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Development of a Sustainable Diagnostic Test for Drilling Fluid

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ABSTRACT

The composition of drilling fluid ranges from a simple clay-water mixture to a complex blend of materials chemically suspended in oil or water. Water-based muds (WBMs) are made of mainly water (salt or fresh), some percentage of oil and toxic chemical additives. The oil-based muds (OBMs) are composed of mineral oils, barite, and chemical additives. In general, diesel, kerosene and fuel oils are used as base fluid. Synthetic-based muds (SBMs) are characterized by the replacement of mineral oil with oil like substance, and are free from inherent contaminants such as radioactive components and toxic heavy metals. Therefore, it needs more stringent pollution-control procedures. Moreover, different environmental agencies around the globe are very much aware and concern about the increasing toxicity level of the environment, surface, marine, and subsurface areas due to drilling waste. The disposal of toxic mud residue and contamination of subsurface structure are the biggest challenges for the petroleum industry. Therefore, it is very important to look for sustainable diagnostic tests before disposal of toxic drilling fluids. It is also important during the development of new drilling fluids which are not harmful for the human, environment and the subsurface formation. This research shows a pathway comparison for current (unsustainable) and natural (sustainable) methods for drilling fluids. It depicts a guideline how to develop a sustainable drilling fluid technology. Finally, this study gives a sustainable technology diagnostic test as a flow chart that would be used as a guideline for sustainable drilling fluid. The article proposes future guidelines for the development of a sustainable drilling fluid technology. The diagnostic test procedure will enhance the understanding of how to handle the current challenges coming from drilling fluid to the environmentalists, manufacturers, government agencies and petroleum industry.

Keywords: drilling waste, Environment friendly drilling fluid, Environmental agencies, petroleum industry, sustainable technology, toxic chemicals

1. INTRODUCTION

Water as the first drilling fluid or mud was introduced in beginning of 19th century when rotary drilling system was developed to drill a hole on earth [1]. It is an essential part of the today's drilling operations. Drilling fluid can be defined as a mixture of clays, water, and chemicals used to drill a borehole into the earth and whose basic functions are to lubricate and cool the drill bit, carry drill cuttings to the surface, and to strengthen the sides of the hole [2]. In short it can be defined as a fluid compositions used to assist the generation and removal of cuttings from a borehole in the ground. The modern definition of drilling fluids leads to the addition of toxic chemicals to enhance its performance. The toxicity effects of diesel oils and mineral oils are well documented in the literature [3]. Therefore, it is one of the biggest issues and challenges for the researchers, manufacturers, and end users to control the drilling waste in a sustainable fashion.

Recently, drilling fluid study and its proper disposal pay considerable attention from the researchers and industry. The correct selection, properties and quality of mud is directly related to some of the most common drilling problems such as rate of penetration (ROP), caving shales, stuck pipe and loss circulation etc. In addition, the mud affects the formation evaluation and the subsequent efficiency of the well. More importantly, some toxic materials are used to improve a desired quality of the drilling fluid which is a major concern of the environmentalist. The addition of toxic materials contaminates the underground system as well as the surface of the earth.

In addition, the current research trend is in the direction of sustainable petroleum operations where drilling fluid's position is very weak. As a result, minimizing the quantity of oil discharged into the marine environment, use of water-based or synthetic-based mud is encouraged. This scenario leads the necessity for developing a drilling fluid diagnostic test which will replace the current fluid composition and waste disposal practices in the industry. Therefore, it is very important to look for a sustainable diagnostic tool to quantify and control the drilling waste toward a sustainable drilling fluid which is not harmful for the industry, human, environment, and the subsurface formation.

The drilling operations involve with the drilling of a hole on earth which generate huge amount of waste. It mainly includes drill cuttings, minerals, formation associated fluid and gases, and used muds. According to an estimation of the American Petroleum Institute in 1995, the onshore well activities in the United States generated around 150 million barrels of drilling waste [4]. Generally, the methods employed in the offshore to manage these wastes are limited to discharge, underground injection, and transport to disposal facilities at shore. The onshore waste management can adopt a varieties of options which may include land-spreading, land-farming, evaporation, burial, underground injection, thermal treatment, bioremediation, reuse, recycle etc. While the waste management practices started with indiscriminate disposal without considering the effects on environment, unfortunately, current practices consider only waste minimization, recycling, and disposal. As an attempt to reduce the volume of waste, drilling fluid companies introduced new types of fluids consist of noaqueous base other than oil such as olefins, esters, linear or poly alpha-olefins, linear parafins. These types of muds are free from polynuclear aromatic. However, those fluids have lower toxicity, faster biodegradability, and reduce bioaccumulation potential compared to OBMs [5]. Generally, the researchers are exploring muds and additives which have lower environmental impacts.

