.

To quantify a decommissioning project's total air pollution and greenhouse gas profile, emissions from each phase, component, and equipment item used for the project are calculated and summed as part of a comprehensive engineering analysis.

Ingvar Tjoestheim, Istockphoto.



International Regulatory Landscape

International Regulatory Landscape

As offshore oil and gas production moved into deeper water and more hostile environments, it became apparent that absolute entire removal would become unreasonably burdensome for the industry. Requiring total removal also raises the question of impacts on the environment.

Prior to briefly analyzing the international regulatory landscape, it is worth putting such analysis into perspective—at least at present, international law provides merely:

> "a tapestry... consisting of norms of various degrees of cogency and enforceability, applying to different groups of states. It provides at best only a framework within which nations and international oil companies may conduct their operations." (Peter Cameron 1999)

Note: International law imposes decommissioning and disposal obligations on States, not on oil producing entities.

Over the last 50 years, global conventions and guidelines for the decommissioning of disused oil and gas installations have been developed that consider the balance between protecting the environment, the rights of other parties (e.g., local industries or local communities) and the cost, safety, and technical feasibility of the decommissioning. Five global conventions and guidelines address decommissioning and offshore disposal of disused facilities (with the Basel Convention addressing hazardous waste management in general):

Removal

- 1958 Geneva Convention on the Continental Shelf
- 1982 Convention on the Law of the Sea (UNCLOS)
- 1989 International Maritime Organization (IMO) Guide lines and Standards

Disposal

- 1972 London Convention (LC)
- 1996 Protocol to the London Convention
- 1989 Basel Convention

Note: Definition of 'Dumping' (UNCLOS Art.1) - Dumping means '... any deliberate disposal of ... platforms or other man-made structures at sea. Dumping does not include placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of this Convention'. It follows that placement of structures on seabed for purposes other than disposal is not dumping.

The definition of 'dumping' in the London Convention also includes the abandonment or toppling of a disused platform for the purpose of disposal. Under both the 1972 London Convention and the 1996 Protocol offshore installations can be disposed of at sea with a permit. However, under the 1996 Protocol, states should avoid dumping in favor of environmentally preferable alternatives such as reuse, off-site recycling, and disposal on land.

1958 Geneva Convention on the Continental Shelf

The Geneva Convention on the Continental Shelf sets the first legal framework to allow industry to explore and exploit continental shelves. The Geneva Convention includes a number of provisions that target the pollution of the marine environment caused by offshore oil and gas activities:

- Precludes offshore operations that constitute an unjustifiable interference with other maritime activities such as marine conservation;
- Requires host states to establish 500-meter safety zones around oil platforms;

- Ensures host states undertake appropriate measures for the protection of living resources from harmful chemicals and agents; and
- Stipulates that 'any installations which are abandoned or disused must be entirely removed' (Article 5).

As offshore oil and gas production moved into deeper water and more hostile environments, it became apparent that absolute entire removal would become unreasonably burdensome for the industry. Requiring total removal also raises the question of impacts on the environment.

1982 United Nations Convention on the Law of the Sea

The United Nations Convention on the Law of the Sea (UNCLOS), also called the Law of the Sea Convention or the Law of the Sea Treaty, defines the rights and responsibilities of nations in their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources.

Article 60.3 of UNCLOS states that any installations or structures that are abandoned or disused shall be removed as necessary to ensure safety of navigation, taking account of any generally accepted international standards established by the IMO. Such removal shall have due regard to fishing, the protection of the marine environment, and the rights and duties of other states. Appropriate publicity shall be given to the depth, position, and dimensions of any installations or structures not entirely removed.

Article 210 of UNCLOS states that nations that are parties to UNCLOS are legally obliged to adopt laws and regulations to prevent, reduce, and control pollution of the marine environment by dumping, which must be no less effective than the global rules and standards. Article 210 also provides that such laws, regulations, and measures must ensure that dumping is not carried out without the permission of the competent national government authorities.

An apparent inconsistency exists between the 1958 Geneva Convention, which provides for total removal of offshore installations, and the 1982 UNCLOS which requires only partial removal. While several attempts have been made to sustain the contention that the 1958 Geneva Convention is no longer applicable (arguing that the treaty later in time usually supersedes the pre-existing treaty), the unwelcome truth remains that--by traditional legal interpretation at least–-the complete removal regime may still be legally applicable to host states. Moreover, while Article 311(1) of UNCLOS 1982 lays down that UNCLOS 'shall prevail, as between States Parties, over the Geneva Conventions on the Law of the Sea of 29 April 1958', this leaves the 1958 Geneva Convention applicable to States party to the later Convention that have not ratified UNCLOS 1982.

1989 International Maritime Organization Guidelines

The primary purpose of the International Maritime Organization (IMO), known as the Inter-Governmental Maritime Consultative Organization (IMCO) until 1982, is to develop and maintain a regulatory framework for shipping and its remit today includes safety, environmental concerns, legal matters, technical co-operation, maritime security, and the efficiency of shipping.

In October 1989, the IMO adopted guidelines and standards for the Removal of Offshore Installations and Structures on a nation's Continental Shelf or its Exclusive Economic Zone (Resolution A.672). The IMO guidelines and standards provide that, in general, an abandoned or disused offshore installation or structure on a Continental Shelf or an Exclusive Economic Zone should be removed as soon as reasonably practical once it is no longer serving the prime purpose for which it was originally designated. The main principles of the IMO Guidelines follow:

- Principal prerequisite is that all disused installations are to be removed;

- Installations in less than 75 meters water depth (mwd) and weighing less than 4,000 tons must be completely removed;
- Structures sited after 1 January 1998 in less than 100 mwd and weighing less than 4,000 tons must be completely removed;
- An unobstructed water column of 55 meters must be maintained in the event of partial removal;
- All installations after 1 January 1998 must be designed for complete decommissioning; and
- Host states should ensure that legal and financial provision is made for decommissioning. This refers not only to the immediate decommissioning obligation but also residual liability for disused offshore structures.

Note: After 1 January 1998, no structure can be emplaced on any continental shelf that is not feasible to remove. This means that floating production technology started to take precedence after the date.

The guidelines provide for leaving offshore installations wholly or partially in place if complete removal:

- Is not technically feasible;
- Would involve extreme cost; or
- Would pose an unacceptable risk to personnel or the marine environment, but should ensure in such cases that an unobstructed water column sufficient to ensure safety of navigation is maintained above the partially removed installation.

The IMO Guidelines are not intended to preclude a coastal state from imposing more stringent removal requirements for existing or future installations or structures on its continental shelf or in its exclusive economic zone.

The IMO guidelines also state that disposal options are to take into account:

- Any potential effect on the safety of uses of the sea;
- Rate of deterioration of the material and its present and possible future effect on the marine environment;
- Potential effect of structure as a whole on the marine environment;
- Risk that the material will shift from its present position at some future time;
- Costs, technical feasibility, and risks of injury to personnel associated with removal; and
- Determination of a new use or other reasonable justification for allowing the installation (or parts thereof) to remain on the seabed.

