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Drilling Fluid Waste Management in Drilling for Oil and Gas Wells

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Drilling operation produces two major wastes which are produced water and drilling waste. The drilling waste must be properly managed to ensure no impact to the environment and human. The environmental and human effects of the exposure to drilling waste are discussed in the paper. Different type of drilling fluids has different composition, which influence the environmental impact of the drilling fluid. Due to the potential impact to environment and human, there are regulations by the host government and international conventions for drilling waste management. Generally, oil based drilling fluid is not permitted for offshore disposal and drill cuttings require treatment before disposal. However, water based drilling fluid is allowed for disposal. Synthetic based drilling fluid is preferred due to its technical performance and minimum environmental effects. Main regulations related to environmental and waste management in Malaysia is Environmental Quality Act and Exclusive Economic Zone Act. There are three options of drilling waste disposal, which are offshore disposal, onshore disposal and drill cutting re-injections. Offshore disposal is limited by the regulations while onshore disposal can give additional liability at the disposal site. Drill cuttings re-injection can be a good option of disposal, with zero discharge to the site. However, not all formation is feasible for the re-injection.

1. Introduction

Drilling wastes are the second largest volume of waste, behind produced water, generated by the oil and gas exploration and production industry. Based on API (American Petroleum Institute) Survey of Onshore and Coastal Exploration and Production Operations for 1995, about 150 million barrels of drilling waste were generated from onshore wells in the United States alone (ICF Consulting, 2000). Drilling process produces two major wastes, which are drilling fluid waste and drilling cuttings (Onwukwe and Nwakaudu, 2012). Depending on the depth and diameter of the wellbore, the volume of drilling wastes generated from each well is different. Typically each well can generate few thousand barrels of drilling waste. With the high volume of waste generated from drilling operation, it requires a proper waste management and disposal to avoid pollution and impact to human and environment. Drilling operation can also potentially give impact to the environment. The most significant impact from drilling operation to the environment is the discharge of drilling waste including drill cuttings to the seabed. Marine population can also be affected by the discharge of drilling waste. The toxicity of drilling fluid can cause high mortality to the marine population. Case studies showed the effect of drilling waste toxicity to the marine population (Gbadebo et al., 2010). The study conducted by Soegianto et al. (2008) also showed the effect of toxicity due to drilling fluid waste. Drilling waste can also cause human affect to the workers. The common effect of drilling fluid is skin irritation, contact dermatitis, coughing and nausea. The understanding and awareness of the effect of improper management of drilling waste changes the way operators manage the drilling fluid waste. Host governments are also imposing regulations on drilling fluid management. Besides that, major oil and gas companies such as Shell, ExxonMobil and PETRONAS set their own standards on how to manage the drilling waste.

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2. Drilling Fluids and its Effects

There are several types of drilling fluids, based on both their composition and usage. Generally there are four main types of drilling fluid, namely Water Based Drilling Fluid (WBDF), Oil Based Drilling Fluid (OBDF), Synthetic Based Drilling Fluid (SBDF) and Pneumatic drilling fluid (air, mist, foam gas). OBDF and SBDF are also known as non-aqueous drilling fluids (NADFs) (Bernier et al., 2003). Generally, there are four main considerations for drilling fluid selection, which are safety, cost, or economic considerations, technical performance and requirement and environment impact (Mitchell, 2006).

2.1 Drilling Fluid Health Effects

The potential and risk of adverse health effects from drilling fluids is depending on the hazardous components of the fluids, additives and by human exposure to those components (Broni-Bediako and Amorin, 2010). The most common health effects from drilling fluid to human, is skin irritation and contact dermatitis (IPIECA and OGP, 2009). Other effects include headache, nausea, eye irritation and coughing. The effects are caused by the properties of the drilling fluid itself and inherent properties of the additives. The route of exposure can give different effects to human health. Workers may be exposed to drilling fluids either by inhaling aerosols and vapours or by skin contacts. Potential exposure to drilling fluid can happens at several scenarios. Activities during drilling such as sampling, maintenance, inspection, etc. can expose the workers to drilling fluid. A very high potential of inhaling mist and vapours is along the flow line from the bell nipple to the solid-control equipment such as desander, centrifuge, shakers, shale shaker and desilters. Exposure is a function of duration and frequency. Factors such as drilling fluid temperature flow rate, well depth, well section and kinematic viscosity of the drilling fluid can influence the exposure level in the working site. To manage exposure and risk to human, hierarchy of control as below must be considered:

a. Elimination - Elimination of hazardous and toxic material in the drilling fluid can significantly reduce the risk to human during drilling operation. Every operation should strive to reduce the number of chemicals being used to an absolute minimum.
b. Substitution - Using low toxicity drilling fluid or WBDF can reduce the carcinogenic hazard of exposure to drilling fluid.
c. Engineering controls - Ideally the design of the workplace should include the engineering controls such as ventilation system and enclosed drilling fluid circulation system, which is required to provide a workplace, which minimises exposure of hazardous substances to the workforce.
d. Administrative controls - Exposure and effects to human health can be managed and assessed by monitoring the level of exposure by conducting the air monitoring and skin monitoring. Workplace health surveillance and maintaining health records of the workers can also help in term of exposure management. Proper shift to manage working hours can also help to reduce the potential exposure to the workers.
e. Personal protective equipment - The final protection and the most significant control is personal protection equipment. Examples are mask, rubber glove, splash goggles, rubber boots and coveralls. This equipment is important to act as last barrier of protection to the workforce.

2.2 Drilling Fluid Environmental Effects

Drilling fluid can potentially give adverse effects to environment. The degree of effect depends on the type, dosage, and exposure duration of chemicals (Sil et al., 2012). The physical and chemical properties of the drilling wastes determine its hazardous characteristics and environmental impact potential. The most common measure of the potential environmental impact of a material is its toxicity (Onwukwe and Nwakaudu, 2012). OBDF is considered the most toxic drilling fluids and possess the most severe environmental effect compared to WBDF and SBDF. Direct discharge of drilling fluid can affect the local ecosystem in three ways (Nediljka et al., 2013: (a) direct toxic effects of drilling waste, (b) by smothering organisms and (c) anoxic conditions caused by microbial degradation of the organic components in waste.

A case study conducted to aquatic fish population showed the chemicals in the drilling fluids are toxic to the fish population (Sil et al., 2012). Laboratory study was conducted to determine the toxic concentration for fish of drilling fluid and base oil over a 4-day period. A significant difference in mortality was observed between control and test concentration. It showed that the chemicals are toxic to the aquatic life. Mortality rate increased with increasing concentration of chemicals.

Ismail et al. (1997) showed that OBDF with diesel as base fluid caused high mortality of tiger prawn during 96 h of toxicity test. From the suspended particle phase 96 h of toxicity test, OBDF (diesel) has proved to be the most toxic. The work showed that the toxicity of drilling fluid is mainly due to its base fluid, comparing results of two OBDF with mineral oil and diesel as base fluid. WBDF was the least toxic in the suspended particle phase but indicates the highest mortality (87 %) compared to OBDF (diesel) with 73 % mortality and OBDF (mineral oil) with 53 % mortality in the solid phase. Besides the toxicity of base fluid, additives such as foralyst and resinex can contribute to drilling fluid toxicity and pollution. Work by Soegianto et al. (2008), also shows the effect of drilling fluid to tiger prawn. The results showed that the 96 h LC50 of used drilling fluids ranged from 30,740 and 78,271 ppm SPP, which is consider high in Indonesian standard of toxicity limit. In this study, drilling fluids from five fields were tested. From the result, generally mortality increased with increasing drilling waste concentrations.

One of the most significant environmental threats from drilling fluid waste is heavy metal. Heavy metal in drilling fluid waste discharge could potentially led to bioaccumulation in aquatic organisms. Studies showed that the growth of flora and fauna was affected by the toxic heavy metals contamination in the environment (Sil et al., 2012).

3. Drilling Fluid Selection

Selection of drilling fluid is not necessarily straight forward. However, understanding of general selection criteria of drilling fluid is required. The selection criteria should include safety consideration, technical requirement, economics and environmental requirement. Nevertheless, few variables must be taken into consideration during selection of drilling fluid. SBDF can substitute WBDF in conditions where OBDF is usually used. Even though SBDF is usually few times higher in cost, the discharge of SBDF can be done on site, compared to OBDF, where most of the regulations do not permit direct discharge of OBDF. This can escalate the cost of drilling using OBDF. The higher cost of SBDF can be justified by its better performance compared to WBDF.

WBDF will not necessarily produce less waste compared to OBDF. It is reported by Burke and Veil (1995), drilling using WBDF produces 3,000 - 6,000 barrels drilling waste per well on continuous discharge and 5,000 - 30,000 drilling waste barrels on intermittent discharge. Drilling using OBDF, on the other hand, produces 2,000 - 8,000 barrels drilling waste only. This is because OBDF is usually recycled and reused rather than discharged. In some cases, WBDF with expensive additives will be recycled, but most WBDF is discharge with cuttings. Besides, drilling with OBDF will produce little slumping or caving in the walls of the walls. However, during designing the drilling program, one must take note on regulatory requirement for OBDF. Most regulations do not allow direct discharge of OBDF. Even with less waste produced, OBDF treatment and discharge can be more complicated and costly compared to WBDF.

