1-Butanol as a Gasoline Blending Bio-component

March 28, 2007 Mobile Sources Technical Review Subcommittee

BP - DuPont Partnership

- BP and DuPont have joined forces to develop, produce and market next generation biofuels to help meet increasing global demand for renewable transport fuels.
- These next generation fuels will harness DuPont's advanced biotechnology capabilities, BP's fuel market expertise and their joint process engineering know how.
- We are seeking advantaged biocomponent molecules which can be:
  - added to the fungible fuel pool using existing supply infrastructure
  - are compatible with the existing vehicle park
  - can be used at reasonable blend concentrations
  - require no compromise in fuel specifications
  - meet the needs of the customer without performance compromise
- Biobutanol (1-butanol) will likely be first product introduced into market

Biobutanol

Technology Developments

- A biobutanol only process using advanced biotechnology currently being developed.
- Advantages:-
  - Enhanced yields / lower production cost.
  - Potential to produce other biobutanol isomers with further enhanced fuel properties.
  - Targeting a value chain which is competitive versus conventional bio-components.
  - Future potential for bio-pathways to be compatible with lignocellulosic feedstocks.

Commercialisation

- BP-DuPont are evaluating commercialisation opportunities of 1-butanol in European markets and other regions.

Fuel Properties

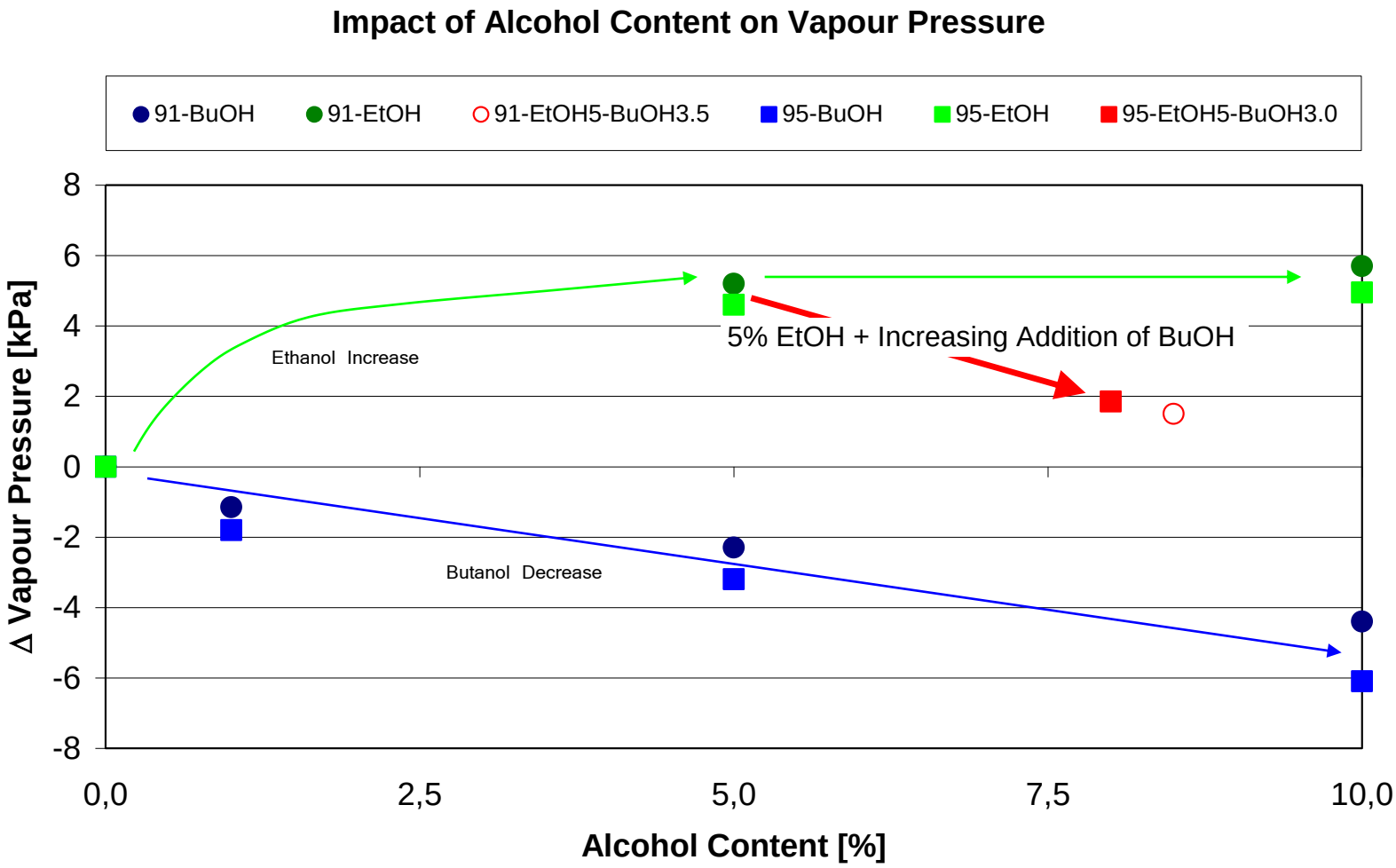
	Ethanol	1-Butanol	Gasoline
Sp. Gravity, 60/60 F	0.794	0.814	0.720-0.775
Heating Value [MJ/l]	21.1-21.7	26.9-27.0	32.2-32.9
RON	106-130[1]	94[1]	95
MON	89-103[1]	80-81[1]	85
Rvp@ 5% /10% [psi]	31[1]/20[1]	6.4[1] / 6.4[1]	< 7.8/15[2]
Oxygen [%wt]	34.7	21.6	< 2.7

