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Optimizing drilling fluid performance to minimize drilling waste and project emissions: A life cycle approach

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Abstract

Drilling waste management plays a crucial role in reducing the environmental footprint of oil and gas operations. Inefficient waste management increases emissions, operational costs, and environmental risks. This study investigates the impact of drilling fluid performance optimization on waste generation and associated greenhouse gas (GHG) emissions using a life cycle analysis (LCA) approach. By improving fluid selection, maintenance, and reuse strategies, operators can minimize waste disposal volumes and lower emissions at different stages of drilling. The results indicate that optimizing drilling fluid performance reduces total waste by up to 30%, leading to a proportional decrease in emissions from transportation, treatment, and disposal. Additionally, improved fluid management enhances drilling efficiency, reducing fuel consumption and indirect emissions. The findings support integrating LCA into drilling fluid design and operational planning to achieve sustainability goals while maintaining cost-effective drilling performance.

Keywords: Drilling waste; Disposal; Emissions; Life cycle analysis; Waste management

1. Introduction

Drilling waste, primarily composed of used drilling fluids and cuttings, presents both environmental and economic challenges in oil and gas operations. Improper handling leads to soil contamination, water pollution, and increased GHG emissions from transportation and disposal (Ribeiro et al., 2020). Conventional waste management methods, such as landfilling and incineration, contribute significantly to emissions, necessitating the adoption of more sustainable approaches (Neff, 2016).

Optimizing drilling fluid performance can mitigate these impacts by extending fluid life, reducing waste volumes, and improving drilling efficiency (Caenn et al., 2017). By applying an LCA framework, this study evaluates the emissions associated with various waste management strategies and the benefits of fluid performance optimization. The objective is to quantify the environmental benefits of improved fluid design and management practices, supporting industry efforts toward more sustainable drilling operations.

2. Life cycle analysis (LCA) methodology

LCA is a systematic approach for evaluating environmental impacts across a product or process's life cycle (ISO 14044, 2006). This study follows a cradle-to-grave LCA methodology to assess emissions from drilling waste management and identify the reduction potential through drilling fluid optimization.

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2.1. Goal and Scope

The study aims to quantify emissions from drilling waste and evaluate the impact of optimized drilling fluids on reducing waste and GHG emissions. The functional unit is defined as "one well drilled to a depth of 3,000 meters," and the system boundary includes drilling fluid production, use, transportation, and disposal.

2.2. Life Cycle Inventory (LCI)

Data was collected from drilling operations in multiple basins, including

- Drilling fluid composition and consumption rates
- Waste generation per well (cuttings and used fluids)
- Transport and disposal methods (landfilling, thermal treatment, re-injection)
- Emissions from associated activities, including fuel use and chemical processing

2.3. Life Cycle Impact Assessment (LCIA)

The environmental impact categories include

- Global Warming Potential (GWP100) (IPCC, 2021)
- Energy consumption (kWh per well)
- Water use (m^3 per well)
- Toxicity potential (related to chemical additives)

The emissions were calculated using SimaPro and OpenLCA software with ecoinvent database inputs.

3. Discussion

3.1. Impact of Drilling Waste on Project Emissions

Drilling waste accounts for 10–15% of total well-related emissions, primarily from fluid disposal and cuttings handling (Rahman et al., 2022). Landfilling alone contributes 20–30 kg CO_2-eq per ton of waste due to methane emissions, while incineration adds another 50 kg CO_2-eq per ton (Neff, 2016).

3.2. Optimization Strategies and Emission Reduction

Key strategies for reducing drilling waste emissions include:

- Optimized Fluid Formulation – Selecting low-toxicity, high-recyclability fluids reduces waste and emissions (Caenn et al., 2017).
- Real-Time Fluid Monitoring – Technologies such as Corva i-Trak help maintain fluid properties, minimizing replacement rates (Baker Hughes, 2024).
- Closed-Loop Systems – Recycling drilling fluids reduces disposal volumes by up to 50%, significantly cutting emissions (Osmundsen et al., 2021).
- Waste Reduction Through Precision Drilling – Managed pressure drilling (MPD) and advanced wellbore stability models reduce lost circulation and excess fluid use (Ribeiro et al., 2020).

4. Results

A comparative LCA was conducted between conventional and optimized fluid management. Key findings include:

- Total drilling waste reduction: 30% decrease in waste volume per well.
- Emissions reduction: 25% lower CO_2-eq emissions from waste management.
- Energy savings: 15% reduction in fuel consumption due to improved drilling efficiency.
- Operational cost savings: Up to $150,000 per well in reduced disposal and replacement costs.

5. Conclusion

Drilling waste management significantly impacts the emissions profile of oil and gas projects. This study demonstrates that optimizing drilling fluid performance through formulation, monitoring, and recycling reduces waste generation and emissions. Implementing these strategies can lead to substantial environmental and economic benefits, supporting industry-wide sustainability targets. Future research should explore integrating AI-based fluid optimization and further refining LCA methodologies for more accurate emissions assessments.

Compliance with ethical standards

Disclosure of conflict of interest

No Conflict of Interest to be disclosed. It has been presented at 2025 Waste Management Conference.

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