Chapter 7
Drilling and Production Discharges in the Marine Environment

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1 Introduction

The widespread exploration and development of offshore oil and gas fields first occurred in the United States' Gulf of Mexico in the early 1950s. Gas was not produced from the British sector of the southern North Sea until 1967 and the large North Sea oilfields were developed in the 1970s. Offshore developments in the Middle East (including Dubai, UAE and Yemen) started in the 1960s, as the initial developments in the area were onshore. More recently offshore exploration and production development has expanded to include the Far East (including Indonesia, Vietnam and China) and West Africa (including Nigeria, Gabon and Ghana). Initially the environmental impact of offshore operations was unknown and there were few, if any, regulations or standards in place to control discharges. However, it was not long before concerns arose about the potential environmental impacts of exploration and production activities. The initial attempts at minimizing any potential impacts involved controlling end of pipe discharges while studies were undertaken to determine what the impacts might be. Over the years, treaties, laws and regulations have been promulgated so that now drilling and production discharges are strictly controlled by a complex system of limits. A complicating factor in the early stages of offshore development was that the technology was rapidly developing at the same time, which presented a moving target. Interestingly, after the initial period, many years of relatively stable technology ensured, until the expansion into deep waters and severe environments. However, the objective of the rules and

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regulations has always been, and still is, to allow offshore exploration and production to occur while minimizing any associated environmental impacts.

In order to develop effective regulations and the technology required to ensure that that the discharges meet the limits, it is necessary to understand both the nature and volumes of the discharges and the sensitivity of the receiving environment. To further complicate matters, offshore operations can be in international, national, or waters under local jurisdictional control. This can result in situations where more than one regulatory body is involved.

The wastes generated by oil and gas exploration and production operations fall into two broad categories: those directly resulting from oil and gas operations; and those associated with support activities [10]. The high volume wastes associated with exploration and production activities include:

- Produced water
- Excess water based drilling muds
- Drill cuttings; and
- Wastes generated during the abandonment and removal of offshore structures.

This waste category had increased significantly over recent years, as a number of developments in the North Sea and Gulf of Mexico become depleted and the aging infrastructure and any associated waste piles have been required to be removed.

The lower volume wastes include:

- Deck drainage
- Tanks bottoms
- Produced sand
- Excess chemicals and chemical containers; and household wastes.

The nature and volumes of the wastes that are actually discharges is affected and controlled by:

- Regulations
- Industry standards
- Individual operator policies and practices
- Limits imposed but financial institutions
- Public interest groups

The characteristics of the water bodies that receive the wastes vary widely, which in turn affects the sensitivity to the impact from the wastes. These include:

- Water depth
- Distance from shore
- Wind and wave forces in the area
- The presence of sensitive marine flora and fauna, and
- The chemical and physical characteristics of the waste.

Depending on the chemical and physical characteristics of the waste and the receiving waterbody, the discharge of the higher volume wastes may or may not be allowed, whereas most of the minor wastes are taken onshore for treatment and disposal.

2 Nature of Offshore Discharges

2.1 Produced Water

Produced water is the water generated from the oil and gas extraction process. It includes: the water native to the producing formation, water injected into the formation to increase reservoir pressure and to sweep oil from the formation and traces of various well treatment solutions and chemicals added during production and the oil/water separation process. The volume of produced water varies over the life cycle of an oilfield, typically increasing over time.

Formation water which comprises the bulk of the produced water, is found in the same rock formation as the crude oil and gas or an adjoining level of the same formation (e.g. below the oil/gas cap). Formation water is classified as meteoric, connate or mixed. Meteoric water comes from rain water that percolates through bedding planes and permeable layers. Connate water (seawater in which marine sediments were originally deposited) contains chlorides, mainly sodium chloride (NaCl), and dissolved solids in concentrations often many times greater than common seawater. Mixed water is characterized by both a high chloride and sulfate-carbonate-bicarbonate content, which suggests multiple origins.

Besides its ionic constituents, produced water may also contain dissolved and dispersed organic compounds, including hydrocarbons (both aliphatic and aromatic) oxygen, nitrogen and sulphur containing compounds (e.g. carbon dioxide, hydrogen sulphide, ammonia and small quantities of heavy metals). Normally formation water is low in sulphate ion and may contain significant quantities of calcium, barium and/or strontium ions. Produced water is usually in a reduced state and it may have both a significant chemical oxygen demand (COD) and biological oxygen demand (BOD).

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Treating chemicals are typically added to produced water and may significantly affect its environmental impact. These chemicals are used to accomplish several functions, including the following most common uses:

- Breaking emulsions to aid in the separation of oil and water
- Preventing the formation of water-formed scales
- Controlling the growth of bacteria in the producing wells and production system
- Aiding in the treating of water to remove oil

The industry magazine, World Oil, annually publishes a list of chemicals currently used in production treating applications. Specific information on the properties of these materials can be obtained from the suppliers' Safety Data Sheets (SDS).

2.2 Drilling Waste

Drilling wastes include drilling fluids (or muds) and the formation fragments (known as cuttings) removed in the drilling process. Drilling fluids are suspensions of solids and other materials in a liquid base. The composition and properties of drilling fluids are determined by their functions. Three of the primary functions that drilling muds perform are:

- Lubricating and cooling the drilling bit
- Maintaining downhole hydrostatic pressure
- Cleaning out the hole by bringing cuttings to the surface

In order to work, muds must have a high density, a high viscosity and lubricity. To meet these requirements the muds contain weighting agents such as barium sulfate (Barite) or ion (III) oxide to increase the density of the mud, clays (bentonite, etc.) or polymers to adjust viscosity and chemical to increase the mud properties. The industry magazine, World Oil, annually published a list of chemicals used in the formulation of drilling muds. Information on the properties of these materials can be obtained from their suppliers from their Safety Data Sheets (SDS). In recent years, great emphasis has been given to selecting mud components that both perform well and are environmentally friendly.

Drilling fluids fall into one the three classes based on the fluid comprising the mud:

- Water based muds
- Oil base muds
- Synthetic based muds

More than one type of mud may be used in a single well depending on the conditions encountered.

A water based drilling fluid or mud is one in which water is the continuous phase and the suspending medium for solids and other liquids, whether or not oil is present [8]. Water based drilling muds are relatively inexpensive. Modern formulations are generally not-toxic to marine fauna. Discharged cuttings will disperse in the water column.

The water in water based muds can be fresh or salt water. Clays or organic polymers are added to achieve the proper viscosity. Barite is added to achieve the correct mud weight (density), and other components are added to mud systems to create the desired characteristics. The United States Environmental Protection Agency (EPA) recognizes eight generic water based mud types (OCS Guidelines).

Oil based drilling fluids are ones in which the continuous phase is oil: diesel, mineral or some other oil [8]. Simplistically they can be viewed as water based muds dispersed in oil. One important difference from water based muds is that viscosity is achieved by emulsification of water in oil as well as through the use of clay. They are also more expensive to use that water based muds.

Oil based drilling fluids are used to solve drilling problems that water based muds cannot handle efficiently, or at all. Conditions warranting the use of oil based muds include: required thermal stability when drilling high-temperature wells, required specific lubricating characteristics when drilling deviated wells, the ability to reduce stuck pipe or hole wash-out problems when drilling thick, water-sensitive formations and drilling through water soluble formations such as salt. Most offshore wells fall into one or more of these classes.

Concerns over the potential toxicity of oil based drilling fluids led to the development of synthetic based drilling muds (SBMs). Synthetic based muds are drilling fluids that use synthetic organic chemicals, principally containing carbon, hydrogen and oxygen, as base fluids. Synthetic based muds are more expensive than oil based fluids, but are more environmentally benign and have increasingly replaced the old oil based muds. SBMs have low toxicity because of the elimination of the polynuclear aromatic hydrocarbons (PAHs). They were also designed to have faster biodegradability, lower bioaccumulation potential and, in some instances, less drilling waste volume. This means that the discharge of SBM cuttings may be permitted. Like oil based drilling fluids, synthetic based fluids are hauled to shore after use to be reprocessed and reused.

Cuttings are small pieces of formation rock that are generated by the crushing action of the drill bit. Drill cuttings are carried out of the borehole by the drilling fluids. Drill cuttings themselves are inert solids from the formation. However, drill cuttings discharges also contain drilling fluids that adhere to the cuttings. The volume of the mud that adheres to the cuttings can vary considerably depending on the formation being drilled and the cuttings' particle size distribution [8]. An old, but still valid general rule of thumb is that 5 % mud, by volume, is associated with the cuttings [13]. In the case of some water based drilling fluids, the formation materials drilled up will become part of the mud solids and chemical adjustments have to be made to accommodate them. This results in an increase in mud volume that is not needed in the drilling process. Some drilling mud then becomes a waste and must be disposed of. Therefore, drilling mud itself becomes a waste material in two ways: as a coating on cuttings and as excess mud.

Drilling fluids are designed to have the required characteristics to aid in the drilling of the well, while at the same time limiting their potential environmental impact. Their potential for environmental impact is partially determined by where they end up in the environment as well as their intrinsic properties. Water based mud and cuttings tend to disperse into the water column on discharge. The dispersion is broken and the solid components slowly settle to the sediment layer at the bottom of the sea. Because of the cuttings are rapidly dispersed and their liquid components diluted, their potential impact should be less than that of oil based, or synthetic muds, but spreads over a much wider area.

