Comparison of On-Road Biodiesel Emissions in Transit Buses

Abhisek Mudgal
Institute for Transportation
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
abhisek@iastate.edu

Massiel Orellana
Department of Agronomy
Iowa State University
102 Snedecor
Ames, IA 50011-1210
massiel@iastate.edu

Shauna Hallmark
Center for Transportation Research and Education
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
shallmar@iastate.edu

ABSTRACT

Depleting fossil fuel resources and environmental protection concerns have triggered research on biodiesel in terms of its emissions reduction potential. However, the emissions impacts of biofuels are not well understood.

The objective of this research was to conduct on-road and laboratory tests to compare the emission impacts of different blends of biodiesel to regular diesel fuel under different operating conditions. The team conducted on-road tests that utilized a portable emissions monitoring system that was used to instrument transit buses. Regular diesel and different blends of biodiesel were evaluated during on-road engine operation by instrumenting three in-use transit buses from the CyRide system of Ames, Iowa, along existing transit routes. Evaluation of transit buses was selected for this study rather than heavy-duty trucks since transit buses have a regular route. This way, emissions for each of the biodiesel blends could be compared across the same operating conditions.

With B20, HC and PM emission rates decreased for all the buses. The decrease in PM emissions is significant, particularly for heavy-duty vehicles that use the most diesel. The decrease in HC is not significant for diesel engines. CO emissions showed inconsistency, which is also immaterial for diesel engines. NOx emissions showed contradictions in the results.

Key words: biodiesel—emissions—transit bus
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Shauna Hallmark
Abhisek Mudgal
Massiel Ore
Background

- Heavy vehicles make up 4% of on-road fleet but account for 8% of VMT and 22% of total fuel used.
- Heavy vehicles account for 38% of nitrogen oxides (Nox), 9% of hydrocarbons (HC), 13% of carbon monoxide (CO), and 70 to 75% of particulates (PM) from on-road vehicles.
- Iowa has a renewable fuel standard of 25% by 2020.
Biodiesel

- Tests suggest biodiesel is lower in PM, CO, HC, and toxins
- Results for NO$_x$ have been less conclusive
- Biodiesel marketed as being cleaner but no on-road tests to evaluate emissions
- Range of biodiesel blends also not evaluated
**Project Overview**

- Measured emission on-road for 3 blends of biodiesel in 3 buses using portable emissions monitoring system (PEMS)
- **Fuel:**
  - Ultra low sulfur diesel (B0), base fuel for other blends
  - 10% biodiesel (B-10)
  - 20% biodiesel (B-20)
- **Vehicle:** CyRide (transit system for Iowa State University and the City of Ames, IA)
  - Bus IDs 971, 973 and 997
- Also measured emissions using same fuel in an engine dynamometer
Portable emissions monitor--Clean Air Technologies: OEM-2100 Montana System

- Samples HC, CO, CO₂, O₂, and NOₓ using dual five-gas analyzer system, measures PM using light-scattering method
- Also has GPS (location, speed, accel)
- Collects data second-by-second
Data Collection

- Tested 3 buses (2-1998 to 2003 standard, 1-2004 to 2006 standard)
- Evaluated during operation over existing route pattern (7:30 am to 5:30 pm)
- Added passenger load using GIS
- Each bus tested 1 to 3 weekdays while ISU was in session
- Collected spring 2008
Data Analysis

- Modeled using a generalized linear model where the response has a gamma distribution and the explanatory variables are included in the linear predictor
- Model fit for each pollutant for each bus

Model specified in SAS:

$$\eta = \text{int} + \text{mode} + \text{fuel} + \text{speed} + \text{passengers} + \text{fuel} \times \text{mode} + \text{fuel} \times \text{speed} + \text{pass} \times \text{fuel}$$
Model Results for Bus 973

- CO₂ emissions, B-20 highest
  - B-0 10% lower and B-10 17% lower than B-20
- PM emissions highest for B-10
  - B-0 75% lower & B-20 70% lower than B-10
- All emissions highest in acceleration mode
- Depending on the pollutant, speed, mode, number of passengers were typically statistically significant
Model Results for Bus 971

- CO₂ emissions, no statistical difference between B-20 and B-0
  - B-10 26% lower than B-0
- PM emissions highest for B-0
  - B-10 85% lower & B-20 90% lower than B-10
- All emissions highest in acceleration mode
- Depending on the pollutant, speed, mode, number of passengers were typically statistically significant
Model Results for Bus 997

- CO₂ emissions, similar for B-10 and B-20
  - B-0 15% lower
- PM emissions highest for B-10
  - Lowest for B-0
- All emissions highest in acceleration mode
- Depending on the pollutant, speed, mode, number of passengers were typically statistically significant
Summary

- Evaluated 3 biodiesel blends on-road in 3 transit buses using PEMS

- Emissions
  - Generally higher for NO\textsubscript{x} with biodiesel than for regular low sulfur diesel
  - HC generally higher for B-0 than for biodiesel blends
  - CO\textsubscript{2} generally higher for biodiesel blends than for B-0
  - Mixed results for CO and PM

- Dynamometer tests
  - Higher NO\textsubscript{x} for biodiesel blends than B-0
  - Decreases in soot, CO, HC for biodiesel blends than B-0
Thank you...