

# Alternatives to Diesel Based Fluids (Onshore) - Health and Environmental Considerations

AADE FMG  
February 21, 2019

**Delina Lyon**  
Ecotoxicologist



# Overview

- Objective : Understand what factors drive health & environmental hazards of drilling base fluids (not muds), particularly when comparing Group I vs Group III NADFs
- Composition of Group I vs Group III NADFs - What drives hazard?
  - General trends in toxicity & biodegradation as related to composition
  - Vapor emissions
- Human Health Impacts from Group I vs Group III NADFs
  - Diesel health impacts
  - Worker exposure study during use of diesel vs a synthetic NADF
- Environment Impacts of Group I vs Group III NADFs
  - Aquatic & soil toxicity
  - Biodegradability
- How do environmental factors affect disposal options

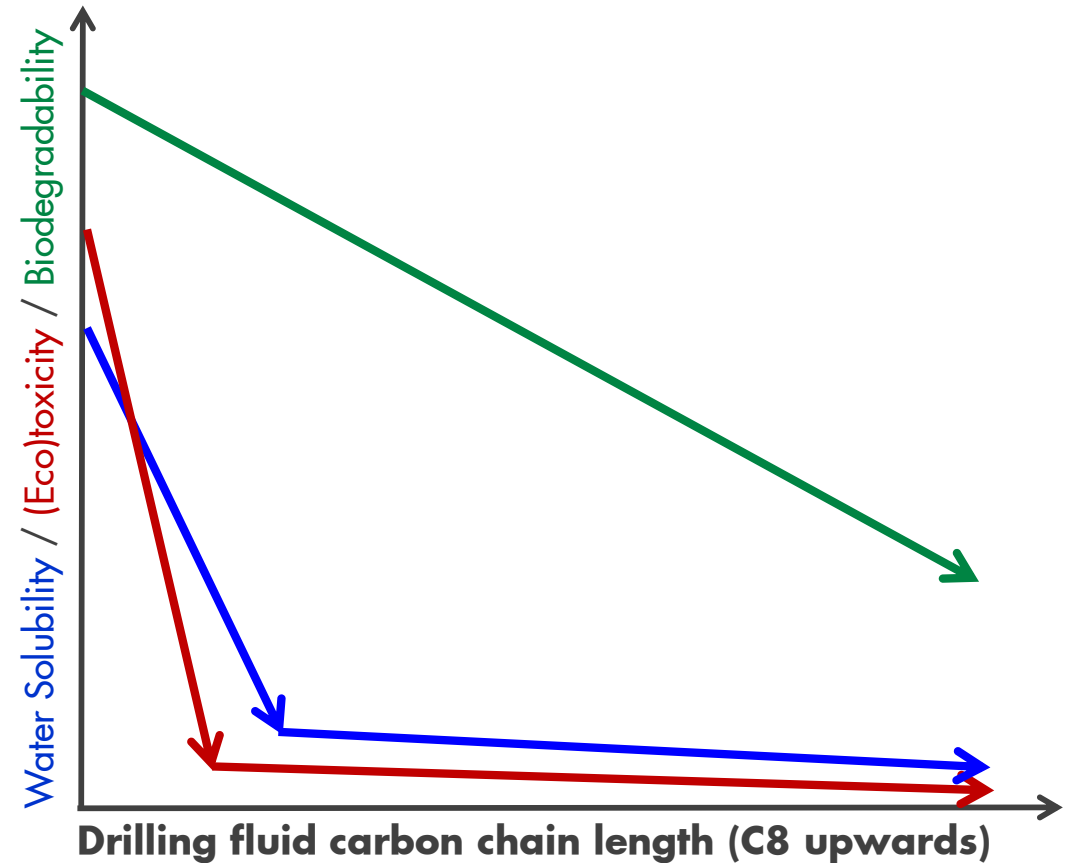


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## **Composition of Group I vs Group III NADFs - What drives hazard?**

# Base Fluid Composition Controls Health & Environmental Properties

- Carbon chain length
  - Longer = less water soluble = less bioavailable
    - Less toxic, less biodegradable
    - Less volatile
- Degree of branching increases solubility, decreases biodegradability
- Aromatic Content (PAHs, BTEX) impacts health
  - Benzene is a known carcinogen
  - Certain PAHs are known carcinogens
- Naphthenics can be slower to biodegrade



## Comparison of Base Fluid Properties

Group I NABFs - >5 wt% aromatics, >0.35 wt% PAH

Group III – synthetic or highly refined - <0.5% aromatics (<5,000 ppm), <0.001 wt% PAH (<10 ppm)

Property	Diesel	Common Group III Fluids*
Flash point, °C	56 – 75	70 -132 (highly variable)
Aromatics, ppm wt	200,000-600,000	<100 – 5,000
Total PAHs, ppm	680 – 3,000	Not Available, but <10 ppm by definition
BTEX, ppm	400 – 2,500	Usually non-detectable
Carbon range, branching, etc.		Varies according to technical specs

\*Range of main Group III fluids in IOGP Report 396

## Vapor Emissions

- Vapor emissions relate to site odor, worker exposure, and can affect air quality
- Depending on the composition, the vapor emissions will vary for Group III, but are in general higher for diesel than for most Group III fluids
  - For example, total petroleum hydrocarbon (TPH) in the headspace above pure product:
    - 1,148 µg/L for a synthetic; 8,267 µg/L for diesel
- BTEX concentration is expected to be higher for diesel
  - In the above study, >16% of the headspace TPH was BTEX for diesel. No BTEX was detected for the synthetic
  - Group III are expected to have no BTEX
- Table adapted from Candler et al. study looking at field and laboratory vapor concentrations of various drilling fluids (Candler, J. et al. "Laboratory and Field Measurements of Vapor Generated by Organic Materials in Drilling Fluids. SPE 35866 (1996).