Cuttings from oil based mud drilling have oil on their outer surfaces and do not tend to disperse in the water column. The solid components tend to settle rapidly to the bottom and collect in piles under the platforms of drilling rigs. Depending on water depth, free oil on the cuttings tends to rise to the surface of the water and spread over the surface of the water. The environmental impact of the cuttings tends to be highly localized initially and persist over a long time in the sediment and water column immediately above it.

In addition to drilling muds, the offshore oil and gas industry uses a number of water based fluids. These include:

- Completion fluids
- Packer fluids
- Workover fluids

Completion fluids are typically solutions of salts in water. They are used to clean out wells after drilling is complete and aid in the setting of downhole equipment. Packer fluids are concentrated salt solutions placed between the tubing and the casing of a well. Their purpose is to hold pressure on the formation in case the packer fails. They must have a high density in order to be heavy enough to exert sufficient pressure on the producing formation. Workover fluids, such as hydrochloric acid, are used in cleaning, repairing, and stimulating wells. Typical operations include washing sand from the tubing or wellbore, fracturing water-formed scales and corrosion products. The salts used to make these fluids include the cations of sodium, potassium, calcium, barium and zinc, and the anions of chloride, bromide and sulfate.

Completion fluids can be either transported offshore as water solutions, or alternatively the solid salt can be taken offshore and the solution prepared on-site. Spills of completion fluids could result from broken flow lines on the platform or on boats, or from tank failures. When large volumes of completion fluids are needed they are generally transported on work boats. In the event that the vessel has an accident, the completion fluids could be released.

2.3 Magnitude of Waste Discharges

The volume of drilling and production discharges varies over time due to two factors:

The level of drilling and production activity
The fraction of wastes discharged to the environment

The American Petroleum Institute (API) estimated that in 1985 in the United States that oil and gas industry (both onshore and offshore) generated 361 million barrels of drilling wastes (1.5 % of the total) and 20.9 billion barrels of produced water (98 % of the total). Another 118 million barrels of associated waste (0.5 %) were generated for a total of 21.4 billion barrels [9]. From this it is clear that the majority of the waste generated by oil and gas operations is in the form of produced water. In 1995, the API web site's waste prevention data showed that the total volume of waste generated declined to 18.1 billion barrels, a reduction of 3.3 billion barrels. This included an increase of 9 % in produced water discharges and decrease in drilling discharges of 53 %. In 2007 produced water generation in the US was 21 billion barrels and remained generally stable in 2012, when 21.2 billion barrels of produced water was produced [17]. In 2012, the produced water was handled as follows [17]:

- approximately 9.2 billion bbls was injected for enhanced recovery
- approximately 8.0 billion bbls was injected for disposal
- approximately 1.1 billion bbls was discharged to the surface
- approximately 0.7 billion bbls was evaporated
- approximately 1.4 billion bbls was sent to an offsite commercial disposal facility
- approximately 0.1 billion bbls was beneficially reused

Produced water volumes are much greater for structures producing oil or a combination of both oil and gas as compared to gas-only platforms. Although the gas-only platforms generate less produced water, the concentration of the chemical constituents of the water is considerably higher than those from oil producing platforms (op ten [12]). The volume of produced water at a given platform is site-specific. For example, in some instances, no formation water is encountered whilst in others there is an excessive amount of formation water encountered at the start of production. It has been estimated that the volume of water produced for every barrel of oil recovered is between 5:1 and 8:1 in the US and between 2:1 and 3:1 worldwide, with an anticipated increase in the US to 12:1, to as much as 50:1 by 2020 [15].

There is increased attention to addressing produced water issues, partly because of aging developments with the associated increase in produced water volumes, as well as the increased volumes associated with horizontal drilling and the expanded use of hydraulic fracturing. In Norway there are some operators who are trying to reduce the amount of oil in the water to as close to zero as possible, in conjunction with regulators beginning to monitor soluble components as well as free and dispersed droplets of oil [15].

In the North Sea, the method of reporting of waste discharge volumes has changed over the years. Initially reports were made on the volumes of waste such as produced water and drill cuttings. For example, the International Association of Oil and Gas Producers (OGP), formerly known as E&P Forum, have estimated that in 1991, oil and gas platforms in the northern North Sea discharged 160 million cubic meters (1 billion barrels) of produced water, with about 5 % of the total volume coming from gas platforms [7]. Recently the practice is to report only oil in the waste. For example, the Oslo Paris Commission (OSPAR) reports that the total oil discharged (including oil in produced water and displacement waters and accidental spills) in the maritime area of OSPAR was 9053 tonnes in 1999, 9420 tonnes in 2000 and 9317 tonnes in 2001. This did not include oil from oil based mud since discharges of cuttings generated when using these muds are prohibited.

Whatever method is used to account for waste generation, oilfield operations anywhere in the world will generate comparable amounts of waste. However, countries have different regulatory schemes that may prohibit certain discharges. Regulations controlling the types and quantities of waste that can be discharged are discussed later in this chapter.

2.4 Accidental Discharges

Materials that might be accidentally discharged to the sea include:

- Crude oil and tanker fuel oil from tankers
- Crude oil from well blowouts
- Crude oil from tank ruptures on onshore installations
- Crude oil from pipeline and gathering line ruptures
- Fuel and chemicals from storage vessel ruptures on offshore installations and supply boat accidents
- Drilling fluids
- Completion fluids
- Packer fluids
- Workover fluids

Oil spilled at sea will disperse into the receiving environment. This is a result of a number of chemical and physical processes that occur to “weather” the oil. The exact nature of the weathering depends on the type of oil that is involved. Part of the weathering process, for example, the natural dispersion of the oil into the water, results in some of the oil leaving the sea surface, whereas other, such as evaporation or the formation of water in oil emulsions, results in the oil components that stay on the surface becoming more persistent.

How spilled oil reacts depends largely on how persistent the oil is. Light products, such as condensate, tend to evaporate and dissipate quickly and naturally, and are classed as non-persistent oils. They do not usually require any extensive cleanup or response actions. Alternatively, in the case of persistent oils, like most crude, the oil is much slower to dissipate and evaporate and so response actions are required. In addition to the chemical changes, the oil's physical properties including: density, viscosity and pour point all affect behavior.

The oil does not immediately disperse. The time required depends on a series of factors, including: the amount and type of oil spilled; the weather conditions; and whether the oil stays in the marine environment or is washed ashore. The whole process can move quickly or slowly depending on the oil involved and the conditions. For example, dispersion will be quicker in rough seas than in shallow, sheltered, calm waters.

There are generally eight main processes that cause oil to weather. The first of these is spreading. Any oil that is spilled will immediately spread out over the sea surface. The viscosity of the oil dictates how quickly the oil spreads. The lower the viscosity, the quicker the spreading occurs. However, even high viscosity oils still spread relatively quickly. Typically the slick that forms will vary in thickness. Due to the action of the wind, waves and water turbulence, over the next few hours the initial slick will begin to break up and form narrow windrows parallel to the wind direction. The water and the air temperatures, currents and wind speeds also have an effect on how quickly windrows are formed – typically, the rougher the conditions, the quicker that the windrows will form.

The second process is evaporation of the lighter components of the oil. The volatility of the oil, that is the amount of light and volatile components in the oil, governs the volume of oil that will evaporate and how quickly this will happen. For example, aviation fluid and condensate will evaporate almost completely in a few days. On the other hand, heavier crude and heavy fuel oil will hardly evaporate. Evaporation tends to increase as the oil spreads out, and in rougher seas and higher temperatures.

The third process is dispersion. Wave action and turbulence on the sea surface will break up the oil slick into separate slicks and individual oil droplets. The droplets become mixed into the upper part of the water column. Some of the smaller droplets will remain suspended in the water column. Larger droplets will rise to the surface and will either attach onto other droplets and make a new slick or, alternatively, will spread out on the surface to form a very thin oil film. The oil droplets that remain in the water column have a larger surface area, which makes it easier for biodegradation and sedimentation to occur. The sea conditions and the viscosity of the oil are the principle factors in determining how quickly a particular oil will disperse. The use of chemical dispersants can accelerate the process.

Emulsification is the fourth process. An emulsion is formed when two liquids combine, with one ending up suspended in the other. Emulsification of crude oil refers to the process whereby seawater droplets become suspended in the oil. This occurs by physical mixing promoted by turbulence at the sea surface. The emulsion that is formed is usually very viscous and more persistent than the original oil and is often referred to as chocolate mousse because of its appearance. Apart from increasing the persistence of the oil, the formation of an emulsion increases the volume of material that has to be recovered by three to four times. The higher the asphaltene content of the oil, the more likely it is that an emulsion will be formed.

Typically oils with asphaltene contents greater than 0.5 % form stable emulsions. It is possible for emulsions to separate into oil and water if the emulsion is in calm seas or on shore and the material is heated by sunlight.

Dissolution is the fifth process. Water soluble compounds in an oil may dissolve into the surrounding water. This depends on the composition and state of the oil, and occurs quickly when the oil is finely dispersed in the water column. Components that are most soluble in seawater are the light aromatic hydrocarbon compounds such as benzene and toluene. However, these compounds are also those first to be lost through evaporation, a process which is 10–100 times faster than dissolution. Oil contains only a small amount of these compounds making dissolution one of the less important processes.