[1]Blend values of alcohol octane numbers and vapour pressure.

[2]Summer / Winter specifications.

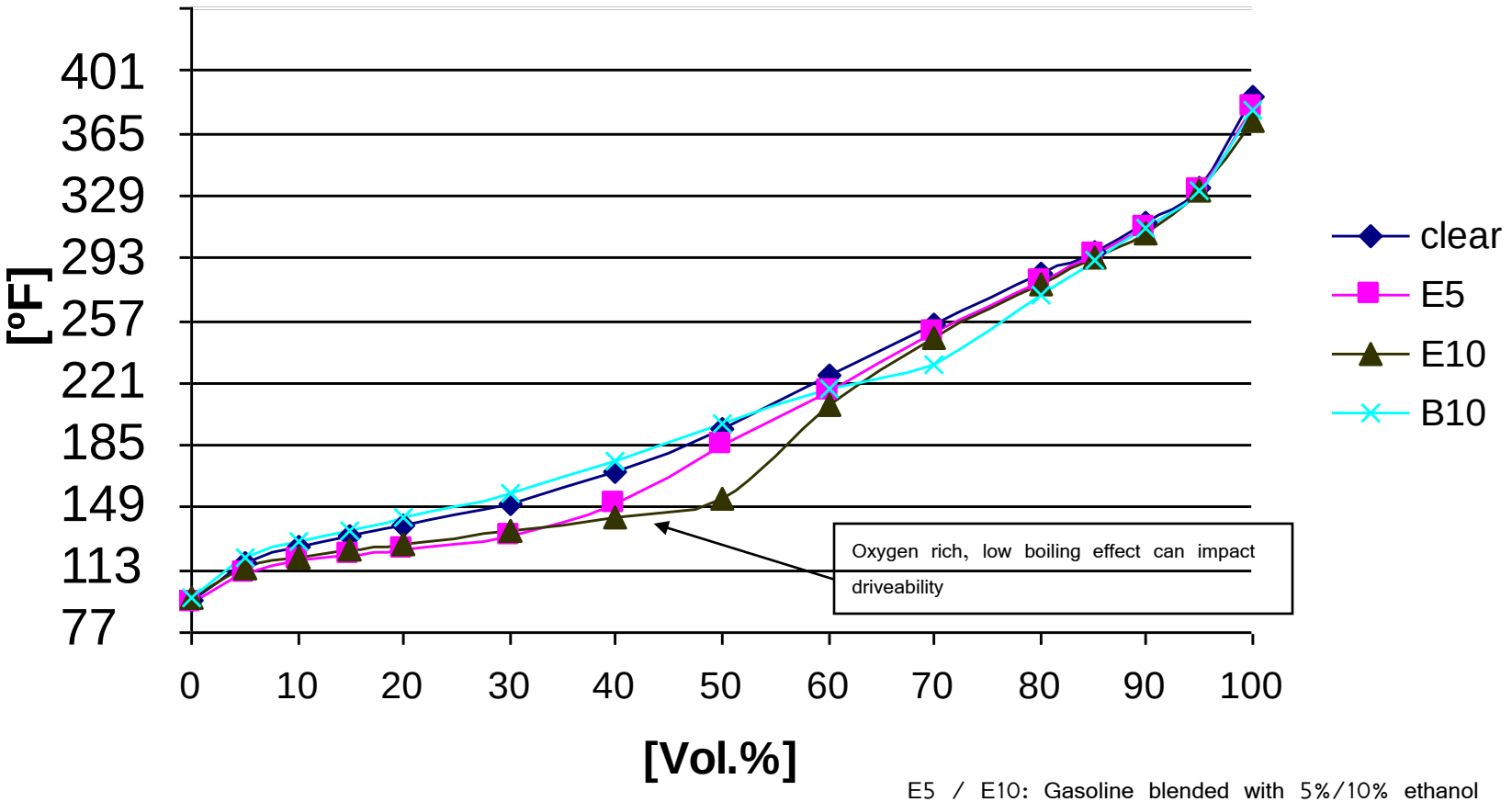
Vapour Pressure of Alcohol-Gasoline Blends