SBDF is developed in 1990s to minimise the volume and environmental impacts of drilling waste. Examples of base fluids for SBDF are esters, linear alpha-olefins, poly alpha-olefins (PAO) and linear paraffin (Veil, 2002). It was reported in 1994, there are a number of wells drilled using SBDF (United Kingdom – 89 wells, Norway – 76 wells, and the Netherlands – 4 wells) (Burke and Veil, 1995). The most used base fluid was linear alkyl benzene and esters. SBDF proved to be a more environmental friendly drilling fluid and having a good drilling performance. SBDF should be considered as drilling fluid to replace the usage of OBDF.

4. Drilling Waste Regulations

Requirement from each host countries and conventions are different, based on previous experience and advancement of drilling technology and operations at the region. There are also international and regional convention related to environmental control and regulations, which include drilling activities such as OSPAR (Oil Spill Prevention, Administration and Response), MEMAC (Marine Emergency Mutual Aid Centre) and Barcelona Convention. Generally, from the review of regulations around the world, OBDF is not a preferable and direct discharge of OBDF to the site is not allowed due to its toxicity and impact to the marine environment. OBDF drill cuttings discharge is allowed in some regulations i.e. North Sea and Norway but required extensive treatment prior to discharge. OSPAR treatment requirement for OBDF cuttings is so stringent, which is cutting discharge with less than 1 % of oil content. Current technology is very limited to achieve the requirement. In some countries such as United States, SBDF is still regulated as OBDF. OSPAR and MEMAC Convention do not allow SBDF discharge to the sea. SBDF cuttings discharge is allowed by these two conventions with treatment before discharge.

However, there is ongoing development to regulate SBDF independently (CAPP, 2009). With the current advancement in SBDF, dedicated regulation or case-by-case discharge must be considered. In some countries such as Great Britain, Netherland and Norway, the discharge of SBDF cuttings is allowed (Burke and Viel, 1995). Requirement for WBDF discharge is generally less stringent. Majority of the regulations allow for WBDF and drill cuttings direct discharge with licenses and approval by authority. This makes WBDF an ideal choice of drilling fluid in less challenging drilling, considering the disposal and waste management of the drilling fluid is less expensive. In Egypt, WBDF is widely used because of its minimum impact to the environment (Agwa et al., 2012).

4.1 Malaysia Drilling Waste Regulations

Offshore operation that is inside the Malaysia is governed by Exclusive Economic Zone (EZZ). EZZ specify the discharge limits for oil-contaminated effluent including drilling waste. Compared to the discharge limits for oil contaminated effluent enforced on offshore operators in other countries, an effluent oil concentration of 100 ppm is relatively straight forward to achieve and a number of oil companies including PETRONAS Carigali Sdn Bhd have adopted more stringent specifications (e.g. 40 ppm) with future targeted limits in the region of 10 ppm. Even though offshore operation that is outside Malaysia water territory (12 nautical miles) is not governed by Environmental Quality Act (EQA, 1974), EIA (Environmental Impact Assessment) is still required from oil and gas operators by PETRONAS before project approval (PETRONAS, 2014). There is no specific regulation in Malaysia related to oil and gas activities. EZZ and EQA are general regulations of environmental law in Malaysia, which includes all other industry. Thus, there is no specific requirement or technical specification mentioned with regards to the drilling discharge and waste management compared to other law in other country such as United States and India, which specify the technical requirement of the drilling waste for discharge and specific EIA for drilling activities. Oil and gas companies operating in Malaysia such as ExxonMobil and Shell showed pro-activeness in environmental preservation by self-regulating against their own company standards which are adopted from other regions and best industry practice. According to Shell Global Environmental Standard, discharge of OBDF to the sea is not allowed. OBDF must be recycled and recovered. SBDF discharge is allowed with prove of low toxicity (Shell, 2007). PETRONAS, as national oil company developed a guideline for upstream operations in Malaysia entitled PETRONAS Procedures and Guidelines for Upstream Activities (PPGUA) (PETRONAS, 2014). This guideline gives a generic requirement for the usage of drilling fluids and drilling waste management and discharge. Comparison between Malaysia requirement and other international conventions are summarised in Table 1. Generally, OBDF and SBDF discharge to sea is not allowed, as per other international conventions. Other company such as ExxonMobil comes up with their own Environmental Drilling Initiatives (ExxonMobil, 2012).