The sixth process is oxidation. Oils react chemically with oxygen. In the reaction, the oil either forms a persistent "tar" or breaks down into soluble products. The rate and extent of oxidation is generally dependent upon the type of oil involved and sunlight. Oxidation is an extremely slow process and, even in favorable conditions, will only break down 0.1 % per day. Tar balls are formed when the oxidation process forms a protective layer of heavy compounds around a less weathered, soft center. The outer layer makes the tar balls very persistent.

Sedimentation or sinking is the seventh process. In the case of heavy crude oils or refined products with densities greater than one, the oil will sink in fresh or brackish water. There are very few crude oils or refined products with a density greater than the 1.025 for seawater, and so the materially will typically not sink when spilled at sea. However, as the oil adheres to particles, flora, fauna or other organic material, it may sink. Oil that impacts a beach or shoreline may become mixed with sands or other sediment. If this material is washed out to sea, it may sink. The residue from spilled oil that has caught fire, or been burned, can also be sufficiently dense to sink. Interestingly, however, it has been reported that oil particles remained suspended in the water column during the Deepwater Horizon spill.

The eighth process is biodegradation. There are naturally occurring microorganisms that live in the marine environment that can degrade oil to water stable compounds and even eventually to carbon dioxide and water. Not all oils are equally susceptible to biodegradation. The amount of nitrogen and phosphorous in the water, the temperature and the oxygen concentration all affect the ability of the microbes to degrade the oil. The degradation can only take place in an anaerobic environment and so the degradation is usually limited to the oil-water interface. Converting the oil into droplets, both through natural processes or by the use of chemical dispersants, increases the surface area available to the microbes and hence raises the rate of biodegradation.

In the early stages of a spill, spreading, evaporation, dispersion, emulsification and dissolution are the most prevalent processes. Oxidation, biodegradation and sedimentation become more important later in the spill and tend to determine the eventually fate of the oil.

Accidental discharges fall naturally into two classes: those that can be recovered and those that cannot. Oil spills can be recovered, assuming that equipment and manpower is available to recover the oil before it reaches the shoreline, evaporates into the air or sinks. Sometimes bad weather or other conditions can interfere with recovery. Water based fluids usually cannot be recovered. Since they are miscible with water they rapidly dilute on reaching the sea and some undergo chemical reactions with seawater constituents.

In a similar way that the Exxon Valdiz spill changed policies, regulations and responses to reduce the potential for releases from oil tankers and the associated response efforts, the Deepwater Horizon blowout and associated spill has significantly changed the industry, regulatory and public response to releases from exploration and production. Previously preparedness and response was predicated on the assumption that any blowout could be quickly capped to prevent the ongoing release of oil, gas and other fluids. The fact that it took 87 days to stop it had not been included in the response strategies and has resulted in more significant and persistent environmental impacts.

According to studies directed by the US regulatory agency, the Bureau of Ocean Energy Management (BOEM), some of the effects of the spill were mitigated by the knowledge, understanding, expertise and mechanisms in place. However, severe hurricanes and flooding increased the spill's potential impacts. The fate and movement of spilled oil in surface waters were identified using multiple remote sensing platforms. The data from the remote sensing platforms was combined with the best existing algorithms for determining surface oil spatial extent and thickness, which have been very important in determining the extent and characterization of surface oil, which in turn has been used in the Natural Resource Damage Assessment (NRDA) process. Some of the most severe and complex economic effects of the Deepwater Horizon Spill were on the Gulf of Mexico seafood industry [2].

2.5 Wastes that Require Handling During Site Abandonment

Although platform disposal is discussed in a separate chapter in this book, site abandonment has the potential for discharging materials to the sea. Platforms having large integral storage vessels might have residual oil or chemicals in the vessels; the presence of the platform or its residue modifies the local environmental habitat by its very existence. For example, most of the northern Gulf of Mexico is a mud bottomed body with few coral reefs or other bottom relief. Abandoned platforms will tend to act as artificial reefs and attract fish species that live around reefs.

Abandoned platforms could be hazardous to shipping or fishing boats. This would be especially troublesome if they were not visible from the surface.

In the North Sea there is the additional problem of old cuttings piles beneath some of the older platforms. These piles resulted from drilling with oil based muds during the period when discharge of such cuttings was allowed. The interior of these piles may be wet with oil and contain no continuous water. Degradation of these cuttings is dependent on wind and wave action and bacterial degradation of any oil. Wind and wave action does not normally reach the bottom of the northern North Sea and with little water content the piles will not rapidly bacterially degrade. Removing a platform without removing the cuttings piles would leave them as hazard to trawling and other activities for periods estimated to be up to 100 years.

There are a number of wastes that are generated as part of the abandonment process. These include wastes resulting from:

- Cleaning and purging vessels resulting in wastes including:
  - scale
  - tank bottoms
  - washwater
- Seabed clean-up

These wastes have to be treated, handled and disposed of if they cannot be reused or recycled.

3 Potential Impacts on the Environment

3.1 Introduction

The term "environmental impact" covers a variety of effects that discharges might have on the receiving environment. These effects range from very minor variations in the chemical composition of water to complex changes in the chemical, physical and biological nature of water columns, sediments, flora and fauna. Even if an environmental effect is defined, it may be very difficult to identify or quantify it in an actual environment. Therefore, in this document, "environmental impact" will be interpreted as any issue that raises concerns in public or regulatory bodies, whether or not actual lasting effects have been proven to occur.

Toxicity is a concern both in the water column and on the sediment. Toxicity is a measure of the power to interfere with the life processes of an organism. The concern is for both immediate lethal toxicity (acute) and sub-lethal (chronic) effects. Acute toxicity is a measure of the immediate danger of poisoning while chronic toxicity is a measure of sub-lethal impacts. These affect such things as growth and reproduction. Toxic impacts are measured by:

- A minimum concentration
- A minimum exposure time
- A time to recover after exposure

Organic materials are removed from the aquatic environment through either aerobic or anaerobic biodegradation. Organic material in both the water column and sediment are consumed by bacteria and converted into simpler material and ultimately into carbon dioxide and water. Aerobic biodegradation requires an oxygen source in the effected environment. The oxygen necessary for biodegradation is termed the biochemical oxygen demand (BOD). Neither the water column nor the sediment contain much oxygen, and a high concentration of organic material will consume available oxygen rapidly making the environment unable to support life. Oxygen is easily replaced in the water column because wind, waves and currents act to replace the oxygen at a rate higher than most degradation depletes it. On the other hand, oxygen is the sediment is easily depleted by biodegradation. In anoxic (oxygen free) sediments anaerobic (non-oxygen) biodegradation takes place.

The persistence of the contaminant in the environment also plays a role in determining the overall impact to the environment. Persistence is the ability to remain in the environment in a detrimental form and not be broken down into more innocuous material. The only materials that might persist in the aquatic environment are highly stable, complex aromatic compounds that degrade very slowly. The materials that would persist in the environment are generally present in very low concentrations and the threat of buildup is low.

3.2 Potential Impacts from Produced Water

The chemical composition of produced water can change the ionic strength of the receiving waters. The individual constituents of produced water can potentially have toxic effects on the flora and fauna in the water column and the sediments. Chemical reactions with seawater can produce solids that can change the nature of sediments both chemically and physically. All these effects can result in significant impacts on the biological communities living in the water and sediments. The organic constituents of produced water can also deplete oxygen in the receiving water body and the sediments under it due both the chemical and biological reactions.

Laboratory tests have demonstrated that produced water has an intrinsically low toxicity level [7]. Therefore, acute toxicity should not be a significant issue for produced water. However, toxicity limits are imposed on produced water by some regulatory authorities.

In the early development of the offshore oil industry it was feared that both the inorganic and organic constituents of produced water would result in:

- Bioaccumulation and fish tainting
- BOD
- Persistence in the environment
- Contamination of the sediments

Many years of intensive investigations and studies have shown that most of these fears have not proven to be a significant threat to the environment.

However, salinity has been shown to have a serious impact on shallow receiving waters, such as bays and estuaries. Consequently the discharge of produced water to these areas has been banned in many places, including the United States.

On the other hand, a large study done jointly in the Gulf of Mexico by various industry groups and government agencies found no bioaccumulation of heavy metals from produced water [4].

The biodegradation of organic compounds in produced water is known to deplete oxygen in limited water bodies such as ponds, streams and shallow bays. Oxygen recharge from wind and wave action minimizes oxygen depletion in the open sea. The oxidation of inorganic compounds does not create significant oxygen demand [7].

It is anticipated that the results of the investigations following the Deepwater Horizon spill will be able to update the understanding of the impacts of major releases.

3.3 Potential Impacts from Drilling Waste

Potential impacts to the marine environment from drilling waste generated by oil and gas operation include:

- Toxicity
- Bioaccumulation and fishing tainting
- Disturbance to the physical environment
- BOD
- Persistence

Both organic and inorganic components in drilling mud can cause impacts. Oil is one of the organic components of drilling muds as even water based muds can contain some amounts of oil from solvents for other components or oil from the formation. Inorganic components consist mainly of inorganic salts, with trace metals and nutrients.

Toxicity is a concern of both in the water column and on the sediment. The chemical components of the drilling fluids have the most obvious potential for toxicity. However, the effect if the chemicals in drilling mud can be significantly impacted by reactions within the mud itself and with the constituents of seawater.

