

DPM Reductions at Underground Metal and Nonmetal Mines Using Alternative Fuels

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Objective

**To evaluate the effect of utilizing
alternative fuel mixtures to decrease
diesel particulate emissions in
underground mines.**

Regulation (30 CFR Part 57)

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

- current limit: $308_{EC} \mu\text{g}/\text{m}^3$
- final limit: $350_{TC} \mu\text{g}/\text{m}^3$ on 1/20/07
 $160_{TC} \mu\text{g}/\text{m}^3$ on 5/20/08

Options for Controlling DPM

dilute emissions

- ventilation

remove employees from emissions

- environmental cabs
- administrative controls

reduce emissions

- low emission engines
- engine maintenance
- filters
- reduce operating times
- alternative fuels
(biodiesel, PuriNOx™, super low sulfur)

Alternative Fuels Studied

Biodiesel

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

PuriNOx™

from Lubrizol Corporation

What is biodiesel?

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

What is PuriNOx™?

- water-blended diesel fuel emulsion mixture
- EPA approved fuel
- formula of additives, deionized water, and commercial diesel fuel
- created using automated blending units installed at fuel terminals
- flash point: 161.0°F summer blend (April-Sept.)
168.8°F winter blend (Oct.-March)
- Power loss can occur, since water does not have any energy content.

Mine Information

(conventional mining system)

Maysville Limestone Mine Carmeuse Lime & Stone, Inc.

- Maysville, KY
- two 10-hour production shifts per day

Black River Limestone Mine Carmeuse Lime & Stone, Inc.

- Butler, KY
- two 10-hour production shifts per day

Mine Information

(conventional mining system)

Stone Creek Brick Mine Stone Creek Brick Company

- Stone Creek, OH
- one 8-hour production shift per day

Durham Mine Martin Marietta Aggregates, Inc.

- Pella, IA
- production shifts
 - 2 limestone levels: one 10-hour day shift
 - gypsum level: one 10-hour evening shift

Maysville Mine 7 Studies

Biodiesel surveys:

DEC 10-12, 2002	RVO 20-80%
JAN 7-9, 2003	RVO 50-50%
FEB 4-6, 2003	No. 2 LSD (biodiesel baseline)
APR 1-3, 2003	VSO 50-50%

PuriNOx™ surveys:

JAN 6-7, 2004	RVO 35-65% (PuriNOx™ baseline)
FEB 2-3, 2004	PuriNOx™ 10 wt% water
MAY 25-26, 2004	PuriNOx™ 20 wt% water

Black River Mine 6 Studies

Biodiesel surveys:

MAR 18-19, 2003	No. 2 LSD (biodiesel baseline)
APR 8-9, 2003	RVO 35-65%
APR 29-30, 2003	VSO 35-65%

PuriNOx™ surveys:

MAR 16-18, 2004	RVO 35-65% (PuriNOx™ baseline)
APR 13-14, 2004	PuriNOx™ 10 wt% water
MAY 25-26, 2004	PuriNOx™ 20 wt% water

Stone Creek Brick Mine & Durham Mine Studies

Stone Creek Brick Mine PuriNOx™ surveys:

JUN 10-11, 2003	No. 2 LSD (PuriNOx™ baseline)
JUL 29-30, 2003	PuriNOx™ 10 wt% water

Durham Mine PuriNOx™ surveys:

APR 6-7, 2004	No. 2 LSD (PuriNOx™ baseline)
MAY 25-26, 2004	PuriNOx™ 20 wt% water

Study Period

- entire underground mine switched to alternative fuel
- purged system 1st week
- sampling conducted 2nd or 3rd week

Sampling Performed (each day)

Maysville Mine

- **6 area samples**
2 main intakes, 2 returns (side-by-side samples)
- **5 personal samples**
drillers, roof bolters, scalers, loaders, truck drivers, powderman, ANFO truck driver

Black River Mine

- **Biodiesel survey**
 - **7 area samples**
1 dump point, 2 main intakes, 2 returns (side-by-side samples)
 - **5 personal samples**
loader, truck drivers, scaler, roof bolter
- **PuriNOx™ survey**
 - **13 area samples**
2 intakes, 3 returns (side-by-side samples), 5 placed on equipment (powder truck, haul truck, face drill, loader, roof bolter)