Note: Artificial reefs are permitted as a reuse of oil and gas facilities.

1972 London Convention (and the 1996 Protocol to the London Convention)

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter in 1972, commonly called the 'London Convention' or 'LC '72' in short and also abbreviated as Marine Dumping, is an agreement to control pollution of the sea by dumping and to encourage regional agreements supplementary to the London Convention. The 1996 Protocol to the London Convention requires contracting parties to prohibit the dumping at sea of any waste or other matter with the exception of dredged material; sewage sludge; fish waste; vessels and platforms; inert, inorganic geological material; organic material of natural origin; and bulky items primarily comprising iron, steel, concrete, and similarly non-harmful materials. Under the Protocol, the dumping of these items shall require a permit from the responsible national authority, under its environmental approval process.

Note: The 1996 Protocol to the London Convention (London Convention 1997) lists materials prohibited from ocean disposal and specifically lists vessels and platforms as exempt from the outright prohibition: 'Industrial waste ... does not apply to: ...(d) vessels and platforms or other man-made structures at sea, provided that material capable of creating floating debris or otherwise contributing to pollution of the marine environment has been removed to the maximum extent.' However, such non-prohibited materials are still regulated and any disposal effort must proceed through extensive assessments related to identifying and designating an appropriate disposal site.

Under the London Convention, the jacket structure could be disposed of in deep water since these materials are steel that has not come into contact with oil or other potential contaminants. This disposal route would involve permitting through the host state, as well as a formal disposal site designation process. However, under guidelines and regulations established by the London Convention, deep water disposal would only be pursued following a finding that there is a need for ocean disposal, i.e., that other alternatives are not practical (Figure 11, next page).

Note: Parties to UNCLOS are not bound by the 1972 London Convention.

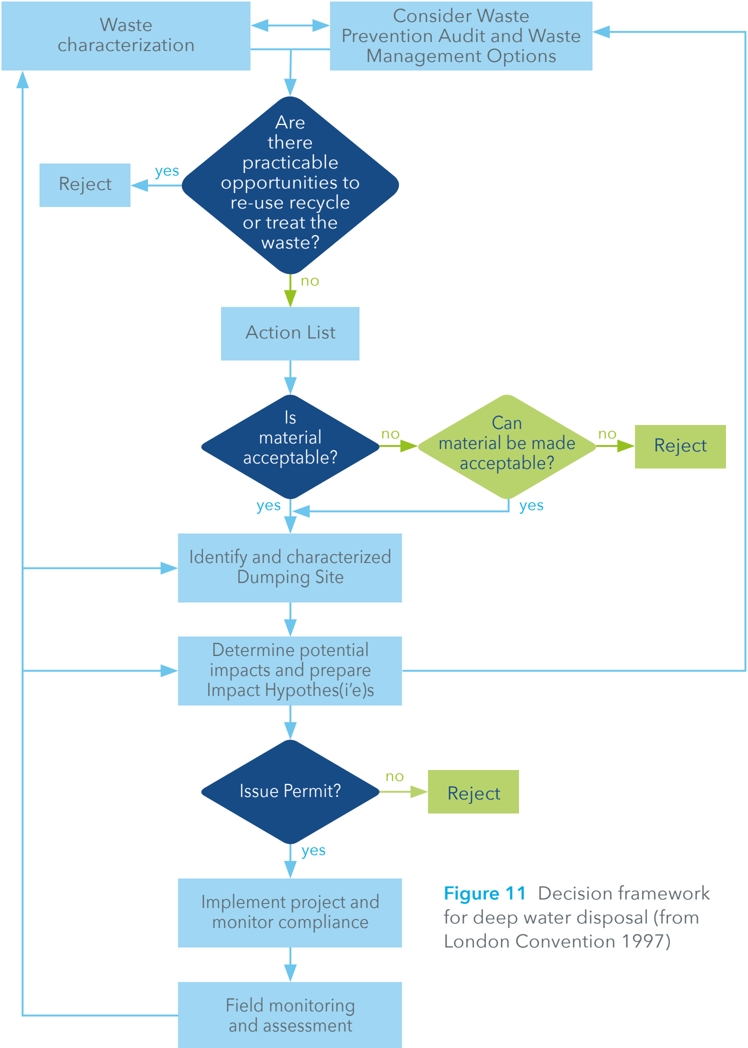


Figure 11 Decision framework for deep water disposal (from London Convention 1997)

1989 Basel Convention

The Basel Convention is an international agreement for addressing the problems and challenges posed by hazardous wastes. The Basel Convention requires all practical steps be taken to minimize generation of hazardous wastes and measures be in place to control hazardous wastes storage, transport, treatment, reuse, recycling, recovery, and final disposal.

One of the guiding principles of the Basel Convention is that, in order to minimize the environmental threats, hazardous wastes should be dealt with as close to where such hazardous wastes are produced as possible. Only if a State does not have the capability of managing or disposing the hazardous waste in an environmentally sound manner, should trans-boundary movement be considered.

Under the Convention, trans-boundary movements of hazardous wastes or other wastes can take place only upon prior written notification by the State of export to the competent authorities of the States of import and transit. Each shipment of hazardous waste or other waste must be accompanied by a movement document from the point at which a trans-boundary movement begins to the point of disposal. Hazardous waste shipments made without such documents are illegal.

1992 Oslo/Paris (OSPAR) Convention

Annex II of the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic deals with prevention and elimination of pollution by dumping or incineration (see also Box 6).

Article 3, Annex II states that offshore dumping of all wastes or other matter is prohibited, except:

- Dredged materials;
- Inert materials of natural origin, that is solid, chemically unprocessed geological material the chemical constituents of which are unlikely to be released into the marine environment; and
- Fish waste from industrial fish processing operations.

Article 4, Annex II provides that Contracting Parties shall ensure that:

- No wastes or other matter listed in Article 3 shall be dumped without authorization by their competent authorities, or regulation; and
- Such authorization or regulation is in accordance with the relevant applicable criteria, guidelines and procedures adopted by OSPAR.

Box 6 Regional Conventions Related to Marine Disposal

Beside the OSPAR Convention, a number of regional conventions related to marine disposal exist:

- Mediterranean (Barcelona Convention adopted 1978 rev. 1995)
- Red Sea and Gulf of Aden (Jeddah Convention adopted 1982)
- Wider Caribbean (Cartagena Convention adopted 1983)
- Eastern Africa (Nairobi Convention adopted 1985)
- South Pacific (Noumea Convention adopted 1986)
- Black Sea (Bucharest Convention adopted 1992)
- Kuwait Region (Kuwait Convention adopted 1978)
- West and Central Africa (Abidjan Convention adopted 1981)
- South-East Pacific (Lima Convention 1981 adopted 1981)
- Baltic (Helsinki Convention adopted 1974, revised 1992)

Decommissioning Environmental Management Planning

Decommissioning Environmental Management Planning

Surveys around the installation to establish the existing environmental baseline are commonly undertaken before decommissioning commences if related environmental data are not readily available. Requirements will differ from site to site; the extent of baseline work is often defined in consultation with involved government authorities.