Mud toxicity can occur in both water column and in sediments. Exposure to a toxic concentration in the water column can be due to dissolved chemicals and dispersed solids and droplets. Exposure to a toxic concentration in the sediments is due to the accumulation of the solid portion of the mud and cuttings. Regulations in most areas ensure that toxicity is not a serious problem.

When solid containing wastes such as cuttings are discharged, the solid portion will eventually end up in the sediment layer. For water based buds the area of sediment covered may be very large because many of the solids tend to disperse into water column and settle slowly over a longer period of time. Furthermore, in shallow waters such as continental shelf of the Gulf of Mexico hurricanes regularly stir up sediments and effectively dilute accumulated cuttings. For oil based muds the cuttings are oil encapsulated particles which are heavy enough that they settle very near the discharge point. The result, after drilling several wells from the same platform, is a large pile of oily material. Since the oil in this pile is not exposed to water containing bacteria it might last a century or more. The environmental concern is that these piles will be a fishing and navigation hazard when the platform is removed and oil escaping from them can affect the environment. In both cases modification to the sediment layer is deemed undesirable.

Since drilling cuttings usually end up on the sediment, if they have an oxygen demand impact it is in the sediment, not in the water column [5]. However, it should be noted that the floor of the ocean in deep water, such as the northern North Sea, is sparsely populated, and so the impact is small and the aerial extent is limited. This concern is recognized and addressed by most regulatory bodies.

3.4 Potential Impacts from Treating Chemicals

Chemicals are used in all phases of offshore oil and gas production. Many of these chemicals have either surface active properties, toxicity, or react chemically with the constituents of seawater. Potential effects include toxicity, oxygen demand and physical fouling of sediments and structures. The oil industry publication, World Oil, publishes lists of all types of treating chemicals annually. These lists provide information on the composition and properties of these materials.

The solubility of treating chemicals can determine where they end up and whether or not they are discharged. For example, many chemicals are water soluble and will end up in the produced water that is discharged. Others are preferentially oil soluble and will end up in the oil stream and will not be discharged. Chemicals used in drilling muds will be in the mud discharged but may have reacted with other chemicals prior to discharge.

To understand the environmental impact of chemicals one must consider:

- The amount of chemical used
- The chemical's properties
- Any reactions it undergoes
- Whether it is discharged

These factors influence the limits that are established in the regulations.

3.5 Potential Impacts from Accidental Discharges

Almost all accidental discharges are of liquid materials. It is important to understand where these liquids will end up when discharged. Some crude oils are relatively volatile and, if spilled, most of the spilled liquid will evaporate into the air. Other crude oils have components that have low volatility. These oils will spread on the surface of the water initially and if not recovered will ultimately end up on the sea floor due to emulsification and absorption of solids. When oil spills reach shorelines and sediments they can physically and chemically impact biological communities as well as physical impact beaches.

The amount of material spilled is an important factor in determining any potential impacts. The size of the release can vary from a few milliliters from a dripping hose connection to thousands of tons in the event of major tanker grounding, or, for example in the case of the Deepwater Horizon the US District Court for the Eastern District of Louisiana ruled that 4 million barrels of oil were released [16]. Water based accidental discharges typically release a much smaller volume than oil spills. They also have a different pathway in the environment. For example, water based fluids such as completion fluids will disperse in the water column and be diluted.

Accidental discharges differ from the waste discharges in that they are generated one time, usually instantaneous events. The maximum volume discharged can be significantly more than routine waste discharges. In addition, there is little control where and when the material is released. Consequently, the discharge may occur in, or close to, very sensitive areas that cannot easily tolerate the discharged material; for example, a tanker spill that impacts a mangrove. In the case of a tanker spill, the response equipment and containment and cleanup crews have to be mobilized. Equipment and crews may be stationed significant distances away from the oil spill site. This potentially allows the spilled material to impact sensitive areas before the spill response equipment arrives. Fortunately however, large tanker spills are extremely rare and represent a very small percentage of the hydrocarbons that enter the environment [11].

Most accidental discharges into the marine environment are crude oil or refined petroleum products. Although the environment impacts of crude oil might be assumed to be similar to the impacts of drilling fluids, they are in fact very different. The highest concerns are for:

- Fouling of beaches and shorelines including manmade structures
- Fouling of birds and sea mammals
- Fouling of sediments
- Impact on breeding habitats

Some of the factors affecting environmental impact include:

- Speed and effectiveness of recovery of the spill and cleanup of the environment, which in turn can be influenced by cleanup liability issues
- Remediation of fouling of birds, mammals and habitats

In the early stages of a spill, spreading, evaporation, dispersion, emulsification and dissolution are the most prevalent processes. Oxidation, biodegradation and sedimentation become much more important later in the spill and tend to determine the eventual fate of the oil.

Recovery and cleanup operations are most effective when performed immediately, or soon after, the spill has occurred. Recovery operations are often made harder when the oil starts to emulsify. Emulsification starts soon after discharge and is exacerbated by wind and wave forces. Emulsified oil does more damage to beaches and habitats than free oil.

If the spill reaches the shoreline, part of the recovery will be decontaminating birds and mammals as well as the beaches and sediments. The sooner remediation starts the higher the effectiveness of the recovery.

With the advent of the use of supertankers in the 1960s the potential for large releases of hydrocarbons was created. The tanker, Torrey Canyon, was the first major spill from a super tanker. It grounded on the southwest coast of England in 1967 and 860,000 barrels of oil leaked into the sea. Much of the south coast of England was affected when oil coated rocky coastlines. The damage was compounded when laundry detergent was applied in an attempt to de-oil rocks, beaches and wildlife and when kerosene was used as the carrier for the oil dispersant which resulted in it being highly toxic to marine fauna. The effects of these efforts retarded the development of non-toxic dispersants for treating oil spills for years.

In 1978, the Amoco Cadiz was grounded off the coast of France and approximately 1,635,715 barrels of crude oil was spilled. Bad weather slowed the response to the spill and rapidly emulsified the oil. Much of this oil ended up on sandy beaches. The removal of large amount of oiled sand severely impacted the beaches.

In 1989, the Exxon Valdez ran aground on a reef in Prince William Sound offshore the State of Alaska. This area is biologically rich and large numbers of sea birds, ducks and sea otters and other animals were coated with oil and had to be rescued and cleaned.

There have been extensive industry, government and privately funded studies to determine the impact of the spill. These studies have come to a variety of conclusions from there being no long-term impact to significant impacts on the flora and fauna in the area.

The UK Royal Commission On Environmental Pollution, Oil Pollution of the Sea (1981) [14], after reviewing a substantial body of information on the environmental effects of actual oil spills, concluded that there is no evidence to substantiate claims for long-term irreversible impact to the marine environment. On the other hand, the short term consequences in relation to amenity loss, interruption of fishing activities and impact on individual sea birds (although not typically on bird populations) are sufficiently serious to justify efforts to develop and implement effective means of oil spill cleanup.

The Deepwater Horizon Semi-Submersible Drilling Rig 2010 oil spill, as explained above, was different from previous releases because of the length and volume of oil released. This has resulted in more significant actual environmental impacts as well as amenity losses, and, for example, interruption of fishing and tourism.

4 Regulatory Approaches

4.1 Regulations for Waste Discharges

It is important to balance the development of natural resources with protection of the environment. Oil and gas exploration activities generate wastes that must be properly handled and disposed of. As previously discussed, some of these, for example produced water, are high volume, low toxicity waste streams that would be very expensive to transport to shore for disposal. Other wastes, such as oil based fluids, have the potential to cause significant environmental impacts. Regulations addressing offshore waste discharges were developed to ensure that the environment is protected while still allowing disposal offshore where possible. A key ingredient in developing and protecting the environment has been obtaining input from all stake holders, including regulatory authorities, industry and environmental groups. Each group has brought data, information and perspective on the issues. The steps in regulatory development include:

- Identifying wastes
- Determining their volumes, properties, potential impacts
- Assessing the sensitivity of the receiving environment
- Determining control strategies
- Implementing systems for monitoring and control

Typically, regional, national and local government authorities are responsible for gathering this information. Industry groups, various industry organizations and environmental groups help identify concerns and supplement the available data.

There are a number of different schemes that are used to regulate waste discharges. In some areas the impact of discharges is controlled by limiting the chemicals that are used in systems that will ultimately be discharged. Other regions apply "end of the pipe" controls. That is they put a limit on the volume and content of the effluent. Generally, there are three major regulatory systems that are used:

- Those for the waters of the United States
- Those for the waters around northern Europe
- Those for Russia and former Soviet Republic waters

There are other additional regional and national regulatory systems. Most of these are modeled on the United States and European systems with local modifications. The following provides an overview of the three different regulatory schemes.

4.2 OSPAR Agreements and National Regulations for the OSPAR Area

The regulations for the North Sea, the Baltic Ocean and the northeast Atlantic Ocean are the result of a treaty organization, the OSPAR Commission, between 15 countries bordering these waters and the European Union. The OSPAR commission identifies issues, investigates impacts and sets goals for controlling pollution of the seas form several sources including offshore oil and gas waste discharges. The member countries through national regulations then implement these goals. For example, the department of Trade and Industry in the United Kingdom issues regulations and limits for the United Kingdom waters.