Table 1: Comparison between Malaysia regulations and guidelines with international conventions requirement

Drilling fluid	Malaysia Regulations and Guidelines	OSPAR Convention	MEMAC Convention	Barcelona Convention
WBDF	WBDF is allowed for usage. Cuttings must be washed properly before disposal to sea.	WBDF is allowed for usage. Discharge of WBDF is allowed.	WBDF is allowed for usage. Discharge of WBDF without persistent toxins is allowed.	WBDF is allowed for usage. Discharge must be at specific and approved site.
OBDF	Low toxicity OBDF is not encouraged (minimised), and only for specific hole problem. Sea disposal is not allowed.	OBDF discharge is not allowed.	OBDF is not allowed for usage, unless approved. Discharge is not allowed at offshore.	OBDF is allowed for usage, with prove of low toxicity and approved permits by authority.
SBDF	Low toxicity SBDF is allowed for usage. Sea discharge is not allowed.	SBDF discharge is not allowed. SBDF cuttings discharge authorised based on BAT.	SBDF discharge is not allowed. SBDF cuttings discharge must be with approval from authority.	Not specified.

5. Waste Management

Waste management is unique, based on the requirement and conditions of the drilling site. However, the selection of the options must be taking into consideration all aspects. Zero discharge is the ultimate target of waste management. Selection of waste management method must consider economics, environmental and operational aspects of the waste management. Proper waste treatment must be done before any direct discharge to sea. Sea discharge may prove to be the most economical option, considering immediate cost of disposal, but the decision must also consider environmental impact, local regulations and operational aspects such as additional equipment for treatment.

Onshore discharge on the other hand, will give zero discharge at drilling site, but will incur additional cost and liability at onshore discharge site. Onshore discharge can incur additional logistic and labour cost, which must be included in the economic evaluation of discharge options. Exposure to human and weather constraint are some other issues, which need to be evaluated apart from direct economic and environmental impact. At drilling site such as the North Sea, where weather is unpredictable, transporting drilling waste to onshore site can be a challenging task. Drill cuttings re-injection is preferred in some area such as North Sea, North Slope in Alaska, the Gulf of Mexico, Canada, Venezuela and Indonesia (Guo and Abou-Sayed, 2003). During the early years, around 30,000 barrels of slurry can be injected into one well. With the current development, several millions of slurry can be re-injected into one well (Guo and Geehan, 2007). One of the major advantages of drill cutting re-injection is zero discharge to the environment. However, not all formation is suitable for the injection. Assessment and simulation must be done before the drill cutting re-injection take place. Additional equipment, maintenance and labour cost must also be evaluated for drill cutting re-injection option.

5.1 API Waste Management

API (American Petroleum Institute) recommends for a waste management system and plan to be available to ensure proper waste management take place (API, 1997). A waste management plan should:

a. Offer a solid waste plan that is area-specific.
b. Provide proper management guidance for each waste generated in E&P operations.
c. Be written for field operations.
d. Be used to ensure regulatory compliance and environmentally sound management of wastes.
e. Form a basis for training, evaluation, monitoring, and pollution prevention programs.
f. Be periodically reviewed and updated as new practices and options are discovered.

6. Conclusions and Recommendations

Drilling fluid waste has the potential to give adverse effects to environment and human health. Bioassay testing can assist to evaluate and study the toxicity and toxicity of drilling fluid to the local environment. From the case studies, it showed that drilling fluid waste can have toxicity level that can affect marine organisms such as tiger prawn and fish. Heavy metal accumulation is also a risk of drilling waste disposal. Heavy metal accumulation can impact the growth of flora and fauna at the discharge site. Human health can also be affected by exposure of drilling fluid. Proper risk management must be in place to reduce the risk and exposure to human. There are lot of regulations related to drilling fluid waste management. The regulations of offshore are under the governance of coastal states. However, some states are bound with international conventions, which influence the directive of waste management of the states. Generally, OBDF usage and disposal are not preferable. WBDF and SBDF can be a technically and economically feasible substitute for OBDF. Generally, drilling waste disposal options are offshore disposal, onshore disposal and drill cuttings re-injection. Zero discharge can be achieved by drill cuttings re-injection. However, extensive study must be completed before drill cuttings can be re-inject to the formation. Disposal options must be evaluated based on economics, environment and operational aspects. Data limitation on Malaysia offshore regulations' implementation limits the analysis of Malaysia offshore discharge practice. Generally, operations in Malaysia are governed by EQA and EZZ, while PETRONAS plays the role as national oil company to impose several other technical requirements such as EIA for the drilling operations.

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