Major decommissioning activities offshore, besides preparation activities, are Plug and Abandonment (P&A) and Platform Removal. Various management tasks go along with these activities.

Site Information Assessment	The first step in decommissioning is collecting and critically reviewing existing site information, e.g. site location and layout, current use of the site and records of waste management, production history, and past environmental assessment/records. Often the desktop review is complemented with a site reconnaissance visit to verify collected site information, identify potential contaminants of concern (CoCs), and identify areas of potential contamination/concern.
Baseline Surveys	Environmental Baseline Surveys are carried out to establish the baseline level of potential contaminants in marine environment surrounding and beneath the offshore installation, to establish the environmental and social setting of the offshore installation as basis of assessing potential impacts associated with decommissioning and to assess the extent of contamination of the installation.
Establishing Level of Potential Marine Contamination	In exploration significant contamination may have result from drill cuttings around the platform on the seabed. The environmental survey determines the potential for present and past site contamination (e.g., hazardous substances, petroleum products, and derivatives). Removal of structures or pipelines may disturb such drill cuttings and thus pollute the environment. The initial environmental baseline serves a benchmark for these post-implementation monitoring programs.
Establishing Environmental Setting	Decommissioning activities will affect marine environment. For example, removal of structures through explosive cutting activity will impact on the immediate marine environment. Shock waves, for instance, are likely to kill or harm sea life.

(Continued)	The environmental baseline survey prior decommissioning serves as the basis for assessing potential impacts. The survey documents existing environmental conditions, and identifies potential vulnerabilities.
Establishing Extent of Contamination of Installation	An inventory of hazardous materials at installation is key to establishing the extent of potential contamination of the installation. Materials used in an installation depend partly on its age. Modules built more than 30 years ago contain more hazardous substances and materials with undesirable properties whose use is now prohibited. The inventory of radioactive and other hazardous materials as a result of production including their location is also an important input for the safety assessment.
Detailed Survey and Testing Program	Based on the outcome of environmental surveys there is more often than not the need to commit to subsequent further detailed investigations to ascertain the extent of contamination in a specific area (e.g., area of accumulated drill cuttings on the seabed or the presence of mercury contamination in equipment) and to gain a better appreciation of a specific sensitive environmental receptor (e.g., an endangered marine species sighted in the larger project area).
Environmental Impact Assessment	Environmental assessment is a well understood practice and should be conducted as early as possible in the decommissioning process to allow environmental mitigation measures to be incorporated into decommissioning planning. The EIA is typically aligned with the feasibility study stage of a decommissioning project.

Stakeholder Engagement	Public consultation in a decommissioning is now accepted as an integrated part of any decommissioning development, as it should be. A number of authoritative guidelines on the public consultation process exist that can guide the formulation of a formal Public Consultation and Disclosure Plan (e.g., Doing Better Business Through Effective Public Consultation and Disclosure – A Good Practice Manual, IFC 1998).
Decommissioning Environmental Management Planning	A document containing environmental management plans, the Decommissioning Environmental Management Plan (DEMP, see Box 7), is established in response to potential impacts of a selected decommissioning option. The DEMP will focus on the selected decommissioning option and on ensuring that mitigation measures and monitoring plans are implemented as outlined in the environmental impact assessment.
Planning for Hazardous Materials Management	A waste management plan, part of the Decommissioning Environmental Management Plan, will consider the different categories of waste produced during decommissioning and will aim at the safe management of such waste. Consideration should be given to optimizing waste management and minimizing cross-contamination and secondary waste generation.
Conduct Well Plug and Abandonment	Well plugging and abandonment (P&A) is generally considered one of the more sensitive portions of the decommissioning process; fortunately P&A is a well understood industry practice. Well P&A work is normally executed by specialized service companies, having task specific tools /equipment and in-house operators.

Cleaning of Installation	Usually, before decommissioning operation takes place, the installation's process systems need to be depressurized, drained, and cleaned. Parts of the operational discharges and system effluent will be taken ashore for disposal, and other waste will be re-injected downhole or discharged into the sea under license. Clean decommissioned platforms still contain at least a residual amount of low specific activity scale, heavy metals, and hydrocarbons. Any structures left over in the marine environment will ultimately corrode and leach contaminants into the marine environment.
Site Clearance	The last stage in decommissioning offshore installations is site clearance. Site clearance is the process of eliminating or otherwise addressing potentially adverse impacts from debris and seabed disturbances due to offshore oil and gas operations.
Post-Decommissioning Survey and Monitoring	Post-decommissioning environmental seabed and marine sampling surveys should be undertaken in particular to monitor levels of hydrocarbons, heavy metals, and other contaminants in sediment and biota after completion of site restoration, and to verify findings over time.

Box 7 Basic High Level Structure of a Decommissioning Environmental Management Plan

1. Introduction and Background
2. Applicable Standards, Regulations, and Policies
3. Decommissioning Principles and Goals
4. Existing Baseline Conditions and Aspects Requiring Protection / Enhancement
   - Environmental
   - Socioeconomic
   - Regional Development Context
5. Environmental Impact Assessment
6. Prevention, Control, And Mitigation Measures
   - Environmental Measures
   - Socioeconomic Measures
7. Stakeholder Involvement
8. Hazardous Materials Management and Disposal
9. Debris Clearance
10. Post-Closure Audit and Monitoring
11. Site Relinquishment
12. Roles and Responsibilities
13. Resources and Cost Estimate
14. Timeline

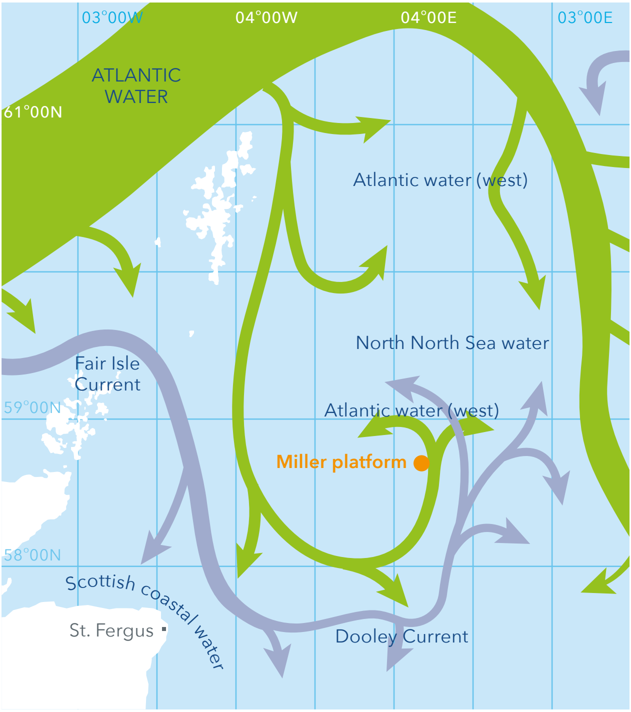
Establishing Environment Baseline

Surveys around the installation to establish the existing environmental baseline are commonly undertaken before decommissioning commences if related environmental data are not readily available. Requirements will differ from site to site; the extent of baseline work is often defined in consultation with involved government authorities. If seabed contamination is of concern, the environmental baseline will include a detailed seabed sampling program to confirm the extent of contamination.

