Bren School of Environmental Science & Management, UCSB

Cost/Benefit Analysis of the Health and Environmental Issues of Oxygenated and Non-Oxygenated Gasoline Formulations

Dr. Arturo Keller

University of California, Santa Barbara

Presented at:

Workshop on the Increased Use of Ethanol and Alkylates in Automotive Fuels in California, April 10-11, 2001

Components of the Analysis

- Air Quality Benefits of Reformulated Gasoline
- Human Health Effects
- Ecological Effects
- Exposure Assessment
- Extent of Contamination of Drinking Water Supplies
- Water Treatment
- Cost-Benefit Analysis of Gasoline Alternatives
- Policy Recommendations

Gasoline Formulations

- Reference point: Conventional gasoline
- Reformulated Gasoline with MTBE
- Reformulated Gasoline with Ethanol
- Non-oxygenated Reformulated Gasoline
  - Toluene increased (e.g. Chevron)
  - Alkyls added (e.g. iso-octane)

Air Quality Considerations

- RFG (Reformulated Gasoline)
  - Reduced benzene emissions
  - Reduced CO, NOx, VOC and toxic emissions
  - Lower ozone forming potential
- RFG with MTBE
  - Useful for older vehicles (~pre-1990): reduce CO
  - No significant difference for newer vehicles
  - MTBE emissions to atmosphere
  - Increased formaldehyde emissions

Air Quality Considerations

- RFG with Ethanol
  - Same benefits as gasoline with MTBE
  - Ethanol emissions to atmosphere
  - Increased acetaldehyde emissions
- Non-oxygenated RFG (with more Toluene or alkyl)
  - Same benefits as gasoline with MTBE or Ethanol
  - Increased toluene or alkyl emissions to atmosphere
  - No additional combustion by-products

Human Health Effects of MTBE

- MTBE is an animal carcinogen at high doses; potential to cause cancer in humans (CAL-DHS level at 13 ppb)
- Mechanisms by which MTBE causes cancer is not understood, but either TBA or formaldehyde may play a role
- Laboratory animal experiments indicate reproductive or developmental toxicity at very high exposure levels
- Acute effects at high concentrations (> 100 ppm)
- Taste and odor are a significant concern at low levels (5-20 ppb)
- Formaldehyde as a Product of Incomplete Combustion

Human Health Effects of Ethanol

- Acute and Chronic Toxicity at high concentrations (several percent by volume)
- Little information at low concentrations expected in environment (ppb to ppm)
- Taste and odor probably not a major issue at low concentrations: may be noticeable and objectionable at higher concentrations (**RESEARCH NEEDED**)
- Acetaldehyde as a Product of Incomplete Combustion

Human Health Effects of Toluene

- Acute and Chronic Toxicity at high levels
- Reference Concentration (RfC) in air of 0.4 mg/m^3 or 400 ?g/m^3 (USEPA, 1993d)
- In California, the mean concentration of toluene in air is 8.5 ?g/m^3
- Not proven to be a carcinogen (animal studies have proven negative)
- Toluene in tap water would require treatment to bring risk to acceptable level (below RfD)

Human Health Effects: Alkylates

- Isooctane not classified as a hazardous air pollutant by USEPA
- Isooctane not considered by Agency for Toxic Substances and Disease Registry (ATSDR) within their priorities
- Acute toxicity at high concentrations in air
- **RESEARCH NEEDED**

Ecological Effects of MTBE

- Acute toxicity only at very high concentrations (44 to 1000 mg/L)
- Chronic toxicity at high levels (200 mg/L and higher)
- No developmental effects detected in fish at concentrations between 10 ug/L and 700 mg/L
- No effect on mammalian reproduction at levels up to 2000 mg/kg-day
- Very few species have been studied

Ecological Effects

- Ethanol, Toluene, Iso-octane
  - As with any gasoline constituent, high damage near the spill
  - Expect damages to be similar to conventional gasoline once the concentrations are diluted in a river or groundwater
  - **RESEARCH NEEDED** on Ecotoxicity

Fate and Transport of MTBE

- Very high solubility => transfers to water easily
- Volatile => can evaporate from spills and can be removed from surface water reservoirs to atmosphere
- Very low sorption => doesn't slow down in groundwater
- Very slow biodegradation under natural conditions => persistent, will travel far

Fate and Transport of Ethanol

- Very high solubility => transfers to water easily
- Volatile => can evaporate from spills and can be removed from surface water reservoirs to atmosphere (slower than MTBE)
- Very low sorption => doesn't slow down in groundwater
- Very FAST biodegradation under natural conditions => will be used first by microbes
- May use up all the oxygen before BTEX, extending benzene plume **(RESEARCH NEEDED)**

