ENVIRONMENTAL ASPECT OF OIL AND WATER-BASED OFFSHORE DRILLING MUDS AND CUTTINGS

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Abstract- The offshore drilling process uses drilling fluids (mud) and generates waste fluids and cuttings. Drilling fluids used in offshore drilling operations are water based drilling fluids (WBF), oil based fluids (OBF) and synthetic based fluids (SBF). The wastes generated in the largest volumes during drilling oil and gas wells are drilling fluids and cuttings. There are several options to manage offshore drilling wastes: offshore discharge, offshore down whole injection and onshore disposal. In many parts of the world, some types of drilling fluids and drill cuttings may be discharged to the sea if they meet certain environmental requirements. The different drilling fluids, the ecological effects of drilling fluids and drill cuttings discharged from offshore platforms, and discharge standards are presented in this paper.

Keywords- Offshore Drilling, Drilling Fluids, Waste Management, EU Standards

I. INTRODUCTION

In early offshore oil and gas development, drilling wastes were generally discharged from the platforms directly to the sea. Until several decades ago, the seas and oceans were considered as limitless dumping grounds. However, during the 1970s and1980s, it has evidenced that some types of drilling waste discharges could have undesirable effects on local ecology, particularly in shallow water. Offshore platforms can impact environment in three ways: the physical presence of the platforms, waste discharges from the platforms and accidental discharges. The impact of offshore oil & gas exploration and production on the marine ecosystem varies from disturbance of sea mammals during acoustic exploration research activities to chemical, physical and toxicological effects of residual waste streams. The residual waste streams from offshore platforms can be distinguished into the following categories:

i. Operational discharges:
- Cuttings contaminated with oil and chemicals (from drilling platforms).
- Production water contaminated with oil and chemicals (from production platforms).
- Rainy, scrub and cleaning water contaminated with oil and chemicals.
- Sanitary waste and refuse.

ii. Accidental discharges (e.g. as a consequence of blowouts and damage of pipelines, discharges due to flaring).

In terms of volume and toxicity, drilling fluids and drill cuttings are among the most significant waste streams from Exploration & Production (E&P) activities in the oil and gas industry. Accidental discharges are not permitted or planned. They are usually shorter in duration but can produce a more intense impact on the environment.

II. DRILLING FLUIDS AND DRILL CUTTINGS

Drilling fluids (muds) consist of a continuous liquid phase, to which various chemicals and solids have been added to modify the operational properties of the resulting drilling system. Because of that the composition of drilling fluids is complex and varies widely depending on the specific down-hole conditions such as down whole temperature and pressure, geology, and other factors. Drilling fluids fall into one of three types depending on their principal liquid-phase component: water- based fluids (WBFs), oil-based fluids (OBFs), and synthetic-based fluids (SBFs) .

A. Water Based Fluids:

A water-based fluid is a suspension of particulate minerals, dissolved salts, and organic compounds in freshwater, seawater, or concentrated brine. When water- based fluids (WBFs) are used, only limited environmental harm is likely to occur. WBF in gradients can be divided into 18 functional categories. Each category of additives may contain several alternative materials with slightly different properties(Table 1).

If permitted by local regulations, the cuttings may be discharged to the sea. Periodically, some of the drilling fluid may be discharged as well. The total mass of WBF and cutting discharged per exploratory well is about 2000 metric tons/well and somewhat less for most development wells.

Table 1. Functional categories of materials used in WBF, their functions, and examples of typical Chemicals in each category