Sampling Performed (each day)

Stone Creek Brick Mine

- **3 area samples**
1 main intake, 1 return (side-by-side samples)
- **3 personal samples**
driller, transloader, locomotive operator

Durham Mine

- **13 area samples**
1 dump point, 2 intakes, 5 returns (side-by-side samples)
- **5 personal samples**
mucking loader, powder crew, drill operator, haul trucks

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 5040 Method

Carbon Concentration

$$\text{Carbon Concentration} \left(\frac{\mu\text{g}}{\text{m}^3} \right) = \frac{C \left(\frac{\mu\text{g}}{\text{cm}^2} \right) \times A (\text{cm}^2) \times 1,000 \frac{\text{L}}{\text{m}^3}}{1.7 \text{ Lpm} \times \text{Time} (\text{minute})}$$

carbon

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

total carbon

- TC = EC + OC
- TC = EC × 1.3

weighted averages

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

Results

Maysville Mine Average Area Samples

Fuel	Airflow (cfm)	Total Carbon	Weighted Return Normalized ($\mu\text{g}/\text{m}^3$)	% Reduction from No. 2 LSD
No. 2 LSD (biodiesel baseline)	892,000	EC×1.3	350	---
		EC+OC	318	---
RVO 20-80%	883,000	EC×1.3	228	35%
		EC+OC	215	32%
RVO 50-50%	858,000	EC×1.3	103	71%
		EC+OC	112	65%
VSO 50-50%	748,000	EC×1.3	179	49%
		EC+OC	175	45%

Results

Maysville Mine Average Area Samples

Fuel	Airflow (cfm)	Total Carbon	Weighted Return Normalized ($\mu\text{g}/\text{m}^3$)	% Reduction from RVO 35-65%
RVO 35-65% (PuriNOx™ baseline)	977,000	ECx1.3	243	---
		EC+OC	217	---
PuriNOx™ 10% Water	918,000	ECx1.3	117	52%
		EC+OC	110	49%
PuriNOx™ 20% Water	842,000	ECx1.3	97	60%
		EC+OC	89	59%

Results

Black River Mine Average Area Samples

Fuel	Airflow (cfm)	Total Carbon	Weighted Return Normalized ($\mu\text{g}/\text{m}^3$)	% Reduction from No. 2 LSD
No. 2 LSD (biodiesel baseline)	259,000	ECx1.3	670	---
		EC+OC	601	---
RVO 35-65%	256,000	ECx1.3	451	33%
		EC+OC	413	31%
VSO 35-65%	214,000	ECx1.3	560	16%
		EC+OC	501	17%

Results

Black River Mine Average Area Samples

Fuel	Airflow (cfm)	Total Carbon	Weighted Return Normalized ($\mu\text{g}/\text{m}^3$)	% Reduction from RVO 35-65%
RVO 35-65% (PuriNOx™ baseline)	464,000	ECx1.3	263	---
		EC+OC	265	---
PuriNOx™ 10% Water	415,000	ECx1.3	143	46%
		EC+OC	146	45%
PuriNOx™ 20% Water	376,000	ECx1.3	103	61%
		EC+OC	122	54%

Results

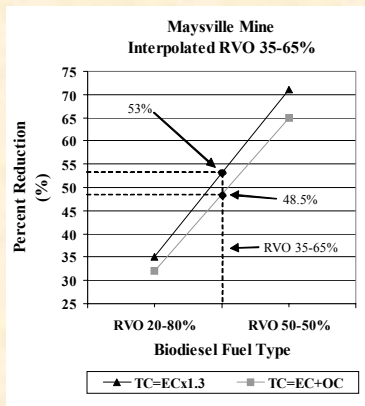
Stone Creek Brick Mine Average Area Samples