Meinhold [6] provided a framework for comparative environmental assessment of different types of drilling fluids used in offshore. A significant number of research works is going on to reduce environmental effects of drillings wastes. Solidification process immobilizes contaminants in drillings wastes with the help of hydraulic binders by creating a durable solid matrix. USEPA referred stabilization and/or solidification as the best demonstrated available technology for more than 50 hazardous wastes listed in US Resource Conservation and Recovery Act [7–8]. Leonard and Stegemann [9] studied the treatment of drill cuttings by stabilization/solidification with Portland cement (CEM I), with the addition of high carbon power plant fly ash (HCFA). The results show that the S/S products can be used as controlled low-strength materials, landfill liner, and landfill daily cover. Ji'an [10] studied the use of solidification agent for solidification of drilling wastes, and the optimization of its composition. He also assessed the environmental impact caused by solidified burial of drilling wastes. The assessment revealed encouraging results for lixivium generated from solidified material. Hui et al. [11] studied oily drilling wastes under microwave irritation. They investigated the effects of operation parameters on oil removal from oil contaminated drilling waste. The results revealed that microwave power, resident time, sample mass, and water content play important role in the treatment. Unfortunately, all the above mentioned researchers tried to minimize the waste through basic principles: waste minimization, recycling, and disposal. Therefore, this study develops a diagnostic test before undergoing any waste minimization process.

2. SUSTAINABLE DIAGNOSTIC TEST TOOLS

To develop any sustainable diagnostic test tool, it is very important to investigate the pathway of the product or material [12–14]. Therefore, pathway, and sustainability analysis of drilling fluids are essential which are true for any new product and/or system. Finally, to certify the product and/or system as a sustainable scenario, it needs to undergo a sustainable diagnostic process which is called in this study as a "sustainable diagnostic test" for drilling fluid.

2.1 The Pathway Analysis of Drilling Fluid

The pathway analysis of drilling fluid helps to know the path it travels. Hence, it is important for drilling fluid characterization. This is because the shape and properties of the material depend on its origin and its pathway travelled with time [12]. According to Khan and Islam, the pathway of a sustainable technology is its long term durability and environmentally wholesome impact while an unsustainable technology is marked by $\Delta t \rightarrow 0$ [15].

The pathways of natural products contain no harmful or toxic operations. However, it contaminates by human intervention. Figure 1 shows the conventional pathway of drilling fluid. Mixtures of natural clay, water and other natural materials have no problem. However, adding toxic chemicals made the conventional drilling fluid questionable. In addition when it comes to the surface, it is contaminated more by formation toxic minerals, acidic gases and fluids. Therefore, it is a very big challenge to dispose the waste drilling fluid.

Figure 2 shows the pathway of a sustainable drilling fluid where natural additives are used instead of using toxic chemical additives. However, it becomes contaminated by formation toxic minerals, acidic gases and fluids. When the used mud comes to the surface, the drilling waste yet needs to be disposed in a safe way due to its toxic contaminant from the formation zone only.