Data on the following aspects are commonly collected:

- Meteorology
- Sediment (including establishing the extent of seabed contamination if any)
- Plankton and Primary Production
- Seabed and Benthic Communities
- Fish Populations including Breeding and Life Cycle Patterns
- Cetaceans
- Spawning and Nursery Areas
- Seabirds
- Marine Mammals
- Inshore and Coastal Areas
- Important Species
- Project-affected communities and fishermen
- Conservation areas.

Figure 12 Regional Current Regime, Miller Platform, Central North Sea



Source: BP Miller Decommissioning Programme 2011

Note: Figure 12 Illustrates the importance of looking beyond the surrounds of the oil rig to understand regional current regime, pathways of migratory turtles, marine mammals, and birds, and other factors.

Establishing Inventory of Hazardous Materials

Prior to decommissioning, a preliminary inventory of existing equipment and hazardous materials is collected. Materials used in an installation depend partly on its age. Modules built more than 30 years ago contain more hazardous substances and materials with undesirable properties whose use is now prohibited. Many of the newer installations are subsea structures consisting largely of steel.

Waste from the petroleum industry may be present in many physical and chemical forms: as produced water, sludge deposits in the process system removed during maintenance, drill cuttings, chemicals used during production, scale/sludge removed at routine maintenance of valves and tubulars, or ordinary household waste. Box 8 lists the range of hazardous waste fractions generated during decommissioning, often delivered to approved onshore facilities for treatment and/or final disposal.

It is worth noting that a wide variety of paint and coatings is used on the structures of offshore facilities for inhibition of corrosion and preventing marine fouling. Different types of toxic components can be present in the paint and coatings, e.g. PCBs, tributyltin (TBT), heavy metals (for example lead, barium, cadmium, chromium, copper, zinc), and pesticides. These compounds can have properties that require precautions during decommissioning. It can be necessary to remove paint and coatings in cutting zones to secure safe working envi-

Box 8 Range of Hazardous Waste Fractions from Decommissioning

Hydrocarbons
- Diesel
- Hydraulic oil, grease, and lubricants

Chemicals
- Flame retardants, for example brominated flame retardants
- Isocyanates from polyurethane paints
- CFC and HCFC gases re-leased from cooling agents
- Chloroparaffins
- PCBs (polychlorinated biphenyls)
- PFOS (perfluorooctyl sulphonate)
- PVC (polyvinyl chloride)
- Organotin compounds from anti-fouling systems
- Phthalates (plasticisers in flooring and cables)
- Other chemicals

Metals and minerals
- Zinc anodes
- Mercury
- Heavy metals
- Asbestos
- Contaminated steel

Scales
- NORM

Other wastes
- Batteries
- Waste electrical and elec tronic equipment (WEEE)
- Paints and other coatings
- Ballast Water
- Heavy Ballast

ronment, as paint can release toxic gases during heating or combustion. Toxic components are typical dealt with at smelting facilities, as paint on large metal surfaces is not normally removed before the metal is delivered for re-melting.

Cleaning Production Installation Prior to Removal

Cleaning removes most pollutants as part of closing down the installation offshore. Cleaning will be executed by water flushing, high-pressure water jetting, and mechanical scraping or scrubbing (Box 9), while in some cases chemical cleaning methods or sandblasting may be used.

Note: Even so the installation is cleaned the installation (or parts of) may remain contaminated due to the long-term contact with crude oil or gas with its natural contaminants (e.g. by mercury as detailed elsewhere).

Water is generally used for internal flushing of topside equipment after oil production has ended. An existing bore well may in some occasions be used to re-inject contaminated flushing water. More often flushing water has to be treated prior to release to the environment.

After Cessation of Production internal flushing of flow lines, process module equipment, and export risers will be executed as well as vessel entries for manual cleaning and inspections. All separators, coalescers, etc. will typically be cleaned manually after flushing to remove residual fractions of bottom sludge and potential scale residues. Waste from the cleaning is collected and brought to shore for disposal.

Only minor waste volumes generated by activities performed offshore during decommissioning activities are discharged offshore, assuming such discharges are within the approved levels. More often minimizing emissions to the sea is of high priority for protecting the environment and human health with respect to the process of decommissioning. Emissions to sea are minimized by a combination of the following means:

- Collect water used for deck and wellhead cleaning via drains;
- Export water used for flushing of topside to neighboring active installation, in vessels or slop tanks, for subsequent treatment to regulated discharge levels;
- Collect sludge and plug and abandonment (P&A) related waste in slop tanks or similar and transport to shore for required treatment;
- Use environmental friendly degreasing agents and soap for topside cleaning; and
- Assess environmental impacts if biocides or MEG (Monoethylene glycol) have been added to the oil and gas riser/pipelines.

After initial cleaning, offshore installations are dismantled and removed to shore, if they are not abandoned and left in place. Offshore dismantling is normally performed by cutting the platform into small sections or by removing whole modules in the reverse of the installation. Another option is to remove the topsides and/or jacket in one piece, but this is rarely performed.

Offshore installations removed to shore are typically delivered to approved demolition and waste treatment plants or reused directly. Although reuse of installations and equipment is desirable, experience has been that the reuse of offshore installations or parts of their equipment is difficult.

Note: While reuse is in general environmentally preferable, it is often more economical to purchase new rather than repaired old equipment.

Box 9 **Elements of Standard Industry Procedures for Flushing of Tanks and Pipework**

(based on Offshore production facilities: decommissioning of topside production equipment, Dr. Peter Prasthofer, Proceedings: Decommissioning Workshop, September 1997)

After the production installation has been taken off stream, cooled down, and pumped out, all items of equipment must be depressurized, drained, and vented.

Depressurizing
Normal practice is to dispose of hydrocarbon gases to fuel gas or flare systems. As systems become depressurized they should then be isolated by valving and subsequent blanking.

Draining
Prior to equipment being isolated, it is essential that it should be drained as far as is possible via fitted drain points.

Venting
Where flammable or other harmful materials are to be vented, the point(s) for release must be located in order to preclude any possibility of vapors encroaching upon areas where personnel are working or where there is likelihood of ignition.