Information on these types of waste controlled and the limits set on them is available from the OSPAR Commission. The issues covered include, abandoned platforms and pipelines, the discharge of treating chemicals and oil in produced water and the discharge of drilling wastes among others. The approach used is primarily to control waste at the source. For example, treating chemicals are controlled by limiting the chemicals and the amounts used in the oil industry process. Both drilling chemicals and production treating chemicals are classified according to their potential impacts into several classes. These classes range from materials too hazardous to discharge down to those considered having very little impact on the environment. The first class cannot be discharged and no limits are placed on monitoring the waste discharged. Limitations on oil in produced water are an exception. Since oil originates in the underground formation the concentrations in the waste discharge stream are limited.

Discharges are of interest to groups other than regulators. Industry members and organizations and environmental organizations also give input to regulations. For the OSPAR areas organizations industry groups such as the International Association of Oil and Gas Producers (IOGP), Oil & Gas UK, the Netherlands Oil and Gas Exploration and Production Association (NOGEPA), and others input industry views and data. The IOGP is an international organization whose members are oil and gas companies around the world. They respond to regulations and develop environmental standards for oil companies to use where no definitive standards exist locally. Oil & Gas UK and NOGEPA are associations of oil and gas operators in the United Kingdom and the Netherlands. The other member countries of the OSPAR also have national associations of operators. In addition, suppliers to the oil industry provide information on environmental impacts. The European Oilfield Specialty Chemicals Association's (EOSCA) members supply chemicals to the North Sea offshore oil industry. The Environmental groups such a Green Peace and Friends of the Earth are active in lobbying for strong environmental regulations and have an impact on regulatory development. Information and data is available from all these organizations on environmental impacts and regulations.

Over time the limits placed on the chemical use and discharge of oil have evolved and changed. Initially oil concentration in produced water was subject to a concentration limit. Now the emphasis has changed to reducing the total amount of oil permitted to be discharged annually. OSPAR published data on volumes of produced water and amounts of oil discharged annually.

Drilling waste concerns have focused on the oil used to make the oil based drilling muds commonly used offshore. Initially there were no limits on what type of oil was used and diesel oil muds were common. Concerns over the toxicity of diesel oils led to a ban on them and muds were prepared using refined mineral oils, which did not contain aromatic compounds and other more toxic components. Later, all refined oils were banned from discharge and manufactured oils with a controlled composition were used until finally the discharge of drill cuttings containing more than 1 % oil, were banned. Current information on discharge regulations for areas controlled by the OSPAR Commission can be obtained from their offices in London or from their web site. Many of the same groups mentioned above for produced water also provide information and lobbying for drilling waste issues. In addition supply groups such as the International Association of Drilling Contractors (IADC) are active on behalf of drilling suppliers.

4.3 United States Regulations

The EPA develops regulations for the discharge of oil industry wastes of the United States waters. All waters of the United States are regulated. The environmental impacts of principle concern are toxicity and oxygen depletion.

In the United States discharges are separated into five (5) subcategories by potential impact:

- Subpart A: Offshore
- Subpart C: Onshore
- Subpart D: Coastal
- Subpart E: Agricultural and Wildlife Water Use (Beneficial)
- Subpart F: Stripper Wells

The waste streams covered include:

- Produced water
- Produced Sand
- Drilling Fluids
- Drill cuttings
- Well treatment, workover and completion fluids
- Domestic*
- Sanitary*
- Deck drainage*

*Subparts A and D only

EPA issued a proposed rule in March 2015 that will cover wastewater pollutant discharges from unconventional oil and gas extraction facilities to municipal treatment plants to address, for example, the handling of water used in the fracing process.

The previously proposed effort to develop effluent limitation guidelines for coalbed methane (CBM) facilities was discontinued in 2014.

The national office of the EPA identifies and classifies waste discharges and develops guidelines for issuing permits to operators wishing to discharge to these waters. Discharges are not allowed in some of these categories and are very restricted in others. For example, no discharge is permitted in the onshore subcategory because produced water and cuttings are biotreated in the aquatic environment and this process uses up the oxygen in the water faster than if can be replenished. There is also concern about the impact of hazardous substances that might be present in the waste.

In two of these subcategories, beneficial use and stripper wells, discharge volumes are very minor. In some dry areas of the United States, produced water is very low in salinity and can be used for watering livestock and for irrigation. These types of produced water discharges are in Subpart E. In one older area of the United States, very old gas wells producing very small amounts of water (stripper wells) are allowed to discharge to rivers as they have done for many years prior to the implementation of regulations. If discharge were not allowed, the wells would be uneconomical.

The coastal subcategory is that area inside the recognized coastline and outside the brine line, the distance inland that is covered in brackish or salty water. Subpart A is divided into the territorial seas and the Outer Continental Shelf (OCS). The territorial seas are those areas outside the recognized coast line to a distance of usually three miles. These waters are deemed to be part of a state. The OCS is the area outside the three mile limit and is controlled by the federal government and not an individual state. In these three subcategories discharge of waste to the waters was the traditional method of disposal. Over time it was shown that in the coastal areas oxygen depletion and increased salinity were affecting the local environmental and discharges to the coastal subcategory are now banned. In the territorial seas and the outer continental shelf waste discharge is allowed under a permit issued by EPA.

For regulatory purposes the EPA divides the United States into ten regions. The identification of wastes and the determination of their potential impacts are done by the national office of the EPA. These findings are published as guidelines for the preparation of permits. The regional offices can then develop and issue permits to discharge for each industry category based on the applicable guidelines. Originally all permits were developed and issued by an EPA Region. Now individual states can apply to the EPA for the right (called primacy) to issue permits to discharge. These permits are based on EPA guidelines and are subject to the approval of the applicable EPA Regional Office. In the case of the offshore oil and gas industry, discharges were deemed to be similar for all operators in a given EPA region and a system of general permits was developed. For each regional subcategory one permit is issued and all oil and gas operators in that area can apply to be covered by that permit.

Environmental concerns for oil industry discharges to United States waters are similar to those in the OSPAR countries. In both produced water discharges and drilling discharges toxic impacts, oil and oxygen depletion are the major issues. Where discharge of produced water is allowed the discharges have a toxicity limit and a limit on oil in produced water. Drilling waste discharges depend on the type of mud used. For water based muds, cuttings and excess mud can be discharged if a toxicity limit is met and the discharge does not produce a sheen on the water. For non-water based muds, discharges are forbidden for all mud bases except synthetic oils. The characteristics of these synthetic oils are specified in EPA guidelines. These discharges are limited to an average of 6 % oil on the cuttings over the discharge portion for the well being drilled. One additional limit on drilling discharges is that the barite used for weighting the mud must meet limits on the trace amounts of cadmium and mercury.

In addition to the major waste streams several minor discharge streams are also limited. These include treated cooling water, deck drainage from platforms, pipeline pressure test water, sewage from platforms and others. Each general permit for a regulated subcategory in a specified EPA region lists the waste streams discharged and the limits placed on them.

4.4 Comparing and Contrasting OSPAR and United States EPA Regulations

OSPAR tends to control what goes into the exploration and productions processes. The chemicals used are limited by the amount or concentration allowed. All treating chemicals and additives are placed in one of a number of specific classes. Each class is assigned a maximum amount to be used. Chemicals in the most toxic class may not be used at all. The theory behind this approach is that controlling chemicals that might have an adverse impact will control the potential impact. In contrast, the philosophy of the United States EPA is that how oil and gas operators conduct their business is for them to determine. However, the operator's actions must not impact the environmental. Control is exerted through so-called end of pipe limits. In this approach control is accomplished by measuring the composition of toxicity of the discharge, not specific additives used in operations. The major exception in United States EPA regulations is the ban on oil in drill cuttings discharged. A minor exception is the limits on cadmium and mercury in barite.

OSPAR regulations do set limits on oil discharged, but the emphasis is on controlling the total amount going into a particular water body not the concentration of individual discharges. In addition to the overall controls, there are also limits on individual discharges. The United States EPA limits oil in produced water as an indicator of toxic pollutants, not for the potential harm caused by the oil itself. This is in contrast to the OSPAR regulations, which assume that the oil itself might harm the environment. This ignores that fact that along the edge of the continental shelf all over the world natural seeps leak tonnes of oil into the marine environment every day. Although it should be noted that the flora and fauna around these naturally occurring seeps has adapted over time to be able to tolerate and/or live symbiotically.

4.5 Russian and Former Soviet Republic Regulations

In Russia and many of the former Soviet Republic States, there is a general prohibition on the discharge of effluents into the marine environment. Then, on a case-by-case basis, approval is obtained to discharge certain materials. The process involves testing the chemicals that will be used in the process to determine their toxicity and potential impact. Those chemicals that pass are given specific limits to control the impact of the discharge. Then discharges of the material are allowed if a compensation payment is made. The monies are generally considered not payment for damage, but rather a usage fee.

4.6 Other Regulatory Systems

Countries outside Europe and the United States tend to base their regulatory systems on features from both the OSPAR system and the United States EPA system. For example, the Arabian Gulf countries have developed a regional organization similar to OSPAR, but have included some United States features. The body is called the Regional Organization for the Protection of the Marine Environment (ROPME), and is comprised of Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates. It also acts as the secretariat for the Kuwait Convention and Plan. In addition almost all countries where the offshore oil industry is active have national regulations. There have been a number of attempts to summarize the regulatory limits for all the countries of the World but in a rapidly changing world these efforts can only be considered to provide preliminary guidance and specific, current information would be needed to get an accurate understanding of discharge limits for a particular country.

