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Evaluation of Biodiesel Fuel and a Diesel Oxidation Catalyst in an Underground Metal Mine

About the Study

The DEEP biodiesel study was undertaken at Inco's Creighton Mine in Sudbury, Ontario in October of 1997. The goals of the study were:

- to measure changes in exhaust emissions, especially diesel particulate matter (DPM), and
- to estimate costs of operating a test vehicle fueled with blended biodiesel.

The study was conducted by the University of Minnesota, Inco, CANMET, Michigan Technological University, ORTECH, and the National Institute for Occupational Safety and Health. The Manufacturers of Emission Controls Association, Deutz Engine Company, Ontario Soybean Growers' Marketing Board, Saskatchewan Canola Development Commission, and the South Dakota Soybean Promotion Committee also contributed to the study.

Background: Biodiesel and Emissions

Biodiesel is usually produced by reacting soybean or canola oil derivatives with methanol. The properties of biodiesel and its blends with petrodiesel are currently covered by a provisional ASTM standard PS121-99.

The general impact of biodiesel and its blends on fuel properties and emissions, relative to petrodiesel, can be summarized as follows:

Biodiesel Properties

- No sulfur content
- No aromatic content (and no PAHs)
- About 11% oxygen content (petrodiesel contains no oxygen)
- Higher cetane value
- Lower heating value
- Better lubricity
- Higher viscosity
- Higher freezing temperature
- Higher flashpoint
- No toxicity or low toxicity

Biodiesel Emissions

- Total particulate matter (TPM) → inconclusive
- Organic particulates (SOF) → increase
- Sulfate particulates → decrease
- Carbon particulates → decrease
- Visible smoke → decreases
- Nitrogen oxides → increase
- Hydrocarbons → decrease
- Carbon monoxide → decreases
- PAHs → decrease

Biodiesel and its blends may be corrosive to some fuel system components. In order to avoid engine problems and engine warranty issues, the use of biodiesel has to be approved by the engine manufacturer.

Test Program

The test vehicle, a Wagner ST-8a scooptram powered by a Deutz F12L 413FW diesel engine rated at 204 kW at 2400 rpm, was operated in a non-producing section of the mine. During the first week of the evaluation, the vehicle used low sulfur, number 2 diesel fuel (D2). During the second week the scoop was operated on a 58 % (by mass) blend of soy-based biodiesel fuel and a low sulfur D2. During both weeks the scoop exhaust system was equipped with a pair of identical, diesel oxidation catalysts (DOCs), designed to reduce the soluble organic fraction (SOF) of diesel exhaust, as well as gaseous hydrocarbons and carbon monoxide.

Day-to-day variation in tailpipe emissions was measured using the Emissions Assisted Maintenance Procedure (EAMP), developed by the University of Minnesota. This procedure requires that the test vehicle be operated for a short time under torque stall conditions while undiluted exhaust gas concentrations are measured at points on the vehicle exhaust system before and after the DOCs. These measurements provide information about the general condition of the engine and DOCs.

The effect of biodiesel on reducing diesel particulate matter (DPM) in emissions was determined by sampling ambient mine air upwind and downwind of the scoop as well as on the vehicle. Three methods were used: the size selective sampling method, the respirable combustible dust method and the elemental carbon method. Final DPM results were calculated by averaging and statistical analysis of samples from upwind and downwind measurements.

Investigators used the Ames mutagenicity test to determine the cancer-causing potential of emissions from both petrodiesel and biodiesel blends. They also assessed the presence of mutagenic PAHs in the emissions.

Results

Tailpipe Emissions

EAMP results showed that the DOCs performed as expected. Carbon monoxide was effectively removed by the DOCs (98 ± 10% D2 fuel and 99 ± 11% blended fuel). However, there was an increase in nitrogen dioxide concentrations (185 ± 78% D2 fuel, 233 ± 59% blended fuel). In the EAMP tests, the blended fuel increased nitrogen dioxide concentrations by 43 ± 28%.

DPM Sampling

Air samples collected in the test section demonstrated that the combination of the blended biodiesel fuel and DOC used in this study decreased total carbon emissions by about 21.4% (± 0.98%), compared to the combination of petrodiesel and DOC. Elemental carbon was reduced by 28.6% (± 0.87%) and organic carbon was reduced 6.0% (± 3.32%) although the organic carbon reduction was not statistically significant. These results, illustrated in the following graph, were lower than the initial expectation of 30% - 50% reduction.

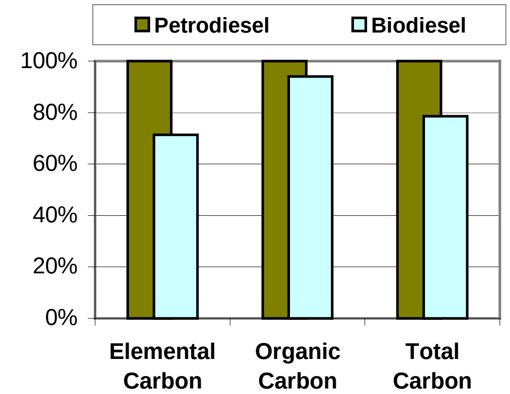

Figure 1: DPM Exposure Comparison

There was a slight, statistically insignificant, increase in nitrogen dioxide concentrations measured at the downwind location and a corresponding decrease in nitric oxide emissions, which was also statistically insignificant. Sulfur oxide levels were low during both weeks.

The biodiesel blend produced reductions in Ames mutagenicity (about 75%) and PAH concentrations. However, not all PAH reductions were statistically significant, due to high variability among measurements on different dates.

Cost Comparison

The study concluded that blended biodiesel fuel used in conjunction with a DOC offers a passive control option to reduce DPM in an underground mine. The primary limitation to the use of biodiesel fuel is cost. At the 1997 price levels, biodiesel fuel ranged from $3.00 - $3.50/gal U.S, while the cost of the D2 fuel was at about $1.00/gal U.S. Therefore, the use of a 50 % blended biodiesel fuel would cost $2.00 to $2.25/gal U.S. This cost must be weighed against the cost of installing and maintaining emission control systems based upon filtration or other methods. It is likely that increased production of a renewable energy source, such as biodiesel, will lower costs and allow biodiesel fuel to become a more viable DPM control option for underground mines in the future.