Purging And Flushing
Pipework can be flushed or purged using steam, water, or inert gas. For many applications, water is used as the primary cleaning method. However, steam cleaning is sometimes used, with a higher degree of safety implications. Pipelines that carried wet oil or hydrocarbons will require flushing with sea water to obtain a satisfactory level of cleanliness. The pipeline can then be filled with sea water and sealed.

Removal Sub-sea Pipelines

Regional Pipelines are not covered by OSPAR Decision 98/3; no international guidelines on the decommissioning of disused pipelines exist. Pipelines are almost universally decommissioned in situ, and usually buried, and this is expected to continue. Where they cannot be buried, e.g., large bundles, prior commitment to removal may be required in future, and there is an expectation in the UK that bundles will be removed. Major trunk lines are cleaned and left in place. Presence of mercury may cause pipelines to be totally removed.

The scale of the problem? If placed end to end, the oil and gas pipelines in the Gulf of Mexico alone could wrap around the Earth's equator (NOAA 2014).

Management of Waste Streams

Waste management must comply with all relevant rules and regulations from national and international authorities for waste handling, storage, and transport--including compliance with any Health and Safety requirements for handling, storage, and shipment of LSA scale or mercury contaminated materials.

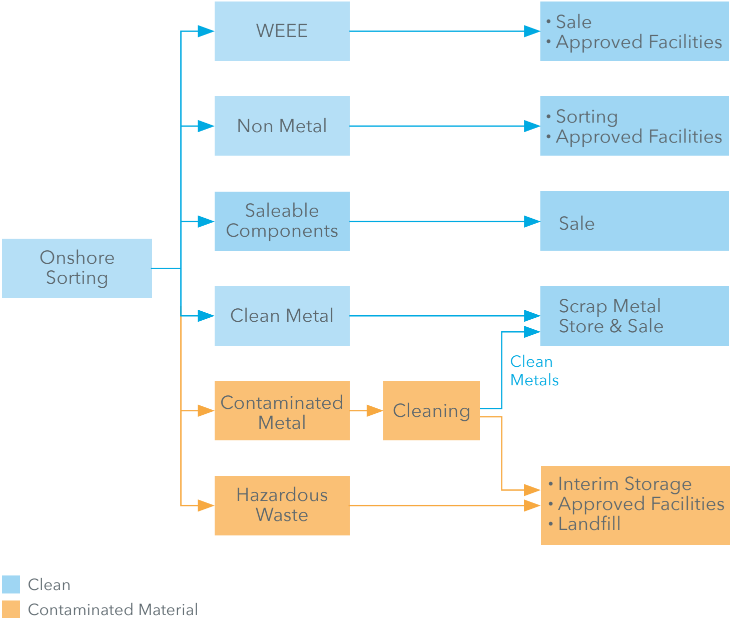
Waste management includes identifying, collecting, processing, and transporting waste to final destruction or disposal at the specialist destruction center (Figure 13, next page). The total waste management chain has to be closely monitored and documented. A final 'Environmental Account Report' commonly provides detailed information of any waste–handling, –reuse, or destruction.

Significant reductions in volumes of hazardous waste can be achieved through decontamination programs, controlled dismantling techniques, contamination control, and sorting of waste materials. Reuse and recycle strategies have the potential to reduce the amounts of waste to be managed.

Once the installation is cleaned and dismantled, the issue of disposal of individual parts becomes pertinent. If an onshore disposal option is chosen, then there is the need to transport the structure to land. It is likely that the structure still contains toxic chemicals and materials that must be carefully treated. Even onshore metal recycling that seems beneficial to the environment may cause problems. Removing the marine growths that have attached to the platform in decades of immersion in sea water will cause visual, smell, noise, and atmospheric disturbances to the local community.

Precautions concerning oil residues, mercury, NORM, and other known hazardous substances are taken into consideration. Finally, as stated elsewhere, onshore

Figure13 Material Flows at Decommissioning Facilities



WEEE: Waste Electrical and Electronic Equipment

decommissioning yards need to be designed to allow safe handling of identified waste, including hazardous substances, e.g., have an effective collection system and an onsite treatment plant and or temporary storage facility, and hold relevant government permits.

Waste handling involves a number of steps:

- **Safety Inspection:** The installation is inspected by qualified personnel to secure the module for later work.
- **Securing:** Based on safety inspection observations, all acute issues, in relation to contamination and general risk of personnel, are taken care of in this phase.
- **Material inspection:** Establish Inventory of Hazardous Waste: identify all types of hazardous waste produced and their sources. If uncertainty arises, then the waste shall be sampled and analyzed to identify the waste characteristics and properties.
- **Characterize the wastes:** Waste characteristics are also important in deciding the types of treatment to be employed for disposal.
- **Classify wastes:** Per national/international waste codes
- **Segregate waste fractions:** (e.g., Mercury waste from non-compatible waste)
- **Packing:** In containers suitable for handling and trans port; waste container materials selected to be corrosion and chemical resistant e.g., high density polyethylene (HDPE) or steel containers with plastic lining. Containers must be tightly sealed not leaking, bulging, rusting, or badly dented.
- **Apply labeling and symbols:** Mark containers in compliance with UN and National standards.
- **Manifests:** Clearly declare inventory of wastes in each shipment according to National regulations and international practice, and maintain chain-of-custody to the limits of Company liability.

- **Hazardous waste removal:** Removal of hazardous waste including all further handling to arrival at final treatment and disposal facility. Ensure contractors appointed to handle or transport hazardous waste comply with relevant legal and Company requirements and have relevant licenses to operate.
- **Reuse/Recycle:** Valuable equipment such as cranes, process units, etc, are removed and sold for direct reuse. Other modules at the installation are sent for metal scraping after hazardous materials are removed.
- **Implement and enforce relevant safety and health requirements:** Ensure workers handling hazardous wastes are included in all work instructions, have been properly trained, and are adequately supervised.
- **Hazardous waste final disposal:** Removed hazardous materials require final safe disposal at a site licensed and by methods permitted under appropriate National authority.

Onshore Demolition

Dismantling and Onshore Scrapping Facilities for Offshore Structures are lacking in many countries, and facilities may need to be developed prior to the onset of physical decommissioning of offshore installations. Although there may be some dismantling yards in the region, these may not accept particular offshore structures due to potential contamination issues, and complications related to import-export regulations (e.g., steel may have been imported under exempted country custom duty).

The onshore demolition site will have access to sea, docking and offloading facilities, and ample area for handling and demolition of structures, including warehouse and office facilities. The harbor area will commonly be surrounded by sheltered waters, for various inshore marine activities. The quayside is constructed to support skidding or trailing operations from flat top barges.

The ideal site would have a deep water quay with capability for receiving Heavy Lift Vessels for direct offloading to the quayside area to facilitate any likely future decommissioning removal method--like topside transported by a Single Lift Vessel or sub-sea foundations for grounding of jackets being removed by buoyancy tanks.