Fuel	Airflow (cfm)	Total Carbon	Weighted Return Normalized ($\mu\text{g}/\text{m}^3$)	% Reduction from No. 2 LSD
No. 2 LSD (PuriNOx™ baseline)	49,300	ECx1.3	201	---
		EC+OC	312	---
PuriNOx™ 10% Water	48,800	ECx1.3	90	55%
		EC+OC	252	19%

Results Durham Mine Average Area Samples

Fuel	Airflow (cfm)	Total Carbon	Weighted Return Normalized ($\mu\text{g}/\text{m}^3$)	% Reduction from No. 2 LSD
No. 2 LSD (PuriNOx™ baseline)	253,000	ECx1.3	127	---
		EC+OC	125	---
PuriNOx™ 20% Water	240,000	ECx1.3	31	76%
		EC+OC	47	62%

Results Maysville Mine Alternative Fuel Compared to No. 2 LSD Fuel



	TC= ECx1.3 ($\mu\text{g}/\text{m}^3$)	% Red. from LSD	TC= EC+OC ($\mu\text{g}/\text{m}^3$)	% Red. from LSD
No. 2 LSD (FEB 2003)	350	---	318	---
RVO 20-80% (DEC 2002)	228	35%	215	32%
Interpolated RVO 35-65%	165	53%	164	48.5%
RVO 50-50% (JAN 2003)	103	71%	112	65%

$$\text{Interpolated RVO} = \text{LSD FEB} \left(1 - \frac{\% \text{ Reduction}}{100} \right)$$

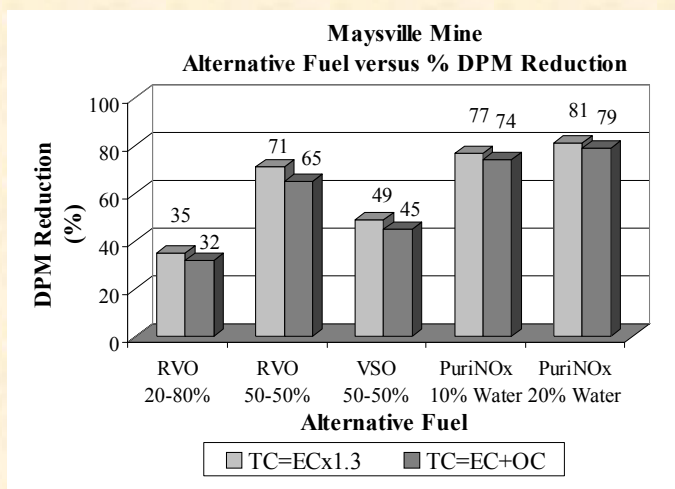
Results Maysville Mine Alternative Fuel Compared to No. 2 LSD Fuel

	TC=ECx1.3 ($\mu\text{g}/\text{m}^3$)	TC=EC+OC ($\mu\text{g}/\text{m}^3$)	Airflow (cfm)
No. 2 LSD (FEB 2003)	350	318	892,000
Interpolated RVO 35-65%	165	164	892,000
RVO 35-65% (JAN 2004)	243	217	977,000
No. 2 LSD Equivalent	515	421	977,000

$$LSD\ Equiv. = LSD\ FEB \left(\frac{JAN\ RVO}{Interpolated\ RVO} \right)$$

	TC=ECx1.3 ($\mu\text{g}/\text{m}^3$)	% Red. from LSD Equiv.	TC=EC+OC ($\mu\text{g}/\text{m}^3$)	% Red. from LSD Equiv.
No. 2 LSD Equivalent	515	---	421	---
PuriNOx™ 10% Water	117	77%	110	74%
PuriNOx™ 20% Water	97	81%	89	79%

