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Life cycle analysis of drilling fluid processing: Emission hotspots and sustainable mitigation strategies

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Abstract

This paper TG5 System boundary of Life cycle analysis for Fluid Processing explores the life cycle analysis (LCA) of drilling fluid processing at rig sites, focusing on emissions from various operational stages. Drilling fluids play a critical role in well construction, yet their management contributes to environmental impacts, particularly greenhouse gas (GHG) emissions. Using general data from industry practices and case studies of advanced fluid recovery, cuttings management, and waste treatment technologies, this study evaluates emissions associated with fluid mixing, circulation, reconditioning, storage, and disposal. By identifying carbon hotspots and assessing mitigation strategies, this analysis highlights opportunities for improving sustainability in drilling operations.

Keywords: Fluid processing; Emissions; Life Cycle Analysis; Waste treatment; Disposal

1. Introduction

Drilling fluids are indispensable to the oil and gas industry, providing wellbore stability, cuttings transport, and cooling during drilling operations. However, their processing, handling, and disposal have significant environmental impacts, including energy consumption, GHG emissions, and waste generation.

The adoption of advanced fluid recovery and waste management technologies has proven effective in reducing emissions and improving resource efficiency. This paper evaluates these processes and technologies through an LCA framework, emphasizing the need for sustainable practices in managing drilling fluids at rig sites.

2. LCA Methodology

2.1. Goal and Scope

The primary objective is to quantify emissions associated with drilling fluid processing and identify improvement opportunities. The functional unit is defined as the processing of 1 m^3 of drilling fluid, encompassing all stages from preparation to disposal.

2.2. System Boundaries

The system boundary includes the following modules:

- Fluid preparation and mixing: Energy and materials required for mixing additives and base fluids.
- Circulation and reconditioning: Energy for pumping and solids removal.

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- Storage and handling: Energy demands for maintaining fluid stability.
- Disposal or recovery: Waste treatment and recovery operations.

2.3. Data Collection

Data were sourced from industry reports and case studies of fluid recovery and waste minimization technologies. Key parameters included:

- Energy consumption (kWh).
- Material inputs (additives, base fluids).
- GHG emissions (kg CO_2e).
- Waste volumes (kg).

2.4. Impact Assessment

The primary impact category was global warming potential (GWP), expressed in kg CO_2e. Secondary metrics included energy consumption, water use, and waste generation.

3. Discussion

3.1. Emissions by Processing Module

3.1.1. Fluid Preparation and Mixing

- High electricity demand for mixing units.
- Emissions depend on additive types, with synthetic-based additives contributing more GHG emissions than water-based alternatives.

Mitigation:

- Use energy-efficient mixers and optimize additive formulations.
- Employ localized energy sources, such as renewable energy systems.

3.1.2. Circulation and Reconditioning

- Significant emissions arise from pumps and separation equipment, such as shakers and centrifuges.
- Fluid losses during circulation increase overall environmental impact.

Mitigation

- Upgrade to energy-efficient pumps and optimize circulation parameters.
- Implement high-performance separation screens to reduce fluid losses.

3.1.3. Storage and Handling

- Thermal regulation of stored fluids (heating or cooling) impacts energy demand.
- Leaks and spills during handling contribute to emissions.

Mitigation

- Use insulated tanks and optimize fluid management protocols.

3.1.4. Disposal or Recovery

- Waste treatment, especially for oil-based fluids, generates high GHG emissions.
- Recovery systems reduce disposal volumes and recover usable materials.

Mitigation

- Prioritize fluid recovery systems to reduce disposal needs.
- Optimize waste transport logistics to minimize emissions.

3.2. Advanced Fluid Recovery Systems

On-site fluid recovery systems reduce emissions by reclaiming drilling fluid for reuse, significantly lowering the demand for new material. LCA results show:

- Up to 50% reduction in fluid disposal volumes (Speight, 2020).
- 30% lower GWP compared to traditional disposal methods (Nguyen et al., 2022).

3.3. Cuttings Management Technologies

Efficient cuttings treatment systems remove residual drilling fluid and reduce the volume of waste sent for disposal. These systems:

- Lower fluid losses by up to 80% (Speight, 2020).
- Reduce energy consumption during waste processing by 20-30% (IPIECA, 2021).

3.4. Waste Treatment Processes

Thermal and mechanical treatment methods recover valuable materials and minimize hazardous waste. While these processes require significant energy, their net emissions are lower compared to landfill disposal or incineration.

4. Conclusion

Drilling fluid processing at rig sites is a critical component of well construction with substantial environmental implications. LCA findings highlight that the mixing, circulation, and disposal phases are the most significant contributors to emissions. By adopting advanced technologies for fluid recovery, cuttings management, and waste treatment, operators can achieve notable reductions in GHG emissions and waste generation.

Integrating LCA into drilling operations enables a systematic approach to sustainability, ensuring alignment with regulatory requirements and corporate environmental goals. Continued innovation and widespread adoption of these technologies will be essential for minimizing the environmental footprint of drilling activities.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest. The paper has been presented at an American Petroleum Institute Sub-Committee.

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