The open land area requires installation facilities for environmental protection from liquid spillage, areas for scrap handling, waste segregation and storage, lifting/crane support, and safe driveways for transport and logistics operations.

The area must be securely fenced and protected from unwanted traffic and personnel movement. The Operator of the Inshore Demolition site needs to comply

Ricardo Azoury, Istockphoto.

with all licenses from local and National governmental authorities, to execute onshore demolition work at the dedicated area, and licenses for any associated waste treatment, storage, handling, and transport, including scrap handling.

When received at the onshore demolition site, all structures will be thoroughly inspected and made safe before any further demolition work. Structures will be mapped for and stripped of any possible remaining hazardous waste, LSA scale, and other non-hazardous industrial waste. Any waste identified will be segregated and removed for further processing and handling. Only when all hazardous waste and non-hazardous wastes are removed from the structure can a 'Ready for demolition' certificate be handed over to the demolition contractor for further physical demolition work.

Impact Assessment

Impact Assessment

Detailed assessment of significant impacts, identification of mitigation needs, and inputs to cost/benefit analysis are activities typically aligned with the feasibility study stage of a decommissioning project.

Assessing Environmental Impacts of Decommissioning Activities

Environmental impact assessment (EIA), a well understood practice (see for example Spitz and Trudinger 2008), should be conducted as early as possible in the decommissioning process to allow environmental mitigation measures to be incorporated into decommissioning planning. Detailed assessment of significant impacts, identification of mitigation needs, and inputs to cost/benefit analysis are activities typically aligned with the feasibility study stage of a decommissioning project. These activities combine to constitute the environmental impact assessment study, which is presented as a set of documents that may include an Environmental Impact

Statement (EIS), an Environmental Action Plan (EAP), and a suite of documents focusing on selected topics such as baseline conditions, hazardous materials management, public consultation, and environmental, health, and safety management.

The preparation of these documents is a fundamental part of environmental planning and should be viewed as an essential part of decommissioning planning. Objectives of the environmental impact assessment at this stage are to:

- Identify sensitive components of the existing environment within the platform area and its surroundings, and ensure that biodiversity issues are adequately addressed;
- Assist decommissioning planning by identifying those aspects of location and decommissioning that may cause environmental and social concerns;
- Enable adverse environmental, economic, and social impacts to be anticipated;
- Recommend measures during decommissioning to avoid/ameliorate adverse effects and to increase beneficial impacts (e.g. rigs-to-reefs);
- Ensure that alternative measures are considered;
- Identify the preferred practicable environmental decommissioning option. The recommended option should result in the least environmental damage, in balance with other social, health, and economic considerations, and be consistent with prevailing regulations;

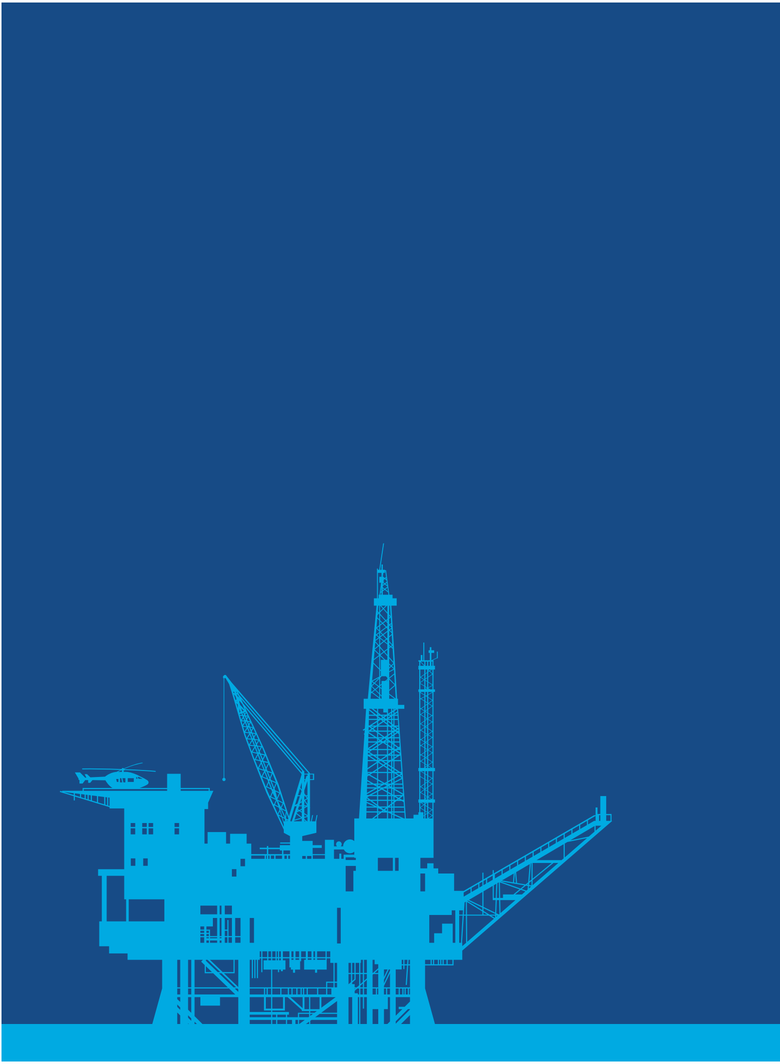
- Estimate and describe the nature and likelihood of environmentally damaging incidents to provide a basis for contingency plans;
- Identify existing and expected environmental regulations that will affect decommissioning and advise on standards, consents, and targets;
- Identify any environmental issues and concerns that may, in the future, affect the preferred decommissioning option;
- Recommend an environmental management program, including post-decommissioning monitoring, site closure auditing, and contingency planning; and
- Provide the basis for structured consultation with and participation of regulatory and non-regulatory authorities and the public.

The Environmental Impact Assessment commonly addresses the following impacts:

- Impacts on the marine environment, including exposure of biota to contaminants associated with the installation, other biological impacts arising from physical effects, conflicts with the conservation of species, with the protection of their habitats, or with marine aquaculture;
- Interference with other legitimate uses of the sea;
- Impacts on other environmental compartments, including emissions to the atmosphere, leaching to

groundwater, discharges to surface freshwater, and effects on the soil (particularly relevant for the onshore decommissioning phase);

- Consumption of natural resources and energy associated with re-use and recycling;
- Other consequential effects on the physical environ ment that may be expected to result from the option; and
- Impacts on amenities, the activities of communities, and on future uses of the environment.



Interested Parties Consultation

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The importance of public involvement in decommissioning planning is generally acknowledged, but there is some disparity in the terminology used to describe this involvement, since there are no consistent definitions for the terms 'public' and 'involvement.'