4.7 Accidental Discharges

Accidental discharges differ from waste discharges in several ways. Waste discharges are necessary and intentional. They are expected and always occur at a specific site. The impact on the receiving environment has been considered and is controlled by the conditions of the discharge permit. Accidental discharges are unplanned; occur randomly at unexpected locations; and discharge volumes are sometimes large in comparison to waste discharges. For waste discharges the regulatory emphasis is on controlling the discharge composition and rate. In addition, equipment should always be in place to maintain the permitted conditions for discharge.

The goal of waste discharge regulations is to control the treatment of waste, the rate of discharge and the potential impact on the environment. In contrast, the aims of accidental discharge regulations are:

- Prevention of releases
- Recovery of the discharge where possible
- Remediation of any damage that occurs
- Determining compensation for damages caused by the discharge

4.7.1 Summary of Accidental Discharge Regulatory History

Much of the regulatory emphasis has been on reducing and responding to accidental releases form transportation-related incidents. As production of oil and gas has expanded throughout much of the world, a concerted effort to address how to respond to accidental releases has been made. The initial steps in this direction tended to come as a direct response to a specific incident.

The first such incident to attract massive public attention was the grounding of the Torrey Canyon off the southwest coast of England in April 1967, which resulted in pollution of the English and French beaches. As a result of the Torrey Canyon, a number of individual governments began to urgently study the situation and look for remedies. However, they quickly realized that oil spills do not recognize or respect international boundaries and, as such, unilateral action would be of very little use. It was clear that were was a need to handle these issues internationally, and so the governments went to what was then called the Intergovernmental Maritime Consultative Organization (IMCO) – a specialized organization of the United Nations – and asked for help. IMCO has since changed its name to the International Maritime Organization (IMO) but it continues to this day to take the lead in this area.

In the meantime during the late 1960s, while IMCO began its work, the tanker and oil industries decided to move ahead with their own plans to address the problem of accidental releases. The objective of the work was to develop a scheme that would ensure that governments and people adversely impacted by oil spills anywhere in the world would be promptly and fairly compensated for any damage that they had suffered. Industry also endeavored to come up with a scheme that would help ensure that cargo and tanker owners would take immediate steps to prevent or mitigate any environmental damage.

In order to meet their objectives, the tanker and oil industries entered into two voluntary agreements:

- The Tanker Owners Voluntary Agreement Concerning Liability for Oil Pollution (TOVALOP)

- The Contract Regarding and Interim Supplement to Tanker Liability for Oil Pollution (CRISTAL)

Both these agreements terminated on February 20, 1997, when they were superseded by international spill compensation conventions.

In November 1969, IMCO convened the International Legal Conference on Marine Pollution in Brussels. The majority of the Governments attending signed the Civil Liability for Oil Pollution Damage Convention (CLC), which closely matched TOVALOP. On November 29, 1969, the CLC was adopted to ensure that anyone who suffered damage as a result of a spill from an oil carrying vessel would be compensated.

In December 1971, the Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (FUND) was signed. The Fund Convention is in addition to CLC and was adopted with the purpose of providing additional compensation to those who could not obtain full and adequate compensation for oil pollution damage under the CLC. The Fund Convention set up the International Oil Pollution Compensation Fund. Companies who receive crude oil and heavy fuel oil in member states, after transport by sea, finance the Fund. The Fund Convention came into force in October 1978, at which time the IOPC Fund was established.

The CLC entered into force on June 19, 1975. Under the convention the liability for the damage rests solely with the owner of the ship. There are a number of exceptions to this strict liability (for example an accident as a result of an act of war). It is the responsibility of the ship owner to prove that one of the exceptions applies. The owner can, however, limit liability per incident unless the owner has been guilty of actual fault.

The CLC applies to all seagoing vessels that carry a cargo of oil. The owner of any vessels covered by CLC must also maintain insurance or some other financial security in an amount equal to the total liability for a release, although only ships that carry a cargo of over 2000 tonnes of oil are required to carry oil pollution insurance. The CLC does not apply to warships. However, vessels in commercial service that are owned by a participating State are covered by the CLC. The State owned vessels are not required to carry pollution insurance but must instead carry a certificate from the appropriate authority of the State in which the vessel is registered certifying that the ship's liability under the CLC is covered. The CLC covers pollution damages that results from a spill of oil in the territory, including the territorial seas of a State that is a Party to the Convention. It applies only to vessels that are carrying bulk oil as a cargo (for example laden tankers). It does not cover spills of ballast or oil that is used as fuel by ship. Nor, ironically, is it possible to recover any cost for the response to the incident if the actions result in no actual release of oil.

There have been a number of protocols adopted over the years in an ongoing effort to improve the Convention and help make it more manageable. The 1976 Protocol came into force on April 8, 1981. The original CLC had used the "Poincaré franc" which was based on the "official" value of gold as the unit in the compensation fund. It was very difficult to convert the gold franc into national currencies and so an alternative unit was found. The alternative was based on the Special Drawing Rights (SDR) as used by the International Monetary Fund (IMF). However, in cases where a member State was not a member of the IMF and it was against the law of the country to use SDR, a mechanism was put in place to use an alternative monetary unit based on the value of gold. The daily conversion rates for the SDR can be found on the IMP web site (http://www.imf.org).

The 1984 Protocol was adopted on May 25, 1984 and was to enter into force 12 months after being accepted by 10 States, including six with tanker fleets of at least 1 million gross tonnes. The Protocol was developed to address the fact that by the mid-1980s it was generally accepted that with the prevalence of the super tankers, the limits of liability in the original CLC were not high enough to adequately respond to a large incident. However, it never came into force and was eventually superseded by the 1992 Protocol. This was largely because the United States did not want to accept the Protocol. The USA preferred a system that did not limit liability, much more the Oil Pollution act of 1990 (OPA) that was passed by the USA largely in response to the Exxon Valdez spill. Therefore, the 1992 Protocol was written in such a way that the ratification of the USA was not needed in order for the Protocol to be ratified.

The Protocol of 1992 was adopted on November 27, 1992 and entered into force on May 30, 1996. The Protocol changed the entry into force requirements so that only four (4) instead of six (6) States with tanker fleets of at least 1 million gross tonnes were needed to ratify the Protocol. The compensation limits were the same as those adopted in the 1984 Protocol. In addition to raising the compensation limits from the CLC, the 1992 Protocol added that a ship owner cannot limit liability if it is shown that owner's act or omission caused the spill. It also widened the scope of the Convention to cover pollution damage caused in the exclusive economic zone (EEZ) or equivalent area of a State Party. The Protocol added a limit to environmental damage compensation to the actual costs associated with reasonable efforts to restore the contaminated environment. You can also recover the costs associated with preventative measure to be covered, even if there was no actual spill, as long as there was a "grave and imminent" threat of pollution damage. An added quirk is that Parties to the 1969 CLC. as a result of a provision in the 1992 Protocol, on May 16, 1968 ceased to be Parties to the 1969 CLC as a result of a provision in the 1992 Protocol that resulted in the compulsory denunciation of the "old" regime. The two regimes are currently co-existing because there are a number of States that are Party to the 1969 CLC, but have not yet ratified the 1992 Protocol as it establishes higher levels of liability. The 1992 Protocol permits States that are Party to the 1992 Protocol to issue certificates to ships that are registered in States that are not Party to the 1992 Protocol. This allows an owner to obtain certificates to 1969 and 1992 CLC, even if the vessel is registered in a State that is not a 1969 CLC State, may be able to do business in a country that is a Party to the 1992 Protocol without the appropriate 1992 Protocol certificate, as higher limits liability are established in the 1992 Protocol.

The 2000 Amendments were adopted on October 18, 2000 and entered into force, by tacit acceptance, on November 1, 2003. The amendments raised the compensation limits by 50 % over those established in the 1992 Protocol. The liability limit for a ship of less than 5000 gross tonnage is 4.51 million SDRs, or approximately $6.27 million at the exchange rates in 2015. For a ship of 5000–140,000 gross tonnage, the liability limit is 4.51 million SDRs plus 631 SDRs ($877.09) for each additional gross tonne. For vessels over 140,000 gross tonnage the limit is 89.77 million SDRs ($124.78 million).

Finally, the 2003 Protocol establishing an International Oil Pollution Compensation Supplementary Fund entered into force on March 3, 2005. The purpose of the supplementary fund is to supplement the compensation available under the 1992 CLC and Fund Convention with an additional third tier of compensation. Participation in the fund is optional, but is open to all States that are Party to the 1992 Fund Convention. The total amount of compensation that is payable for an incident will be limited to 750 million SRDs (just over $1042.5 million at 2015 exchange rates). The purpose of the supplementary fund is to ensure that victims of oil pollution damage will be fully compensated. It is expected that increasing the liability limit will end the practice of pro-rating payment of claims that exceeded the old limit. This practice, although unavoidable, had led to criticism of the 1992 Fund.

An International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001, was adopted on March 23, 2001, and entered into force on 21 November 2008. The Convention was adopted to ensure that adequate, prompt and effective compensation is available to those affected by a release of oil that was carried as fuel in the ship's bunkers. It is generally modeled on the CLC and follows the same liabilities. It differs in requiring the registered owners of ships over 1000 gross tonnes (gt) to maintain insurance, or other equivalent financial instrument, to cover damages for pollution resulting from bunker oil releases up to the amount specified in CLC.