Butanol has a vapour pressure synergy with ethanol. Butanol's DVPE in a co-blend with ethanol is negative. In this example ~ minus 35kPa.



Distillation

Ethanol blends (E5/E10) lead to a distillation curve abnormality

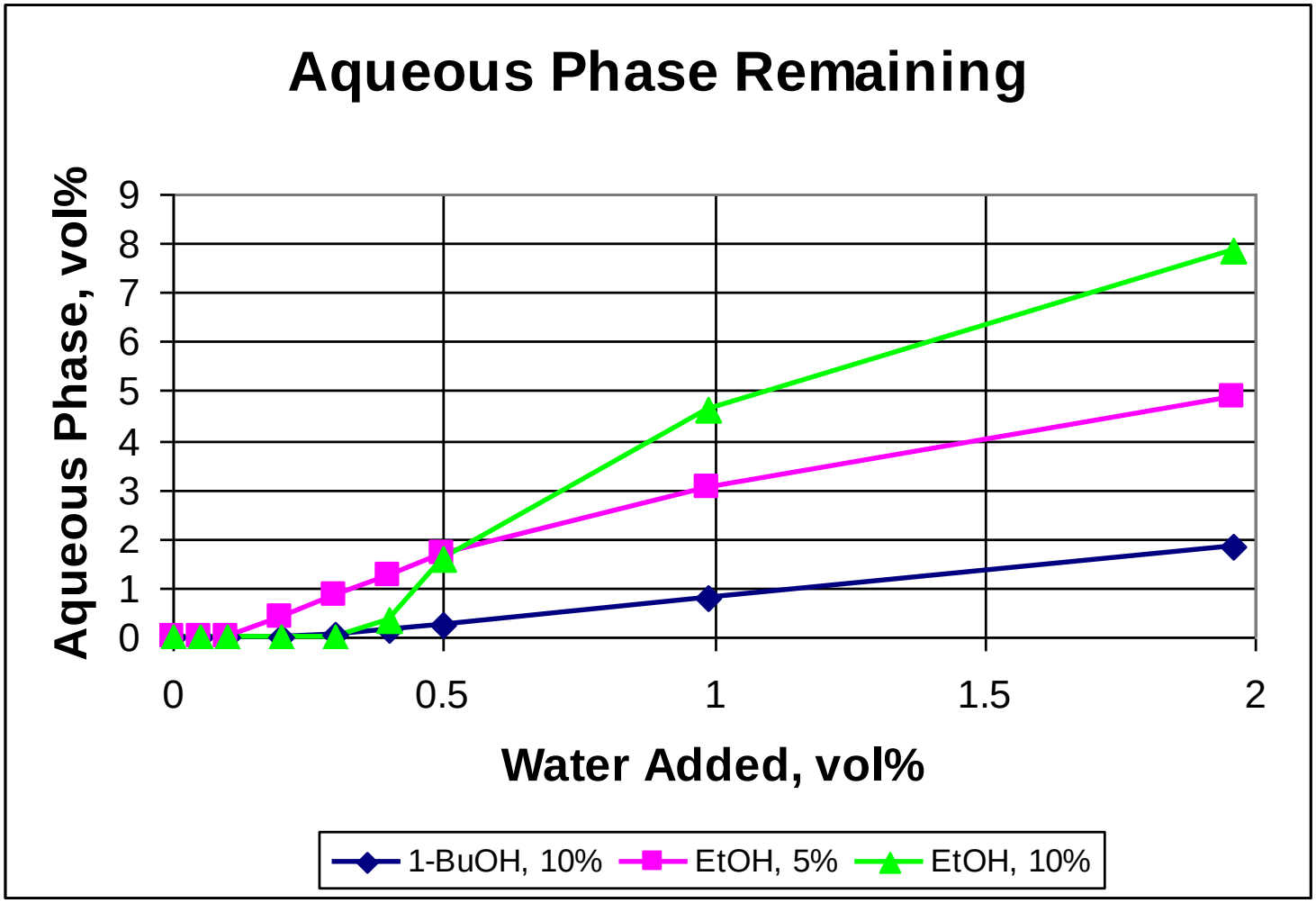


E5 / E10: Gasoline blended with 5%/10% ethanol

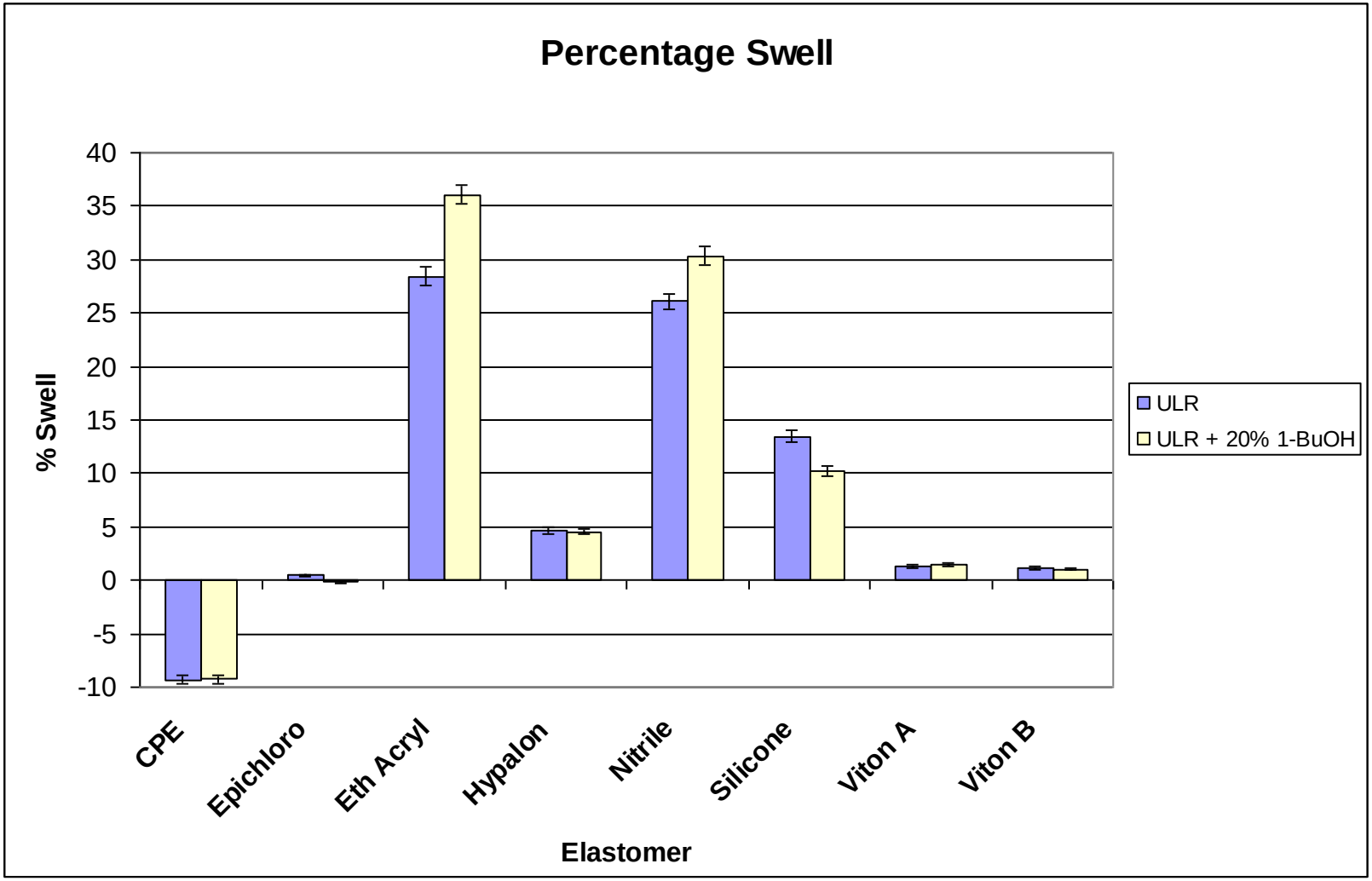
B10: Gasoline blended with 10% butanol

Alcohol-Water Interactions

Butanol does not phase-separate in the presence of water, unlike ethanol



20% 1-Butanol Gasoline Elastomer Swelling



6-weeks-corrosion test (water addition)

	10% 1-butanol (chemical grade) in gasoline		5% ethanol in gasoline	
	visual (compared to base fuel)	analytical evaluation	visual (compared to base fuel)	analytical evaluation
Copper				
Brass				
Zinc				
Aluminium				
Steel ST12	☺		☺	
Lead	☺			

Green: pass / no impact of alcohol compared to base fuel

☺: positive impact of alcohol compared to base fuel

Yellow: pass / minor impact of alcohol compared to base fuel

Corrosion test will be repeated when process grade 1-(bio)-butanol is available.

Ongoing Test Work

- Protocol 1 Laboratory Testing
- Protocol 2 EVL-Test Bench
  - Testing of Fuel Pumps (EKP: Siemens, Bosch and Pierburg)
  - VW 1.6l engine test bench (Fuel BB10)
    - Inlet valve deposit
    - Combustion chamber deposits