Involving Interested or Affected Shareholders

Public consultation in decommissioning is now accepted as an integrated part of any decommissioning development, as it should be. The importance of public consultation and participation is also reflected in the World Bank's Policy on Environmental Assessment OP/BP 4.01 and the more recent IFC Performance Standards (IFC 2012), parts of what is now referred to as 'The Equator Principles' (EP), the industry standard for best environmental and social assessment practice.

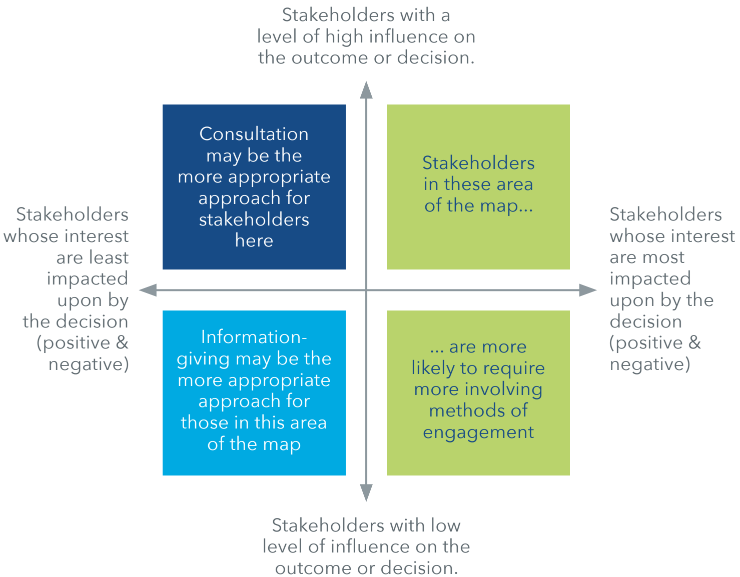
The importance of public involvement in decommissioning planning is generally acknowledged, but there is some disparity in the terminology used to describe this involvement, since there are no consistent definitions for the terms ‘public’ and ‘involvement.’

The use of the general term public has raised concern in the past. Oil and gas companies, quite correctly so, prefer to see a direct causal link between the decommissioning project and parties having a genuine stake in the project. For this reason oil and gas companies prefer to clearly identify all interested and affected parties (e.g., involved government authorities or potentially affected fishermen), commonly referred to as stakeholders, in the early stage of a decommissioning proposal. Companies tend to group stakeholders depending on their power to influence, and the degree to which they are impacted by, the project (Figure 14, next page).

The use of the term ‘involvement’ also has different meanings for different people. It is commonly accepted, however, that involvement includes disclosure, consultation, and participation.

Of note is the increasing voice of Non Government Organizations (NGOs). NGOs are not an invention of recent history. Historically, associations of private individuals have gathered for public purposes, usually to provide a service not available from the state, well before the establishment of democratic governments. In more recent times, however, a new class of NGOs has evolved, which focuses directly on changing public

Figure 14 Decommissioning Stakeholder Mapping Tool



Source: Guidelines on Stakeholder Engagement during Decommissioning Activities, The United Kingdom Offshore Oil and Gas Industry Association Limited, 2013

policy. Though membership-based, they are unlike the representative interest groups of employers and employees that provide both services to membership and public advocacy on behalf of their members. Many such NGOs consist, typically, of middle-class activists who want government to reallocate resources or change laws according to their views on a good society.

Few matters of public policy or industrial development, not to mention oil and gas decommissioning ventures, pass without an NGO spokesperson advocating a position (Box 10). They have, in some regards, become the official opposition to government policies and private sector investments, a reality painfully known to all senior oil and gas management (Spitz and Trudinger 2008).

Box 10 **Brent Spar**

In 1995, the transnational controversy posed by Shell and the United Kingdom's attempt to dispose the Brent Spar caused significant public outcry in Europe and showed that obedience to rules may be insufficient and might cause regulatory failure. This wake-up call for the industry was witnessed by a global audience and brought to the forefront the centrality of public acceptance to the offshore decommissioning and disposal process.

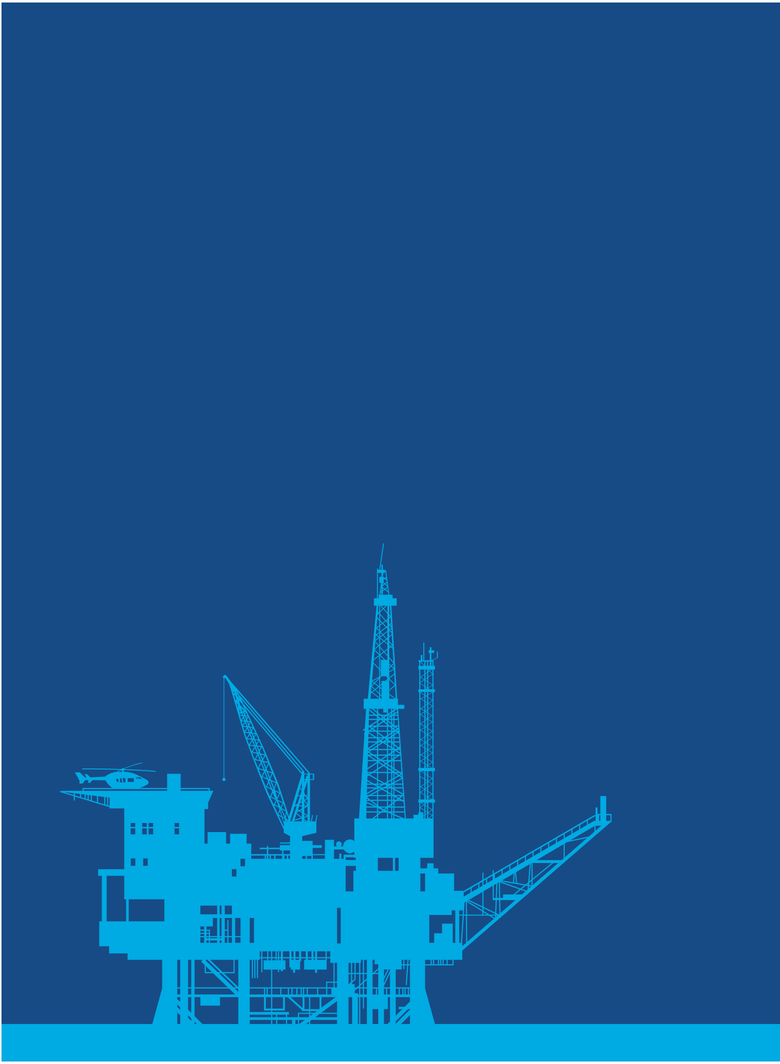
The Brent Spar was a 65,000 metric ton floating storage and off-loading installation located in 140 meters of water in the Brent Field in the UK sector of the North Sea. It was a temporary arrangement put in operation in 1976 to allow initial throughput from the Brent Field before the final installation of the necessary pipeline infrastructure. But even after the installation of the pipeline, it was retained as an alternative for off-take. It became due for decommissioning in 1991 after it ceased operation owing to high maintenance cost.