4.7.2 International Conventions on Prevention of Pollution

In addition to developing International Conventions that address liability and compensation issues associated with accidental discharges, there are also a number of International Conventions that address pollution prevention. The first international convention on the prevention of oil pollution at sea, was the International Convention for the Prevention of Pollution of the Sea by Oil, OILPOL 1954. It specifically controlled oily water discharges from general shipping and oil tanker transportation operations. OILPOL has now been largely superseded by "MARPOL: 73/78", the International Convention for the Prevention of Pollution from Ships 1973, as Modified by the Protocol of 1978. MARPOL 73/78 defines a ship to include "floating craft and fixed or floating platforms" and, as such, oil production platforms are covered by the Convention. This means, for example, that drainage discharges must not exceed 15 ppm, and so, in the UK, offshore installations are required to maintain an oil record book of all such discharges. Over the years MARPOL has been expanded and now addresses such issues as the phasing out of single hull tankers. For example, the December 2003 amendments to MARPOL 73/78 revising regulation 13G of Annex I of MARPOL, brought forward to April 5, 2005 from 2007, the final phasing out of Category 1 single hull tankers for ships delivered on April 5, 1982, or earlier and Category 2 ships delivered on, or before April 5, 1977. The amendments also banned the carriage of heavy grade oil in single hull tankers after April 5, 2005. The October 2004 amendments to MARPOL came into force on January 1, 2007. They include additional construction and equipment provision designed to help prevent accidental discharges. The amendments also establish the Oman Sea as a special area. Existing special areas under Annex I of MARPOL are the Mediterranean Sea, Baltic Sea, Black Sea, Red Sea, "Gulfs" Area, Gulf of Aden, Antarctic, North West European Waters, Oman area of the Arabian Sea and Southern South African Waters. There are stricter controls in the special areas.

The latest convention concerning oil pollution at sea is the International Convention on Oil Pollution Preparedness, Response and Cooperation 1990 (OPRC). It was adopted in November 1990, and entered into force on May 13, 1995. The objective of OPRC is to improve the level of preparation and preparedness to respond to an oil pollution incident, and to increase and promote international cooperation. OPRC seeks to build on the regional agreements (such as the Bonn Agreement for the North Sea area) to establish an interlocking series of plans that will ensure that all affected countries can adequately respond to any oil pollution incident in a coordinated, effective and rapid manner.

The impetus for the development of the OPRC was the much publicized Exxon Valdez spill in Prince William Sound, Alaska. The incident pointed out that to some extent governments and industry, having developed spill prevention and response plans, had become complacent, and some of the plans had become merely paperwork exercises to meet a regulatory requirement, rather than working documents. The Oil Pollution Act of 1990 (OPA 90) was passed in the United States largely in response to the same incident.

4.7.3 Government and Industry Initiatives to Help Prevent Accidental Releases

The previous section addressed the conventions and agreements that govern the response to an accidental release. This section will discuss some of the initiatives that have been taken to prevent accidental releases, and to minimize the impact of any releases that might occur. Obviously, as stated elsewhere, the best method of avoiding environmental damage from an accidental release of oil is to prevent the release from ever occurring. To this end, industry groups and governments have developed voluntary and regulatory requirements to ensure that plans are in place with the objective of prevention, control and cleanup of any release. The plans range from individual facility prevention and response plans, to regional intergovernmental and industry plans, as oil spills do not recognize or respect international boundaries.

To be effective, it is necessary to develop spill prevention planning on site-specific, local and regional bases. This is because successful planning has to start with prevention at the source, but then must address the potential regional impact of a spill, and how best to respond quickly and decisively to minimize any potential negative impact.

The first generation of facility spill plans was fairly rudimentary. They covered a description of the facilities involved, discussed the possible type and size of releases that could occur, identified appropriate control measures that would be employed to prevent a release, addressed what to do in the event of a release, and listed both the internal and external notifications that must be made in the event of an reportable spill, as well as some of the contractors who could help in a cleanup. A good example of such a plan is the Spill Prevention, Control and Countermeasure (SPCC) Plan that is required in the US under the Clean Water Act. The regulations also require that all personnel be adequately trained to respond appropriately in the event of a release.

Although the SPCC type of plans were an excellent start to a good spill prevention planning, over the years they have the tendency to become merely paperwork exercises. This was graphically illustrated with the Exxon Valdez spill in Prince William Sound, Alaska. The contingency planning that had been done, when tested, did not perform as had been anticipated. Consequently the new breed of spill planning requires not only extensive reviews of the potential impact of any release, but also requires detailed planning that ensures that responders will know exactly how to respond to all types of releases. Equipment has to be either on-site, or available on-site within specified time limits. In order to do this, operators have to enter into binding contracts with equipment providers who will guarantee a certain level of response within a specific time. The equipment had to be regularly inspected for operability, and the equipment has to actually be used in drills or actual responses on a specified schedule. Company and agency personnel who would be responsible for responding to a release have to receive regularly scheduled training that must include classroom and field segments. A good example of this type of plan is the Facility Response Plan required under the Oil Pollution Act of 1990 (OPA 90) in the United States.

In the case of the Deepwater Horizon release, although the companies involved had developed and implemented prevention and response plans, they were based on worst case discharge volumes that assumed that any blowout could be relatively quickly brought under control. This obviously did not happen, as it took 87 days to finally stop the releases. On May 21, 2010, President Barack Obama issued Executive Order 13543 to create the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling. The final report from the commission was released in January 2011. It resulted in a comprehensive reorganization and internal reforms to remove the complex and sometimes conflicting missions of the former Minerals Management Service (MMS). An interim agency, the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) replaced the MMS for 18-months until the creation of three (3), independent agencies on October 1, 2011 with clearly defined roles and missions: the Bureau of Ocean Energy

Management (BOEM), the Bureau of Safety and Environmental Enforcement (BSEE) and the Office of Natural Resources Revenue (ONRR). In addition, the Oil Spill Commission Action was formed to periodically assess and provide updates on the Deepwater Horizon reform and recovery efforts. Some of the changes that have occurred since 2010 are:

- Reducing risk through enhanced well design and casing standards
- Increasing the inspection and engineering workforce within the agency
- Promoting safety culture and continuous improvement at all levels of the industry
- Enhancing blow-out preventer (BOP) testing and maintenance review
- Requirement for operators to demonstrate that they have subsea containment capabilities
- Developing a well control rule that requires, for example, increased equipment reliability
- Strengthening environmental review by requiring site specific environmental assessments for all deep water exploration plans
- Improving worst case discharge calculations
- Increasing limits of liability from $75 million to $134 million for offshore oil and gas facilities, with a mechanism in place to increase the limits over time to keep pace with inflation.
- Developing proposed shared international standards for the Arctic to help ensure that operators will take the steps necessary to ensure that the appropriate steps are taken to plan for and conduct safe drilling operations.

A more detailed description of some of these measures can be found at www.boem.gov [1].

On a regional basis, industry groups and governments have recognized the need for a cooperative effort to pool resources so that spill response can be as quick and effective as possible. The initial thrust came from industry that formed regional equipment cooperatives, which allowed each company to have access to a stockpile of equipment usually stored at strategic locations, for example the Clean Gulf and Clean Seas in the United States. In the UK the Maritime and Coastal Guard Agency (MCA) maintains some stockpiles of equipment. The Oil Spill Prevention and Response Advisory Group (OSPRAG) conducts periodic reviews of response capabilities and equipment and makes recommendations for improvements and updates. On a worldwide basis, groups, such as the Marine Spill Response Corporation (MSRC), and Oil Spill Response Limited, stockpile equipment at strategic locations throughout the world.

Again, in response to a series of usually tanker spills, although there were also a few exploration and production releases (Ixtoc blowout, Ekofisk and the Santa Barbara release), individual governments began to set up their own response groups. Each country has established a program that meets its individual needs, and as such they vary from country to country.

As the programs are developed to meet specific needs, there is a wide variation in the nature and type of system that is established and how it operates. However, their objective is to be as prepared as possible to respond to any oil pollution incident.

For example, in the United Kingdom, the Coastguard Agency's Marine Pollution Control Unit (MPCU) was formed in 1967 following the Torrey Canyon incident, to provide a command and control structure for decision making and response following a shipping incident that causes, or threatens to cause, pollution in UK waters. This replaced the previous non-dedicated central government organization for dealing with oil and chemical pollution at sea, with a small dedicated unit. This change came about as a result of the work done by the United Kingdom Royal Commission on Environmental Pollution which, amongst other things, stated that they considered it essential that the response to a major spill should be a single coordinated operation overseeing the response at sea, inshore and on the land, hence the MPCU. MPCU was then restructured during the merger between Marine Safety Agency and the Coastguard Agency in 1998, to become the Counter Pollution and Response (CPR) Branch of the MCA. MCA's CPR is now based on a regional response with central operational, technical and scientific support. A Counter Pollution & Salvage Officer (CPSO) is based in each region, supported by scientists, mariners, cost recovery specialist and logistics support specialists in the MCA's headquarters in Southampton.