Functional Category	Function	Typical Chemicals
Weighting	Increase	Barite, hematite,

materials	density (weight) of mud, balancing formation pressure, preventing a blowout	calcite, limonite
Viscosities	Increase viscosity of mud to suspend cuttings and weight agent in mud	Bentonite or attapulgite clay, carboxymethyl cellulose, and other polymers
Thinners, and temperature stability agents	Deflocculated clays to optimize viscosity and gel strength of mud	Tannins, polyphosphates, lignite, lignosulfonates
Filtrate reducers	Decrease fluid loss to the formation through the filter cake on the wellbore wall	Bentonite clay, lignite, Na-carboxymethyl cellulose, polyacrylate, pregelatinized starch
Lost circulation materials	Plug leaks in the wellbore wall, preventing loss of whole drilling mud to the formation	Nut shells, natural fibrous materials, inorganic solids, and other inert insoluble solids
Lubricants	Reduce torque and drag on the drill string	Oils, synthetic liquids, graphite, surfactants, glycols, glycerin
Shale control materials	Control hydration of shale's that causes swelling and dispersion of shale, collapsing the wellbore wall	Soluble calcium and potassium salts, other inorganic salts, and organics such as glycols
Emulsifiers and surfactants	Facilitate formation of stable dispersion of insoluble liquids in water phase of mud	Anionic, cationic, or nonionic detergents, soaps, organic acids, and water-based detergents
Bactericides	Prevent biodegradation of organic additives	Glutaraldehyde and other aldehydes
Pipe-freeing agents	Prevent pipe from sticking to wellbore	Detergents, soaps, oils, surfactants
	wall or free stuck pipe	
Calcium reducers	Counteract effects of calcium from seawater, cement, formation anhydrites, and gypsum on mud properties	Sodium carbonate and bicarbonate (Na_2CO_3 and $NaHCO_3$), sodium hydroxide (NaOH), polyphosphates
Corrosion inhibitors	Prevent corrosion of drill string by formation acids and acid gases	Amines, phosphates, specialty mixtures
Temperature stability agents	Increase stability of mud dispersions, emulsion and rheological properties at high temperatures	Acrylic or suffocated polymers or copolymers, lignite, lignosulfonate, tannins

When WBF and cuttings are discharged to the sea, the larger particles and flocculated solids, representing about 90% of mass of the mud solids, form a plume that settles quickly to the bottom. The remaining 10% of the mass of the mud solids consisting of fine-grained un-flocculated clay-sized particles and a portion of the soluble components of the mud from another plume in the upper water column that drifts prevailing currents away from the platform and is diluted rapidly in the receiving waters. In well-mixed sea waters, drilling fluids and cuttings are diluted by 100-fold within 10 m of the discharge and by

1000-fold after a transport time of about 10 minutes at a distance of about 100 m from the platform9. Because of rapid dilution of the drilling mud and cuttings plume in the water column, harm to communities of water column plants and animals is unlikely and has never been demonstrated.

WBF and cuttings solids settle to and accumulate on the sea floor. If discharged at or near the sea surface, the mud and cuttings disperse in the water column over a wide area and settle as a thin layer of a large area of the sea floor. If mud and cuttings are discharged just above the sea floor the drilling solids may accumulate in a large, deep pile near the discharge pipe. The accumulation of mud and cuttings on the bottom, the cutting pile, may contain higher concentrations of several metals, particularly barium (from drilling mud barite), and sometimes petroleum hydrocarbons than nearby uncontaminated sediments. Chromium, lead, and zinc are the metals, in addition to

barium, that are most often enriched in cutting pile sediments. The metals associated with drilling mud barite or cutting piles have a low bioavailability to marine animals; they do not accumulate in the tissues of bottom-living animals.

WBF are non-toxic or partially non-toxic to marine animals, unless they contain elevated concentrations of petroleum hydrocarbons, particularly diesel fuel. Most drilling mud ingredients are non-toxic or used in such small amounts in WBF that they do not contribute to its toxicity. Chrome and ferrochrome lignosulfonates are the most toxic of the major WBF ingredients. Although used frequently in the past, these deflocculates are being replaced in most WBF by non-toxic alternatives to reduce the ecological risk of drilling discharge.