Base Fluid (IOGP Group)	Average Vapor Concentration	
	Lab Data (ppm)	Field Data (ppm)
Diesel (Group I)	310	42
Mineral Oil (Group II)	166	340
Synthetic Fluids (Group III)	9	0.3



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## Human Health Impacts from Group I vs Group III NADFs

# Key toxicological differences between Diesel & Group III NADFs

- Potential Health Hazards of Diesel
  - Inhalation
    - Neurotoxicity, Pulmonary effects, Odor (indirect health issue)
  - Dermal
    - Irritation, Dermatitis, Carcinogenicity
- Group III NADFs raise no significant health hazards with the exception of aspiration of oil mist, contact dermatitis

Endpoint	Diesel (CAS 68334-30-5)	Group III NADF
Acute inhalation toxicity (LC <sub>50</sub> )	4100 mg/m <sup>3</sup>	NAE
Skin irritation/corrosion	Irritating	Mild to non-irritating
Repeated dose toxicity (inhalation; NOAEC & NOAEL)	880 mg/m <sup>3</sup> & 30 mg/kg bw/day	None
Carcinogenicity via dermal route (LOAEL)	25 mg/kg bw/day	None
Mutagenicity	Positive	Negative
Aspiration	Asp. Tox. 1	Asp. Tox. 1

Data obtained from ECHA registrations or SDS; NAE = No Adverse Effect Observed

# Human Health Improvements of Group III vs Group I NADFs

Less risk of eye irritation from fumes than with diesel<sup>1</sup>

Synthetic fluids should not be swallowed<sup>1</sup>

Is not carcinogenic<sup>1</sup>



No odor and not harmful if inhaled<sup>1</sup>

Does not cause damage to organs through prolonged or repeated exposure<sup>1</sup>

Less risk of skin irritation from contact; however repeated exposure may cause skin dryness or cracking<sup>1</sup>



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## **Environmental Impacts from Group I vs Group III NADFs**

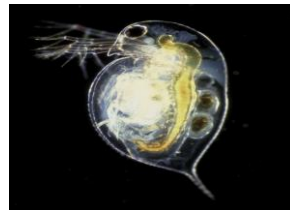
# Ecotoxicity of Group I and III NADFs

Endpoint	Diesel (CAS 68334-30-5)	Group III NADFs
Acute toxicity to fish (96h LL50)	21 mg/L <sup>1</sup>	>1000 mg/L <sup>2</sup>
Acute toxicity to invertebrates (48h EL50)	68 mg/L <sup>1</sup>	>1000 mg/L <sup>2</sup>
Acute toxicity to algae (72h ErL50)	22 mg/L <sup>1</sup>	>1000 mg/L <sup>2</sup>
Earthworm 14 day survival w/ 2 wt% NABF	>90% reduction <sup>3</sup>	For synthetic, there was some effect <sup>3</sup>
Ready Biodegradability (OECD 301)	Readily biodegradable <sup>1</sup>	Readily biodegradable <sup>2</sup>
Biodegradability in soil (half-life)	314 days <sup>3</sup>	For synthetic, 188 days <sup>3</sup>

<sup>1</sup> Data taken from ECHA registration dossier

<sup>2</sup> Data collated from various base fluid SDSs, supported by IOGP Report 543

<sup>3</sup> Data from Hughes et al. "Terrestrial Toxicity Performance of Different Base Oils in Two Different Aging Conditions and Soil Types. SPE 163788. 2013.



## Long-term liability of various waste disposal options

	Method	Description	Cost; Time*	HSSE Concerns	Long-term Liability?
Disposal	On-site burial	Cuttings collected in lined pits near drilling	\$\$; D	Air emissions; Surface/ground H <sub>2</sub> O contamination	Yes
	Landfill	Cuttings trucked to a hazardous waste facility	\$\$\$; D		
	Slurry Re-injection	Cuttings diluted and injected into well.	\$\$\$\$; D-W	Air emissions; Ground H <sub>2</sub> O contamination	Yes
	Disposal in salt caverns	Cuttings transported to salt cavern for disposal			Possible
Land application/ bioremediation	Land-spreading	TPH removal by volatilization and aerobic biodegradation	\$\$; W-M	For low contamination; Surface/ground H <sub>2</sub> O contamination	Possible
	Land-farming/Composting	TPH removal by volatilization and aerobic biodegradation	\$\$; W-M	Air emissions; Surface/ground H <sub>2</sub> O contamination	Possible
	Vermiculture	Using worms to assist biodegradation	\$\$\$; W	Air emissions; Surface/ground H <sub>2</sub> O contamination	Possible
	Bioreactor	On-site, containerized rapid biodegradation	\$\$\$-\$\$\$\$; D-W	Requires H <sub>2</sub> O	Possible
Physical methods	Thermal Desorption	High energy process to recover some base fluid	\$\$\$\$; H	Must dispose of residue; Air pollution	No
	Incineration	High energy	\$\$\$; H	Air pollution	No
	Beneficial Reuse	Cuttings treated and solidified/stabilized for construction material (roads) or well pads			Yes

\*Hours, Days, Weeks, Months

# RISK MANAGEMENT FOR DRILLING FLUIDS – Achieving ALARP

## THE HIERARCHY OF CONTROLS AT EACH STEP:

### OCCUPATIONAL EXPOSURE

- Eliminate
- Substitute
- Engineering controls
- Administrative controls
- Personal Protective Equipment (PPE)

### ENVIRONMENTAL IMPACTS

- Eliminate
- Substitute
- Engineering controls
- Administrative controls
- Reduce discharges to environmental bearing capacity

Controls may be different for occupational and environmental issues but overall approach needs to be linked as one can impact on the other