The 2012 "National Contingency Plan for Marine Pollution from Shipping and Offshore Installations" (NCP), is currently under review. The Plan explains the procedures and arrangements that have been established to deal with pollution, or the threat of pollution as a result of accidental releases from ships and offshore installations. It also details that responsibilities of the Department for Transport, the Department of Energy and Climate Change and the Maritime and Coastguard Agency, harbour authorities, offshore installations operators and other bodies with relevant functions. These procedures have built-in thresholds to allow for flexibility of response to different degrees of incident.

The UK has studied carefully the short and long term impacts an accidental release could have on the environment and leisure activities, and established its resources within financial limits set by the level of impact anticipated. Generally, for example having government owned, strategically located stockpiles of equipment, coordinating the government owned stockpiles with the industry cooperative stockpiles, and the Bonn signatory government ones.

The MCA's CPR manages a series of framework agreements with technical experts to assist the MCA during incidents. Computer programs are used to model the fate and trajectory of both oil and hazardous substance spills. This information assists MCA decision making, to determine the appropriate response level for all types of threat to the UK interests.

In addition to the MCA, there are a number of other organizations in the UK that have a responsibility to respond to accidental releases. For example, offshore oil and gas facilities have the statutory responsibility to be able to respond to and clean up any release associate with their activities. Local authorities, or the Northern

Ireland Environment Agency have the non-statutory responsibility for shore cleanup.

The MCA runs and participates in many spill drills and also runs a series of training courses for local authorities to prepare their personnel to respond to shoreline pollution. CPR also runs courses in Oil Spill Response, aimed at local authority Beachmasters, which are hosted by local authorities. Both courses are accredited by the Nautical Institute. In addition, MCA runs Decision Making in Oil Spill Response Courses to prepare the statutory nature conservation agencies, the environmental regulators and the Government fisheries departments for their role in the Environmental Group set up in response to maritime incident. Counter Pollution & Response works closely with international colleagues. This includes the European Marine Safety Agency (EMSA) and the Bonn Agreement, which it currently chairs.

In contrast to the UK, which is well established program that has developed over many years, China has taken a different approach, which more close meets its specific needs. Unlike the UK, China is a vast country, which did not open up to oil exploration and production until the 1990s. The initial program was based on requiring the operator to do the spill contingency planning and to maintain any equipment necessary to provide an initial response until the international spill response community could get equipment and expertise into the area, if needed. The China National Offshore Oil Company (CNOC) was charged with reviewing the contingency planning and equipment to ensure that is adequate. Subsequently, the Chinese Government instituted the State "Emergency Plan for Oil Pollution Management on the High Seas" and formed an emergency response team for pollution in port areas [3].

RPC follows International Conventions including OPRC 1990 and OPRC-HNS Protocol and the International Convention relating to Intervention on the High Seas in Cases of Oil Pollution casualties, 1969, and has passed the following domestic laws:

- Marine Environment Protection Law of the People's Republic of China (PRC)
- Law of the PRC on Emergency Response Regulations on Administration of the Prevention and Control of Marine Environmental Pollution Caused by Vessels.

Several new regulations have been developed to implement these International Conventions and Domestic Laws. These include Regulations on Emergency Preparedness and Response on Marine Environmental Pollution from Ships (Ministerial Order No. 4 2011) as well as rules issued by China MSA.

The law requires that an environmental impact statement must be completed, submitted and approved by the National Environmental Protection Agency prior to a company being able to begin exploration and production activities. The information collected in the environmental impact statement is used for contingency planning. The contingency planning must include, at a minimum, the following elements: a general description of the project; the environmental conditions of the area, including the oceanography, meteorology, and the sensitive environmental zones; risk analysis; response organization and responsibilities; oil spill response procedures; and how spilled oil will be handled (in particular taking into account that most of the offshore discoveries have been high density, high pour point, waxy crudes, which means that standard skimmers and dispersants might not be effective).

Regulations of the PRC on the prevention and control of marine pollution from ships were issued in 2010 and were most recently updated in January 2012. The Regulations which came into effect on 1 March 2010 require owners/operators of (a) any ship carrying polluting and hazardous cargoes in bulk or (b) any other vessel above 10,000 gt to enter into a pollution clean-up contract with a Maritime Safety Agency (MSA) approved Ship Pollution Response Organization before the vessel enters a PRC port. The Maritime Safety Agency (MSA) of the PRC published Detailed Rules on the implementation of the Administration Regime of Agreement for Ship Pollution Response (Detailed Rules) which came into effect on 1 January 2012. On 14 September 2012, MSA revised the Detailed Rules (Revised Detailed Rules) and the Revised Detailed Rules came into effect on 14 September 2012 [3].

The Ivory Coast, West Africa, has developed a coordinated approach to responding to oil spills. In early 1990s the government teamed with the Danish International Development Agency (DANDIA) who sponsored a study to determine the current situation, to propose and implement any needed changes, and to purchase any necessary equipment. The Centre Ivoirien Antipollution (CIAPOL) under the Ministry of Environment, is the organization that deals with marine pollution problems. CIAPOL has three divisions: an administrative division; a division that deals with combating oil and chemical spills at sea, known as the Centre Ivoirien de lute contre les Pollution Marines et Lagunaires (CIPOMAR); and the Central Laboratory for the Environment (LCE) which carries out most types of water analyses, including analyses for total and individual hydrocarbons.

The national oil and spill plan, Plan Pollumar, was originally developed in the early 1980s, and has since been completely revised. The government has decided that CIAPOL will act as the national authority, and so is responsible for all matters related to marine oil and chemical spill contingency planning for Ivory Coast. The day-to-day running of the program and the implementation of the Plan Pollumar have been delegated to the CIAOMAR division. CIPOMAR has been organized into three sections, namely Operations, Maintenance and Administration. The Operation Section has setup a national communications center, which receives the reports of spills in the Ivory Coast response area, as well as pollution reports from neighboring countries within the West and Central Africa region (Cǒte d'Ivoire is a signatory of the Abidjan Convention). The duty officer at the communications center evaluates the report, and decides on the appropriate response, including for example, enacting Plan Pollumar.

The Maintenance Section is responsible for maintaining the spill response equipment. The Administrative Section is responsible for creating all the documentation that will be used for the claim and compensation procedures. Employees from all three sections have been trained to perform the functions of the Incident Commander and On-scene Coordinators. CIAPOL currently has nine (9) pollution response vessels for releases in coastal lagoons and near shore areas as well as boom, skimmers, pumps and inflatable storage barges.

However a country organizes its Spill Contingency Planning; all countries have recognized the importance of conducting regular drills. In some cases the drills are self -contained within the country. In other cases combined drills are held by neighboring states.

5 Should the Release Be Remediated?

Since the first oil spill and resultant cleanup, the question has been raised as to how clean is clean? Over the years considerable effort and resources have been expanded to determine not only impact of spilled crude oil on the environment, but also the impact of the cleanup. In the early days the cure was often worse than original incident. For example, as previously mentioned, the dispersants used on the Torrey Canyon Spill were several orders of magnitude more toxic than the oil that they were trying to disperse. Eventually the recommendation arising from the results of individual companies and by the agencies responsible for a Country's response planning. It began to be an accepted credo that the net impact on the environment should be important factor in deciding on the appropriate response to an accidental release.

However, it is important to remember political reality will not always allow the responders to a spill to base their decisions solely on what is best for the environment.

For example, natural biodegradation, and bioremediation of a beach may be the best ecological solution, however, the company responsible for the spill, and cleanup, and the agency overseeing the response may have to attempt to clean up the area in order to be seen as responsive.

In spite of political pressures, it is important to try and always make the minimum net environmental impact the objective of a responsive plan. Exactly how to do this will depend on the nature of the crude oil spilled the location of the oil, and the systems that are or maybe, impacted. For example, it is generally accepted that crude oil spilled in a salt marsh is best left to degrade naturally, as any attempt to mechanically remove the oil will result in a much greater impact on the biosystem.

Another critical component of the "how clean is clean" debate is the importance of the stakeholders coming to an agreement on the appropriate end point, beyond which cost of remediation far exceeds the net benefit to the environment.

6 Sources of Data on Discharges to the Marine Environment

Much of the information on oil industry discharges to the sea is not reported in scientific studies but in industry technical documents or legal documents. At the present time the best sources of such information on discharges to the sea from oil industry operations are the websites of the various regulatory and industry bodies. These organizations include:

- Regulatory bodies
- Industry associations
- Technical societies
- Industry support groups and suppliers
- Environmental activist organizations

Some of the important regulatory bodies are:

- The Oslo Paris Commission (OSPAR)
- The United States Environmental Protection Agency (USEPA)
- The United Kingdom Department of Energy & Climate Change
- The UN Regional Organization for the Protection of the Marine Environment
- International Maritime Organization (IMO)

Some of the important industry associations are:

- The International Association of Oil & Gas Producers (OGP)
- The American Petroleum Institute (API)
- Oil & Gas UK
- The Society of Petroleum Engineers International (SPEI)

Some important industry support groups and suppliers associations are:

- European Oilfield Specialty Chemicals Association, (EOSCA)
- International Association of Drilling Contractors, (IADC)

Some important environmental groups are:

- Friends of Earth
- The Natural Resources Defense Council (NRDC)

These organizations can be assessed on the Internet by entering their names or acronyms into a search engine. Much of the information in this chapter was verified using these web sites.

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