B. Oil based fluids:

Oil based-fluid have traditionally been used to improve lubricity, reduce friction and address site-specific conditions such as: high down hole temperatures, hydra table shale's, high angle drilling, and extended reach wells. An oil based-fluid has diesel, mineral oil, or some other oil as its continuous phase, with water as the dispersed phase. Other constituents are barite, clays, emulsifiers, water, $CaCl_2$, lignite, lime and other additives. Discharge of OBF cuttings has far greater toxicity than waste from WBFs and poses the most severe environmental impact on the seafloor of the three fluid types. The use of OBFs are declining because of the added cost of transporting waste fluids to shore, regulatory restrictions, and the development of SBFs. Cuttings piles, created when oil-based fluids (OBFs) are used on deeper sections of wells, impair zones beneath and adjacent to the platforms. Piles of oil-based cuttings can affect the local ecosystem in three ways: by smothering organisms, by direct toxic effect of the drilling waste, and by anoxic conditions caused by microbial degradation of the organic components in the waste (Figure 1).

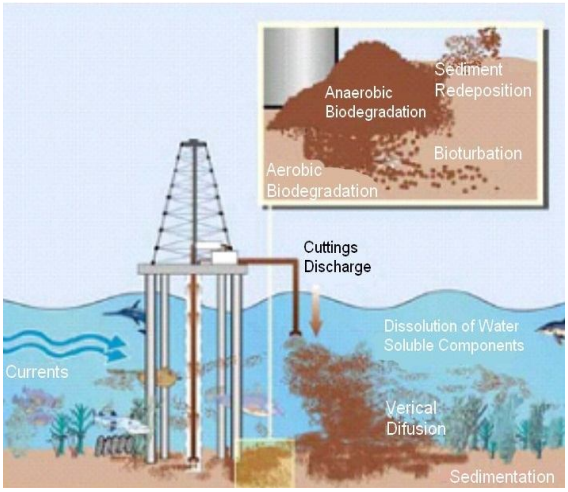


Figure1-Effect of drill cuttings discharge on marine environment

C. Synthetic based fluids:

During the mid-1990s, mud companies developed and promoted synthetic-based fluids (SBFs) that offered strong drilling performance like OBFs but were much closer to WBFs in environmental impact8. SBFs are formulated as an emulsion in which the synthetic liquid forms the continuous phase while brine serves as the dispersed phase. The SBFs used in the field to date are classified according to the molecular structure of their synthetic compounds: esters, ethers and olefins (initially polyalphaolefins-PAOs, now linear alpha olefins-LAO). The use of ethers was primarily in the Norwegian Sector of the North Sea and was discontinued following the introduction of linear alpha olefins.

D. Drill cuttings:

Cuttings are primarily formation rock materials brought to the surface by the drilling fluids. They contain the same chemical parameters as the formation, along with drilling fluids that adhere to their surface. The volume of fluid that adheres to the cuttings can vary considerably, depending on the formation being drilled and the particle size distribution of cuttings. A general rule of thumb is that 5% drilling fluid, by volume, is associated with the cuttings. Disposal of drill cuttings is the same as with the used fluid.

III. WASTE MINIMIZATION HIERARCHY

The European Union (EU) has a set of common rules on permitting for industrial installations3. These rules are set out in the so-called IPPC Directive of 1996. IPPC stands for Integrated Pollution Prevention and Control. In essence, the IPPC Directive is about minimizing pollution from various point sources throughout the European Union. Unless they have a permit, they are not allowed to operate. The permits must be based on the concept of Best Available Techniques (BAT).

In many cases BAT means quite radical environmental improvements and sometimes it will be very costly for companies to adapt their plants to BAT. The waste minimization hierarchy is described in the IPPC Directive. The first step is investigate options that prevent waste generation, next is to reduce waste, then reuse and recycle as much as possible, while the last and the least preferred option is to deposit residues. Waste minimization in drilling operations starts in the preplanning phase. The selection of BAT solutions, when balancing drill cuttings, had to take into account following issues11: drilling technology (well design, drilling fluid, solids handling equipment on rig), drilling waste (disposal options, transport and logistics, drilling waste treatment technology), impact of different waste disposal options, and cost. Integrated fluids engineering helps to achieve several benefits: reduced health, safety and environmental risks, environmental compliance, reduced waste

volumes, reduced fluid-disposal costs, optimized product usage, reduced site-closure costs, maximized pollution prevention (Figure 2).

