

Study on Biodiesel Fuels to Reduce Diesel Emissions in Underground Mines

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Objective

To evaluate the effect of utilizing biodiesel fuel mixtures to decrease diesel particulate emissions in actual underground.

Joint Study

Mine Safety and Health Administration

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Carmeuse North America, Inc.

George Love, Mine Personnel

NIOSH

Larry Patts, James Knoll

Acknowledgement

- Ms. Melissa Howell, Executive Director for The Kentucky Clean Fuels Coalition, coordinated the funding to conduct the surveys which was provided from two outside sources. This funding was provided by The Kentucky Division of Energy and by Griffin Industries, Inc..

Regulation (30 CFR Part 57)

Reduce Diesel Particulate Matter (DPM)
Exposure of Underground Metal and
Nonmetal Miners

- 400 $\mu\text{g}/\text{m}^3$ limit by 7/20/03
- 160 $\mu\text{g}/\text{m}^3$ limit by 1/19/06

Options for Controlling DPM

- Dilute Emissions
 - Ventilation
- Remove Employees from Emissions
 - Environmental Cabs
 - Administrative Controls
- Reduce Emissions
 - Low Emission Engines
 - Engine Maintenance
 - Filters
 - Alternative Fuels — Purnox, Biodiesel, Super Low sulfur

What is biodiesel?

- methyl ester product
- produced by combining methanol oil or feedstock
- catalyst added
- glycerin is spun off
- mono-alkyl ester remains

Biodiesel Fuels Studied

- recycled vegetable oil (RVO)
"yellow grease"
from Griffin Industries, Inc.
- virgin soy oil (VSO)
from Peter Cremer North America

Mine Information Carmeuse North America, Inc. (conventional mining system)

Maysville Limestone Mine

- Maysville, KY
- two 10-hour production shifts per day
- produces 3.5 million tons annually

Black River Limestone Mine

- Butler, KY
- two 10-hour production shifts per day
- produces 2.5 million tons annually

Maysville Mine 4 Studies

DEC 10-11-12, 2002	20-80% biodiesel mixture (RVO)
JAN 7-8-9, 2003	50-50% biodiesel mixture (RVO)
FEB 4-5-6, 2003	No. 2 low sulfur diesel fuel (baseline)
APR 1-2-3, 2003	50-50% biodiesel mixture (VSO*)

*different outside weather conditions

Black River Mine 3 Studies

MAR 18-19, 2003	No. 2 low sulfur diesel fuel (baseline)
APR 8-9, 2003	35-65% biodiesel mixture (RVO)
APR 29-30, 2003	35-65% biodiesel mixture (VSO)

Each Study was a 2 Week Study

- Entire U/G Mine switched to Alternative Fuel
- First Week Purged System
- Second Week DPM Sampling was Conducted
 - Air Measurements

Sampling Performed (each day)

Maysville Mine

- 6 area samples
2 main intakes, 2 returns (side by side samples at slope & return shaft)
- 5 personal samples
(included drillers, roof bolters, scalers, loaders, truck drivers, powderman)

Black River Mine

- 7 area samples
(dump point, 2 main intakes, 4 returns)
- 5 personal samples
(loader, 2 truck drivers, scaler, roof bolter)

Sampling Equipment

- SKC pumps and MSA Elf's
(calibrated at 1.7 Lpm)
- 10-millimeter nylon preseparator cyclones
- SKC, Inc. diesel particulate sampling cassettes
- analyzed using NIOSH Method 5040

Carbon Concentrations

carbon

- elemental carbon (EC)
- organic carbon (OC)

total carbon

- $TC = OC + EC$
- $TC = 1.3 \times EC$

weighted averages

- area samples use shift weighted averages (TWA)
- personal samples use time weighted averages (SWA)

Results Maysville Mine Average Area Samples

	Baseline		RVO 20-80%		RVO 50-50%		VSO* 50-50%	
	TC= ECx1.3 ($\mu\text{g}/\text{m}^3$)	TC= EC+OC ($\mu\text{g}/\text{m}^3$)	TC= ECx1.3 ($\mu\text{g}/\text{m}^3$)	TC= EC+OC ($\mu\text{g}/\text{m}^3$)	TC= ECx1.3 ($\mu\text{g}/\text{m}^3$)	TC= EC+OC ($\mu\text{g}/\text{m}^3$)	TC= ECx1.3 ($\mu\text{g}/\text{m}^3$)	TC= EC+OC ($\mu\text{g}/\text{m}^3$)
Weighted Return	352	321	235	225	109	121	178	175
Percent Reduction		---	33%	30%	69%	62%	49%	45%

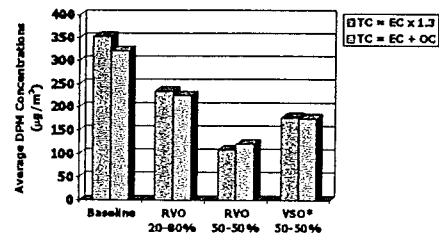
*results adjusted for changes in airflow and intake concentrations