Results Maysville Mine Alternative Fuel Compared to No. 2 LSD Fuel



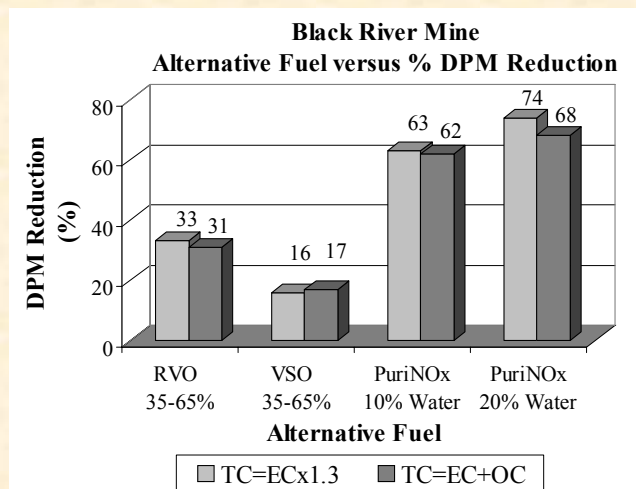
Results Black River Mine Alternative Fuel Compared to No. 2 LSD Fuel

	TC=ECx1.3 (µg/m³)	TC=EC+OC (µg/m³)	Airflow (cfm)
No. 2 LSD (MAR 2003)	670	601	259,000
RVO 35-65% (APR 2003)	451	413	259,000
RVO 35-65% (MAR 2004)	263	265	464,000
No. 2 LSD Equivalent	391	386	464,000

$$LSD\ Equiv. = LSD\ MAR \left(\frac{MAR\ RVO}{APR\ RVO} \right)$$

	TC=ECx1.3 (µg/m³)	% Red. from LSD Equiv.	TC=EC+OC (µg/m³)	% Red. from LSD Equiv.
No. 2 LSD Equivalent	391	---	386	---
PuriNOx™ 10% Water	143	63%	146	62%
PuriNOx™ 20% Water	103	74%	122	68%

Results Black River Mine Alternative Fuel Compared to No. 2 LSD Fuel



Personal DPM Sampling

- Many variables affected personal exposure to DPM concentrations.
- Not as useful in determining effectiveness of alternative fuel as are the area samples.

Summary - Findings Maysville Mine Reductions (TC = EC × 1.3)

weighted exhaust TWA DPM biodiesel concentrations from No. 2 LSD

- RVO 20-80% indicated a 35% reduction
- RVO 50-50% indicated a 71% reduction
- VSO 50-50% indicated a 49% reduction

weighted exhaust TWA DPM PuriNOx™ concentrations from RVO 35-65%

- PuriNOx™ 10% water indicated a 52% reduction
- PuriNOx™ 20% water indicated a 60% reduction

weighted exhaust TWA DPM PuriNOx™ concentrations from calculated No. 2 LSD equivalent

- PuriNOx™ 10% water indicated a 77% reduction
- PuriNOx™ 20% water indicated an 81% reduction

Summary - Findings

Black River Mine Reductions

(TC = EC × 1.3)

weighted exhaust TWA DPM biodiesel concentrations from No. 2 LSD

- RVO 35-65% indicated a 33% reduction
- VSO 35-65% indicated a 16% reduction

weighted exhaust TWA DPM PuriNOx™ concentrations from RVO 35-65%

- PuriNOx™ 10% water indicated a 46% reduction
- PuriNOx™ 20% water indicated a 61% reduction

weighted exhaust TWA DPM PuriNOx™ concentrations from calculated No. 2 LSD equivalent

- PuriNOx™ 10% water indicated a 63% reduction
- PuriNOx™ 20% water indicated a 74% reduction

Summary - Findings

Stone Creek Brick Mine & Durham Mine Reductions

(TC = EC × 1.3)

weighted exhaust TWA DPM PuriNOx™ concentrations from No. 2 LSD

● Stone Creek Brick Mine:

PuriNOx™ 10% water indicated a 55% reduction

● Durham Mine

PuriNOx™ 20% water indicated a 76% reduction

Conclusions

The use of alternative fuels have shown to reduce DPM concentrations in underground nonmetal mines.

- **Maysville & Black River Mines**

- alternative fuels tested
 - various blends of biodiesel mixtures
 - PuriNOx™ 10% water & 20% water
- PuriNOx™ blends have shown greater reductions than biodiesel mixtures.

- **Stone Creek Brick Mine**

(PuriNOx™ 10% water)

- **Durham Mine**

(PuriNOx™ 20% water)