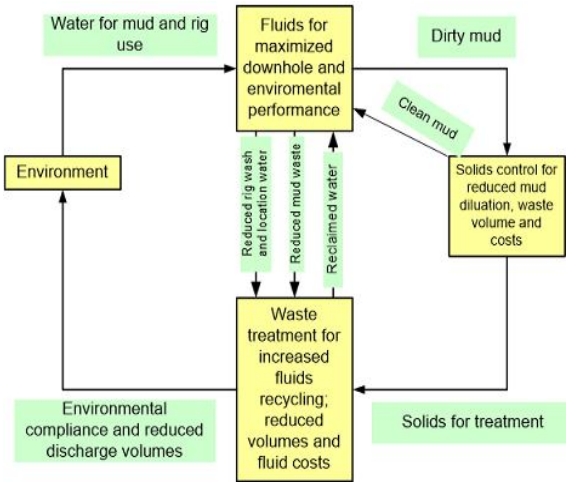


Figure 2. Integrated fluids engineering approach

IV. DRILLING WASTE DISPOSAL OPTIONS

There are three options to manage offshore drilling wastes (Figure 3):

i. offshore discharge – fluids and/or cuttings are discharged overbroad from the drilling platform after undergoing treatment by solids control equipment designed to remove solids and recover fluids,
ii. offshore downhole injection –cuttings are ground to fine particle sizes and disposed of, along with entrained fluids, by injection into permeable subsurface formations,
iii. Onshore disposal – cuttings and the associated fluids are collected and transported for treatment if necessary and final disposal.

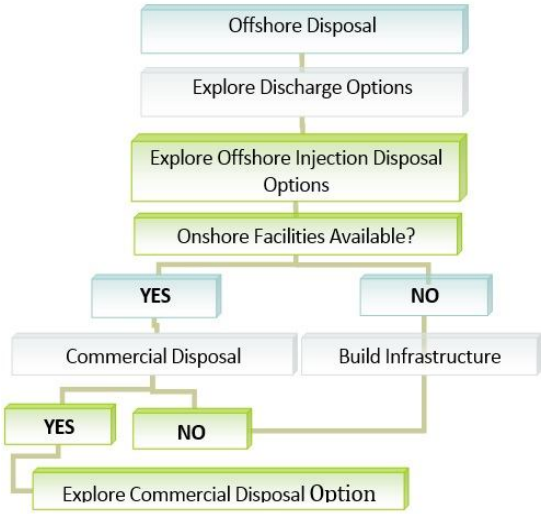


Figure 3. Offshore waste disposal options decision three

All options have advantages and disadvantages with regard to total life cycle environment impact, safety, cost, and operational performance. In making decisions regarding disposal options, one should establish a framework to compare the pros and cons for each alternative option in this framework factors other than potential environmental impacts should be considered (Table 2).

Table 2. Parameters for evaluating disposal options

ECONOMIC	OPERATIONAL	ENVIRONMENTAL
Immediate costs	Safety	Air emissions from drilling and supporting operations
$/m^3 for disposal	Human health issues/chemical exposure	Power requirements
Energy cost	Processing rate	Reduction in volume of waste
Maintenance cost	Mechanical reliability	By-products of process
Labor cost	Size and portability of unit (s)	Compliance with regulations
Equipment cost	Space availability	Receiving physical environment
Transportation costs	Energy requirements	Marine species potentially at risk
Disposal costs of end products	Condition of end products	Potential environmental stressors
Future liabilities	Method of disposal after processing	Removal of hydrocarbons, heavy metals and salts from solids and water

V. ENVIRONMENTAL LEGISLATION CONCERNED WITH OFFSHORE PLATFORM DISCHARGES

Regulatory control of offshore oil industry operations falls under a variety of international, regional, and national agencies (Figure 3). In addition, in some areas, states or other local bodies may regulate portions of offshore areas.