A number of authoritative guidelines on the public consultation process exist that can guide the formulation of a formal Public Consultation and Disclosure Plan (e.g., Doing Better Business Through Effective Public Consultation and Disclosure – A Good Practice Manual, IFC 1998). The IFC standards are widely acknowledged as industry best-practice, and they became the 'role model' for subsequent guidelines published by other multilateral funding agencies.

In decommissioning planning and implementation, a documented description is required of the consultation process employed, including a summary of the statutory consultations with interested parties and the extent to which they have been taken into account in the program. Relevant correspondence and meeting minutes and summaries should be annexed to the program documentation. In those cases where it has been necessary to conduct a wide ranging public consultation/dialogue process, details of the approach taken and the outcome of the process should be included.

In practice, decommissioning programs are issued for public consultation by placing a notice in relevant newspapers advising the public of the consultation process, how to obtain copies of the documents, and how to comment on the contents. In emerging economies, public hearings may be arranged for potentially affected communities. Details on the decommissioning program are further sent directly to involved government authorities and statutory consultees such as relevant national or regional fisher organizations.

Note: Stakeholder engagement has emerged as an overused and fashionable buzz–word phrase. Experience has been that NGOs (and for that matter environmental consultants) with limited technical knowledge tend to rely on such buzz phrases and the underlying high level concepts to raise their voice with authority, though often without practical content.



It is Not Over When it is Over

It is Not Over When it is Over

Upon completion of decommissioning, the remaining structures are to be surveyed and their positions recorded. This information is commonly submitted to the relevant authorities.

Site Clearance

The last stage in decommissioning offshore facilities is site clearance, the process of eliminating or otherwise addressing remaining, potentially adverse impacts from debris and seafloor disturbances due to offshore oil and gas operations.

Note: The cumulative sum of materials lost overboard in the vicinity of an offshore installation can become significant over a time frame that may exceed 30 years. It should be understood, however, that the debris associated with an offshore site is rarely a result of intentional dumping. Virtually all of it can be attributed to accidental losses associated with routine activities, some of which may not be directly related to production activities on the installation.

Site clearance also attempts to address such issues as seafloor disturbances around the installation. Mounds of shell debris from repeated maintenance cleaning of bio-fouling from the structure can accumulate around its base. Such accumulations, combined with mud, cuttings, and cement discharged during drilling operations, have been observed to reach a thickness of several meters above the original seafloor at shallow water locations where dispersion was minimal (Table 3).

Table 3 Decommissioning of the Miller Field in the Central North Sea in Water Depths of Approximately 100m – Size and Composition of Miller Cuttings Pile Surrounding the Jacket Footings.

Contaminant	Weight (in tonnes)
Total Hydrocarbon	1,350
Nonyl-phenol	3
Arsenic	0.26
Chromium	1
Copper	3
Mercury	0.04
Nickel	1
Lead	3
Zinc	13

Source: BP Miller Decommissioning Programme 2011

The area to be covered in site clearance will depend on the circumstances of each case. However, the minimum required will be typically a radius on the order of 300 to 500 meters from the location of the installation. In case of decommissioned pipelines, debris monitoring may be required up to 100 meters either side over the whole length.

There are many ways to locate and remove debris; the choice may be affected by the equipment available in the area and the water depth. A preliminary survey of the site with side scan sonar can provide a target listing and location for existing debris. A common method for debris removal is the use of trawl nets to recover debris. Heavy nets called 'gorilla nets' are used from trawl vessels to gather debris. In shallow waters divers can assist in completing the debris recovery operation as required.

Since the introduction of Remotely Operated Vehicles (ROV) into the commercial world in 1970's, unmanned vehicles have become essential not only in the exploitation and development of deep water oil and gas reserves --far beyond the reach of divers--but also decommissioning work. Recovery with ROV assistance is an effective technique when heavy trawl vessels and equipment are not available. The ROV is deployed with color scanning sonar to locate debris items on the target list provided by the preliminary side scan data. Global Positioning System (GPS) satellite navigation is integrated with an acoustic tracking system to provide real time position data on the ROV during search and recovery operations. Deeper water recovery work may be more economically performed using remote intervention techniques.

Verification

Following the removal of any debris, independent verification of seabed or site clearance will be required. The best method to test the adequacy of site clearance operations, when conditioning for trawling is the objective, is to trawl the area with the type of gear that will be used. Local fishers can be contracted to improve acceptance with local communities. The advisability of over-trawling will be dependent upon the extent of any cuttings piles and any other relevant circumstances. Side scan sonar can be used to ensure no equipment clutters the sea floor.

In addition to debris surveys, a post-decommissioning environmental seabed or site sampling survey should be undertaken, in particular to monitor levels of hydrocarbons, heavy metals, and other contaminants in sediment and biota.

Monitoring of Remains

In case of partial removal, the condition of the remains will need to be monitored at appropriate intervals. The form and duration of the monitoring program will depend upon the particular circumstances and if necessary will be adapted over time.

Upon completion of decommissioning, the remaining structures are to be surveyed and their positions recorded. This information is commonly submitted to the relevant authorities. Periodic post-commissioning surveys over the next few years confirm the location of decommissioned pipelines relative to the seabed to evaluate the stability of the pipelines and the effectiveness of the self-burial process, and the integrity of remaining structures.

It is recommended to include post-decommissioning monitoring seabed sampling surveys to verify the residual levels of any contamination and to assess the level of biological activity in the area.

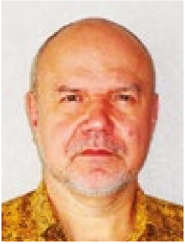
Marking of Offshore Remains

In those cases where installation element, 'footings' of a steel installation, or sub-sea pipelines remain in place, the position (horizontal datum to be stated), surveyed depth, and dimensions of the remains are forwarded to relevant Government authorities for inclusion on navigation charts.

It is commonly the Company's responsibility to install and maintain navigational aids for any remains of installations or structures that project above the surface of the sea.

•••

Authors



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Notes

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Reverse Engineering Services Ltd (RESL, formally also known as Reverse Engineering Ltd.) offers extensive experience in a wide range of decommissioning disciplines, continuously working on decommissioning for most of the major oil & gas companies for over 20 years. To date RESL has completed decommissioning work on close to 800 facilities around the world, including Australia, UK, Norway, Canada, Gulf of Mexico, Japan, Indonesia, Thailand, Brunei, and South Africa.

RESL is an engineering consultancy specializing in all aspects of abandonment, decommissioning, deconstruction and reuse of obsolete or redundant facilities both onshore, offshore and subsea. Many of previous RESL studies have included socioeconomic impact analyses, cost/benefit assessment and decision analysis methodology.

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