Fate and Transport of Toluene

- Soluble => transfers to water
- Volatile => can evaporate from spills and can be removed from surface water reservoirs to atmosphere
- Some sorption => slows down in groundwater
- Easily biodegraded under natural conditions => used by microbes in first 1000-3000 ft.
- Travels behind Benzene, so degraded after it

Fate and Transport: Isooctane

- Low Solubility => stays longer in gasoline spill
- Volatile => can evaporate from spills and can be removed from surface water reservoirs to atmosphere
- Higher sorption => slows down appreciably in groundwater
- Easily biodegraded under natural conditions => used by microbes in first 1000-3000 ft.
- Travels behind Benzene, so degraded after it

Cost of Water Treatment

- Cost of treating water with:
  - MTBE is about 40 to 100% higher than conventional gasoline
  - Ethanol should be similar to conventional gasoline **(RESEARCH NEEDED)**
  - Toluene similar to conventional gasoline
  - Iso-octane similar to conventional gasoline

Direct Costs

- Fuel Prices increase for MTBE, Ethanol and Iso-octane, relative to conventional gasoline (CEC, 1999)
- Fuel Prices increase initially for Toluene (first 1-3 years) then may drop in long-term
- Fuel Consumption increases for MTBE and Ethanol (get lower MPG)
- Fuel Consumption decreases for Toluene and Iso-octane

Cost/Benefit Analysis for California

	CaRFG2-MTBE	CaRFG2-Ethanol	Non-oxy CaRFG2
Air Quality Benefits	**$2 to $84 million**	**$2 to $84 million**	**$2 to $84 million**
Health Costs			
air quality damages	**$0 to $27 million**	**$3 to $200 million**	**N.S.[1]**
water treatment	**$340 to $1480 million**	**N.S.[1]**	**$1 to$10 million**
alternate water supplies	**$1 to 30 million**	**N.S.[1]**	**N.S.[1]**
Direct Costs			
fuel price increase	**$135 to $675 million**	**$290 to $991 million**	**$141 to $1300 million**
fuel efficiency decrease	**$310 to $400 million**	**$290 to $580 million**	**($150) to ($230) million**
Other Costs			
water monitoring	**$2 to $4 million**	**N.S.[1]**	**N.S.[1]**
recreational costs	**$160 to $200 million**	**N.S.[1]**	**N.S.[1]**
ecosystem damages	**N.S.[1]**	**N.S.[1]**	**N.S.[1]**
Costs Subtotal	**$0.9 to 2.8 billion**	**$0.6 to $1.8 billion**	**($0.09) to $1.2 billion**
Net Benefit or (Cost)	**($0.9) to ($2.7) billion**	**($0.5) to ($1.8) billion**	**$0 to ($1.2) billion**

[1]N.S. = not significant

Cost-Benefit Analysis

- RFG with MTBE: most expensive option to meet 1990 CAA objectives due to water treatment costs, higher fuel prices and higher fuel consumption
- RFG with Ethanol: intermediate option, with some air quality concerns (acetaldehyde) as well as need for ethanol subsidies to make it competitive
- Non-oxygenated RFG: least expensive option in long-term, and best considering the current average vehicle technology

Policy Recommendations

- Issues:
  - Need to evaluate risk of increasing toluene levels in gasoline
  - Premium grade probably needs oxygenate
- Flexibility in CAAA requirements, to find the least-cost option to achieve air quality objectives, considering the risks
- Study health and environmental impacts of any option **BEFORE** changing the law

Policy Recommendations

1) Promote accelerated removal of older, high emitting vehicles
2) Waive Federal requirement for oxygen content
3) Facilitate production of non-oxygenated gasoline
4) Assess groundwater contamination as soon as possible and avoid delays in clean-up: reduce risk and cost

Policy Recommendations

5) Provide incentives to adopt Best Management Practices for surface water reservoirs

6) Establish specific emissions requirements for motor boat engines

7) Fully assess environmental impacts of ethanol, toluene, alkylates as MTBE substitutes

8) Invest in long-term research program to determine toxicological effects of untested industrial products and fuel alternatives

Acknowledgements

- Dr. Linda Fernandez, now at UC Riverside, was co-investigator in this study and provided the economic tools to analyze the various costs and benefits
- Research funded by UC Toxic Substances Research and Training Program under SB 521