Regarding the maritime environment, the United Nations Convention of the Law of the Sea (UNCLOS, 1982) is the key overall regulatory framework at global level for all activities at sea. Conventions supporting this at global level are

i. The International Convention for the Prevention of Pollution from Ships (MARPOL, 1973/78),
ii. The Framework for prevention of dumping of pollutant material (London Dumping Convention, 1972)
iii. The International Convention on Pollution Preparedness, Response and Cooperation (OPRC, 1990).

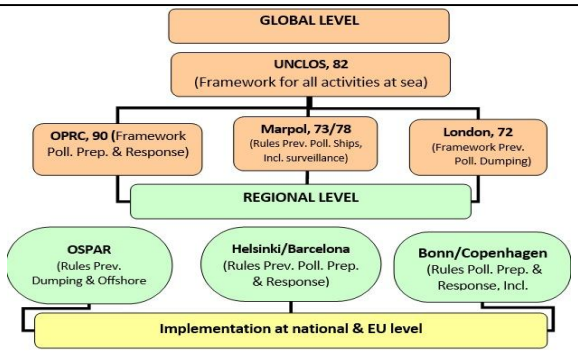


Figure 4. Overview of global and regional legislations

The MARPOL Convention is the most ambitious international treaty covering maritime pollution. It deals not only with oil, but with all forms of maritime pollution except the disposal of land-generated waste into sea by dumping. The Convention covers discharges from ships (both accidental pollution and that from routine operations; and currently includes six technical Annexes); however, the definition of «ships» covers a wide range of operations including fixed and floating platforms.

One of the main points to note with respect to protection of the marine environment in Europe is the wide range of international bodies, treaties, conventions and organizations concerned with different aspects of protection and monitoring at regional and national level (Figure 4).

These include specific conventions and agreements relating to particular maritime regions, such as the Oslo and Paris Commission for the North-East Atlantic (OSPAR), the Helsinki Convention (HELCOM Convention) for the Baltic, the Barcelona Convention for the Mediterranean, the Copenhagen and Bonn agreements for many of the EC and national economic zones.

The Barcelona Convention is a UN sponsored initiative to support sustainable development and pollution reduction in the Mediterranean Sea (sign by France, Spain, Italy, Slovenia, Greece, Cyprus, Malta, Turkey, Croatia, Morocco, Algeria, Tunisia, Libya, and Egypt). Discharge practices and standards for offshore operations are presented in table 3.

Table 3. Discharge Practices and Standards for Offshore Operations

Legal basis	Discharge in Sea			
	WBF & Cuttings	SBF Cuttings	Oily Cuttings	Produced Water (Oil in Water Limit)
OSPAR Convention (North Sea countries)	Discharge allowed under PARCOM	1 mg/kg	1 mg/kg	40 mg/l now 30 mg/l by 2006
Baltic Sea Convention and HELCOM standards	Discharge allowed based on HELCOM Recommendation No. 95/1	Not determined	HELCOM Recommendation No. 95/1	15 mg/l max; 40 mg/l if BAT cannot achieve 15 mg/l
KUWAIT Convention and Protocols (Red Sea region)	Discharge allowed based on UNEP: Kuwait Protocol on protection from Pollution	Not determined	Discharge allowed under Kuwait Protocol on a case by case basis	40 mg/l 100 mg/l max
Barcelona Convention and Protocols (Mediterranean countries)	Discharge allowed under Barcelona Protocol[2]	Not determined	100 g/kg	40 mg/l 100 mg/l max

Regarding to chemicals used and discharged offshore OSPAR agreed on two lists of chemicals: the list of "chemicals for priority action" (i.e. the most hazardous ones), and "PLENOR" list, the list of chemicals which have been considered as "posing little or no risk to the environment".

At present time no "chemicals for priority action" is intentionally used offshore; substances listed on the PLONOR list do not request further investigation.

CONCLUSION

The disposal of drill cuttings and produced water has become a major concern for operators and environmental controls have been tightened by regulatory authorities. Most oil and gas operators today develop and implement an environment management system (EMS) for all operations which is in line with international standards. Through the adoption and implementation of an EMS, potential

environment impacts and consequences are identified, managed and minimized where possible.

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