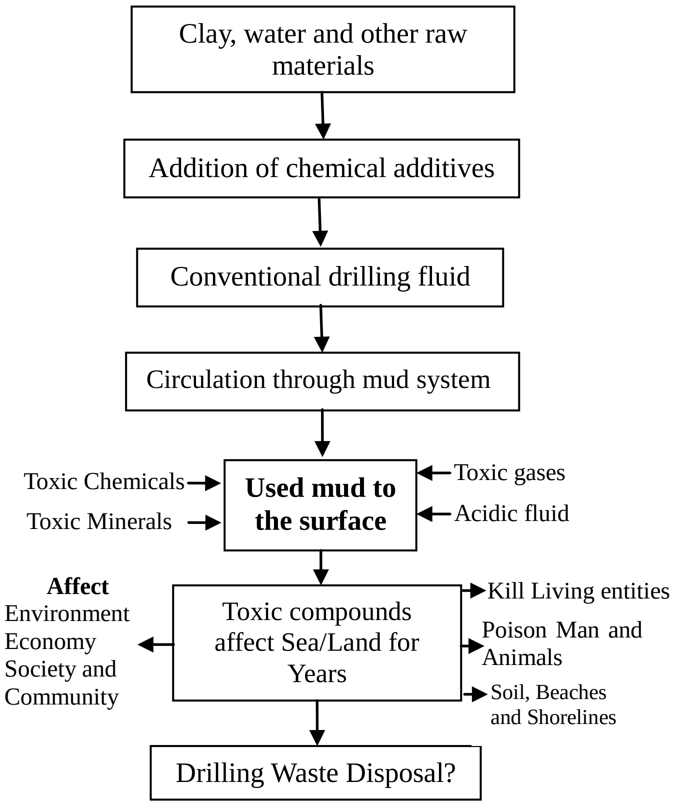

Figure 1: Pathway for current (unsustainable) drilling fluid

2.2 Sustainability of the Drilling Fluid Technology

In this globalization era, technology is changing every day. Due to the continuous changes and competition between the organizations, it is becoming a challenge for saving this planet. As a result, in management, a sustainable organization can be defined as an organization where i) political and security drivers and constraints, ii) social, cultural and stakeholder drivers and constraints, iii) economic and financial drivers and constraints, and iv) ecological drivers and constraints exist. Thus sustainability concept is the vehicle for the near future R&D for technology development. A sustainable technology will work towards natural process. Khan and Islam [15–16] mentioned that the model "time-tested" of sustainability hypothesizes the sustainability of a technology which can be achieved if it emulates nature. In nature, all functions or techniques are inherently sustainable, efficient and functional for an unlimited time period, i.e. $\Delta t \rightarrow \infty$. By following the same path as the function inherent in nature, we can develop a sustainable technology. Figure 3 shows the proposed sustainable drilling fluid development technology as a flow chart. The chart shows that if the life cycle of the technology is not long, immediately it will fall under unsustainable technology. On the other hand, if the technology passes this condition, it will go for 2nd layer of test which is called ESS Test (Economically attractive, socially appealing, environment friendly, and finally sustainable). Through different steps, it has to undergo if the technology passes, it becomes a sustainable drilling fluid technology. The flowchart is sufficiently self explanatory.

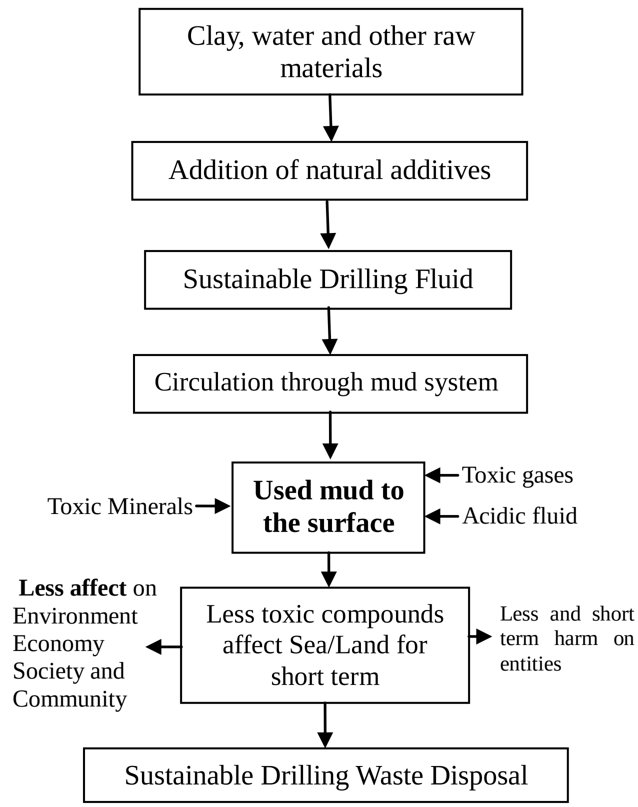

Figure 2: Pathway for future (sustainable) drilling fluid

2.3 Conditions of Sustainability: Diagnostic Test Tool for Drilling Fluids

From the definition of a sustainable technology as mentioned earlier, a technology should pass the four basic tests related to: i) Environment, ii) Economy, iii) Society, and iv) Ecology. Figure 4 is an extension of Figure 3. It suggests that the total critical natural resources should be conserved in the whole technological process. Based on the above concepts, the following criteria are taken into consideration:

Environmental Capital	: C_{en}
Ecological Capital	: C_{ec}
Economic Capital	: C_e
Societal Capital	: C_s
Natural Capital	: $C_n = C_{en} + C_{ec}$

To satisfy the sustainability criterion, the sum of all the capital costs should be greater than or equal to constant for all time horizons, i.e. $(C_n + C_e + C_s)_t \geq$ constant for any time, *t*. However, these conditions have underlying assumptions that: $\frac{dC_{nt}}{dt} \geq 0$, $\frac{dC_{et}}{dt} \geq 0$, and $\frac{dC_{st}}{dt} \geq 0$. Figure 4 also depicts a complete diagnostic test procedure of the proposed sustainable drilling fluid development. If someone develops a new mud and/or mud technology, and if it passes through these procedures, we can certify that the proposed new technology and/or development is sustainable.

3. FUTURE WORKS

The current trend of the drilling fluid is toward the use of environment friendly drilling fluid. The conventional muds are also being used by the industry. However, the real challenges to develop a sustainable drilling fluid underlying behind the replacement of toxic chemicals by natural substitute materials without losing its desired quality and functions. The other challenges lay on the replacement of oil by natural oil. Therefore, the future focus on this research can be toward the above mentioned direction.

4. CONCLUSIONS

A sustainable drilling fluid testing system is developed and proposed to test the technology. The pathway of both conventional and sustainable drilling fluid is analyzed which shows that conventional mud system is unsustainable. A diagnostic test procedure is also outlined for guidance. This study will help to analyze and categorize the new technology in terms of sustainability.

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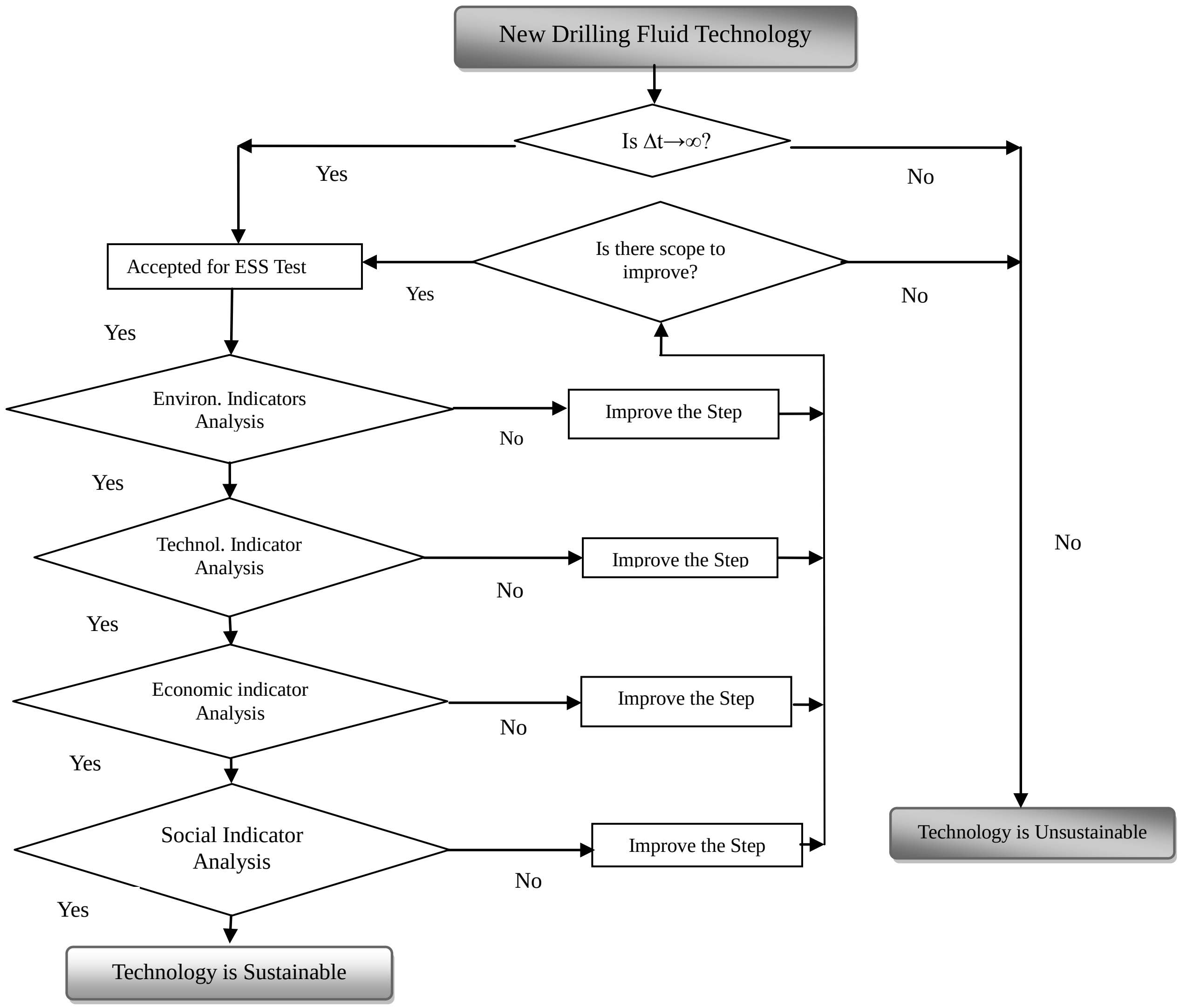