- Protocol 3 Performance/Emissions (Fuels: RON 91, BB5, BB10, E5, E10, E5+BB2.5)
  - Acceleration, power
  - Driveability - hot/cold
  - Emissions
- Protocol 4 Field Trial
  - 6 cars, 20k km
- Protocol 5 Mileage Accumulation (Fuels: RON 91, E5, BB10)
  - 3 cars, 50k km, emissions testing

Summary Performance Test Work

- Fuels
  - Alcohols splash blended into regular fuel
    - Octane not adjusted

- Results
  - Power
    - Alcohols generally increase power, even with a limited increase in octane
  - Fuel economy
    - Alcohols generally lead to lower fuel economy
      - Butanol is better than ethanol, due to its higher energy content

Regulated Emissions Summary - USA

- Limited investigations of four vehicles with butanol in gasoline at 11.5 vol% within current substantially similar limit of total oxygen 2.7 wt. % were performed
- Butanol in gasoline did not change CO, HC, NOx emissions in standard FTP cycle
- Fuel consumption increases are consistent with the reduced energy content of the fuel

Health and Environmental Effects (Literature)

- Ethanol is a commodity chemical currently used as an intermediate in the production of other chemicals and as a gasoline blending stream.
- Low acute oral, dermal and inhalation toxicity.
- Not irritating to the skin or eyes.
- Not genotoxic.
- Evidence of developmental toxicity in animals.
- Evidence of reproductive toxicity in animals.
- Carcinogenic potential at high exposures.
- High odour threshold.
- On release to the environment ethanol is expected to partition mainly to air, and readily move through soil to groundwater.
- Readily bio-degradable and will not persist in the environment/groundwater.
- Not expected to accumulate in biota, and is of low eco-toxicity concern.

- 1-Butanol is a commodity chemical currently used as an intermediate in the production of other chemicals (for adhesives, building material agents, cleaning agents, detergents, dyestuffs, fertilisers and surface treatment agents) and as a solvent (especially in surface coatings).
- Low acute oral, dermal and inhalation toxicity.
- Moderate skin irritant, a severe eye irritant.
- Not genotoxic.
- Not considered to be a developmental toxin.
- Studies suggest that reproductive function is not likely to be affected and carcinogenic potential is low.
- Low odour threshold, and detectable at levels below those expected to cause harm.
- On release to the environment 1-butanol is expected to partition mainly to air, and readily move through soil to groundwater.
- Readily bio-degradable and will not persist in the environment/groundwater.
- Not expected to accumulate in biota, and is of low eco-toxicity concern.

Thank you

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