Results Black River Mine Average Area Samples

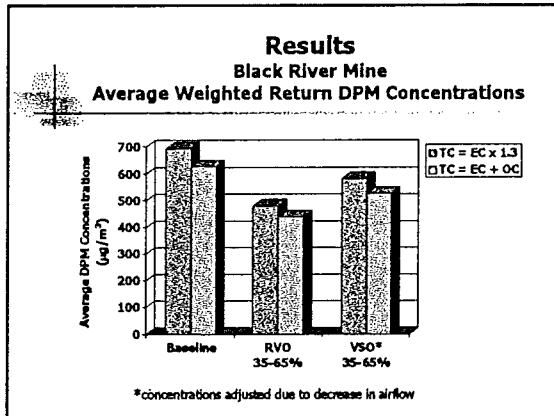
	Baseline		RVO 35-65%		VSO* 35-65%	
	TC= ECx1.3 ($\mu\text{g}/\text{m}^3$)	TC= EC+OC ($\mu\text{g}/\text{m}^3$)	TC= ECx1.3 ($\mu\text{g}/\text{m}^3$)	TC= EC+OC ($\mu\text{g}/\text{m}^3$)	TC= ECx1.3 ($\mu\text{g}/\text{m}^3$)	TC= EC+OC ($\mu\text{g}/\text{m}^3$)
Weighted Return	693	626	480	439	582	526
Percent Reduction		---	31%	30%	16%	16%

*concentrations adjusted due to decrease in airflow

Results Maysville Mine Average Weighted Return DPM Concentrations



*results adjusted for changes in airflow and intake concentrations



Results
Maysville Mine
Average Personal DPM Concentrations
Inside and Outside of Cab
TC = EC x 1.3 (µg/m³)

	Baseline	RVO 20-80%	RVO 50-50%	VSO 50-50%
Average Workers Inside of Cab	220	219	89	212
Percent Reduction	---	0%	60%	4%
Average Workers Outside of Cab	300	208	216	313*
Percent Reduction	---	31%	28%	(4%)

Results
Black River Mine
Average Personal DPM Concentrations
Inside and Outside of Cab
TC = EC x 1.3 (µg/m³)

	Baseline	RVO 35-65%	VSO 35-65%
Average Workers Inside of Cab	1,611	731	967
Percent Reduction	---	55%	40%
Average Workers Outside of Cab	1,369	771	1,013
Percent Reduction	---	44%	26%

Results
Maysville Mine
Summary of Personal DPM Concentrations Limits
(µg/m³)

Baseline			RVO 20-80%			RVO 50-50%			VSO 50-50%		
Date	2:400	5:160	Date	2:400	5:160	Date	2:400	5:160	Date	2:400	5:160
Feb 4 2003	1	3	1	Dec 10 2002	0	3	2	Jan 7 2003	0	0	4
Feb 5 2003	1	2	2	Dec 11 2002	0	6	0	Jan 8 2003	0	0	5
Feb 6 2003	0	4	1	Dec 12 2002	0	4	2	Jan 9 2003	0	1	4
Total	2	9	4		0	13	4		0	1	13

Results
Black River Mine
Summary of Personal DPM Concentrations Limits
(µg/m³)

Baseline			RVO 35-65%			VSO 35-65%					
Date	2:400	5:160	Date	2:400	5:160	Date	2:400	5:160			
Mar 18 2003	5	0	0	Apr 8 2003	4	1	0	Apr 29 2003	5	0	0
Mar 19 2003	5	0	0	Apr 9 2003	5	0	0	Apr 30 2003	4	1	0
Total	10	0	0		9	1	0		9	1	0

Results
Maysville Mine
Nitrogen Dioxide (NO₂) Concentrations

- NO₂ diffusion tubes collected with all samples
- MSA Passport Detectors with Data loggers at Return and Slope
- highest personal concentration of NO₂ recorded did not exceed 2.0 parts per million (ppm):
 - high scaler 1.5 ppm
 - loader 1.5 ppm
 - roof bolter 1.0 ppm
 - downhole driller 1.0 ppm
- no significant change in numbers between baseline and biodiesel fuels

Findings Maysville Mine (TC = EC x 1.3)

- weighted exhaust TWA DPM concentration reductions from baseline
 - RVO 20-80% Indicated 33% reduction
 - RVO 50-50% Indicated 69% reduction
 - VSO 50-50% Indicated 49% reduction
(results adjusted for changes in airflow and intake concentrations)
- average personal SWA DPM concentration reductions from baseline

	Inside of Cab	Outside of Cab
RVO 20-80%	0%	31%
RVO 50-50%	60%	28%
VSO 50-50%	4%	(4%)

Findings Maysville Mine (TC = EC x 1.3)

- number of employees exceeding the 400 $\mu\text{g}/\text{m}^3$ limit standard
 - baseline 2
 - RVO 20-80% 0
 - RVO 50-50% 0
 - VSO 50-50% 2
- biodiesel fuel has no significant effect on NO_2

Findings Black River Mine (TC = EC x 1.3)

- weighted exhaust TWA DPM concentration reductions from baseline
 - RVO 35-65% Indicated 31% reduction
 - VSO 35-65% Indicated 16% reduction
(concentrations adjusted due to decrease in airflow)
- average personal SWA DPM concentration reductions from baseline

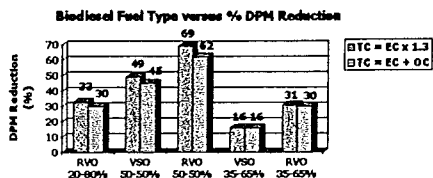
	Inside of Cab	Outside of Cab
RVO 35-65%	55%	44%
VSO 35-65%	40%	26%

Findings Black River Mine (TC = EC x 1.3)

- number of employees exceeding the 400 $\mu\text{g}/\text{m}^3$ limit standard
 - baseline 10
 - RVO 35-65% 9
 - VSO 35-65% 9

Conclusions

- biodiesel fuels reduce DPM concentrations
 - reduction in the weighted exhaust DPM concentrations



Conclusions

- reduction in the average personal DPM concentrations
- an increased number of employees met the 160 $\mu\text{g}/\text{m}^3$ and 400 $\mu\text{g}/\text{m}^3$ limit standard
- biodiesel fuel has no significant effect on NO_2