Figure 3: Proposed sustainable drilling fluid development technology flow chart

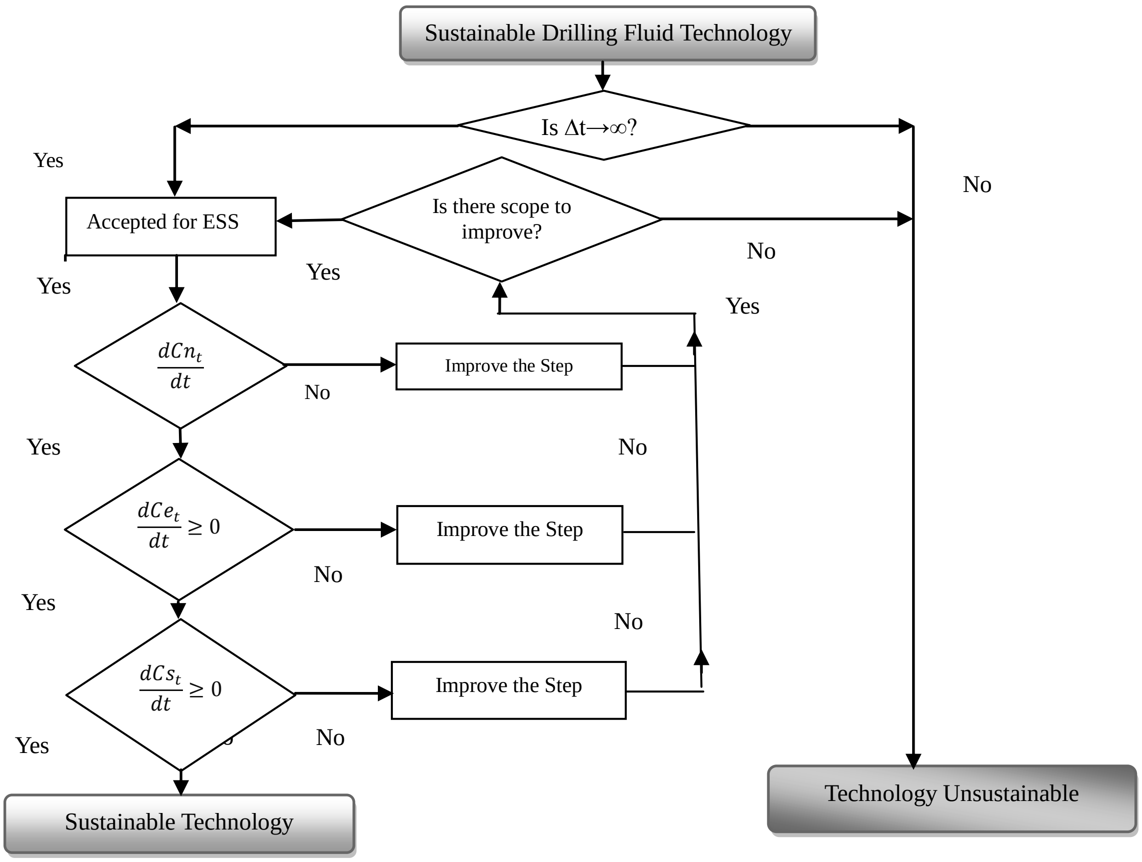

Figure 4: Proposed sustainable technology diagnostic test flow chart for drilling fluid