May 2003 • NREL/SR-540-33793

Impact of Biodiesel Fuels on Air Quality and Human Health

Summary Report
September 16, 1999–January 31, 2003

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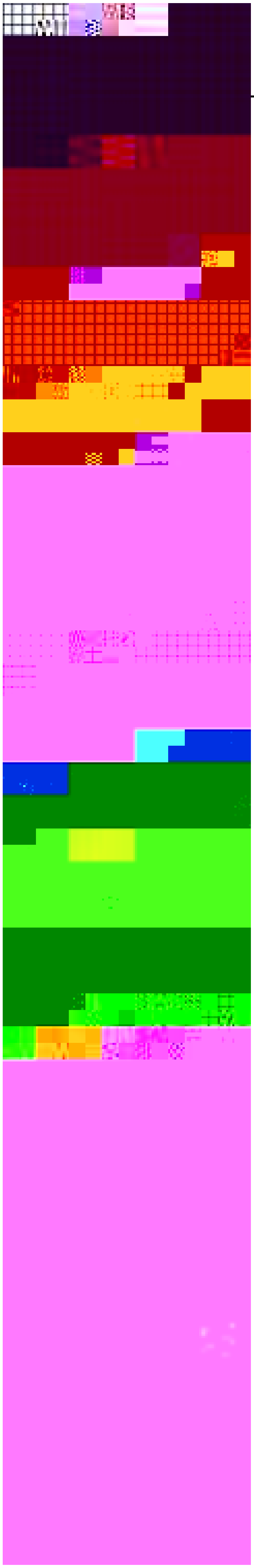

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Prepared under Subcontract No. AXE-9-29079-01

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Contract No. DE-AC36-99-GO10337

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EXECUTIVE SUMMARY

Biodiesel is derived from domestic renewable resources and can be used as an extender for petroleum based diesel fuels. One reason for the interest in biodiesel is because of its ability to reduce emissions from diesel engines for many air pollutant precursors, and the lower toxicity of the diesel particulate matter (PM) emissions. There have been numerous studies on the effects of biodiesel fuel on diesel engine emissions, however, the effects of biodiesel fuel use on air quality have not yet been quantified, although EPA is studying this issue. The National Renewable Energy Laboratory (NREL) contracted with ENVIRON International Corporation to conduct the "Impact of Biodiesel Fuels on Air Quality and Human Health" study. The study employed inventory and air quality modeling to analyze the impacts of biodiesel use in the on-road heavy-duty diesel vehicle (HDDV) fleet on:

- ambient ozone (O_3) concentrations in the Northeast Corridor, Lake Michigan, and the South Coast (Los Angeles) Air Basin (SoCAB) regions;
- carbon monoxide (CO) in Las Vegas, Nevada;
- particulate matter (PM) in the SoCAB; and
- air toxics, risk, and human health in the SoCAB.

Biodiesel test data were analyzed to determine the average effect that biodiesel (B100) and a 20%/80% biodiesel/diesel fuel blend (B20) would have on mass emissions from diesel vehicles. Table ES-1 summarizes the estimated average changes in mass emissions from diesel engines using biodiesel versus standard diesel that were used in the air quality modeling. The analysis of the diesel test data also found that diesel PM emissions from B100 and B20 biodiesel have, respectively, 20% and 5% less toxicity than standard diesel fuel.

Table ES-1. Average change in HDDV mass emissions due to use of a biodiesel fuel relative to a standard diesel fuel[1] (Lindhjem and Pollack, 2002).

Biodiesel Fuel	NOx	PM	CO	VOC	SO_2
B20	+2.4%	-8.9%	-13.1%	-17.9%	-20%
B100	+13.2%	-55.3%	-42.7%	-63.2%	-100%

[1] Standard diesel has sulfur content of < 500 ppm.

Three emissions scenarios were analyzed: (1) a standard diesel base case; (2) a 100% penetration of B20 biodiesel in the HDDV fleet; and (3) a 50% penetration of B20 biodiesel in the HDDV fleet. Table ES-2 summarizes the estimated peak pollution concentrations for the standard diesel and 100% [illegible]

Table ES-2. Change in peak estimated pollutant concentrations and maximum increase and decrease in daily maximum pollutau

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1. INTRODUCTION

BACKGROUND

Biodiesel is derived from domestic renewable resources and can be used as an extender for petroleum based diesel fuels.

There have been several studies regarding the effects of biodiesel on exhaust emissions of nitrogen oxide (NOx), volatile organic compounds (VOC), CO, and PM. Almost all of these studies have examined emissions from heavy-duty diesel vehicle (HDDV) engines. However, the effects of biodiesel use on ambient air quality have not been quantified. Thus, the National Renewable Energy La

Table 1-2a. Relative fraction (x 10^6) of selected PAH compounds to PM emissions from Sharp (1998) and Durbin (1999).

Compounds	**Standard Diesel**		**B20**		**B100**	
	Sharp	**Durbin**	**Sharp**	**Durbin**	**Sharp**	**Durbin**
Benzo(a)anthracene	1.59	1.01	1.51	0.43	1.37	1.11
Chrysene	2.21	1.01	1.32	0.65	1.04	0.89
Benzo(b)fluoranthene	0.96	0.50	0.97	0.22	0.77	0.22
Benzo(k)fluoranthene	1.01	*	0.92	*	0.73	*
Benzo(a)pyrene	1.12	0.25	0.69	1.72	0.49	0.00
Indeno(1,2,3-cd)pyrene	0.72	0.00	0.56	0.00	0.60	0.00
Dibenz(a,h)anthracene	0.21	0.00	0.19	0.00	0.13	0.00
Benzo(g,h,i)perylene	0.94	0.00	0.88	0.00	0.93	0.00
Total	**8.76**	**2.77**	**7.04**	**3.02**	**6.06**	**2.22**

* Included in Benzo(b)fluoranthene.

Table 1-2b. Relative fraction (x 10^6) of selected Nitro-PAH compounds to PM emissions.

Compounds	**D2**	**B20**	**B100**
2-Nitrofluorene	0.14	0.11	0.09
1-Nitropyrene	0.11	0.11	0.02
7-Nitrobenz(a)anthracene	0.01	0.00	0.00
6-Nitrochrysene	0.00	0.00	0.00
6-Nitrobenz(a)pyrene	0.01	0.00	0.00
Total	**0.27**	**0.22**	**0.11**

OVERALL EFFECTS OF BIODIESEL FUF t I S

2. EFFECTS OF BIODIESEL ON AMBIENT OZONE CONCENTRATIONS

The effect of biodiesel use on ozone air quality was evaluated in the SoCAB, lower Lake Michigan (Chicago), Northeast Corridor (New York, Philadelphia, Baltimore, and Washington, DC), and other cities in the Eastern United States . The largest impacts on ambient ozone concentrations due to the use of biodiesel are expected to be due to changes in NOx emissions from diesel vehicles. Studies, such as the Ozone Transport Assessment Group (OTAG), have concluded that regional NOx controls are one of the most effective control strategies for reducing regional ozone concentrations in the eastern United States. However, in some cases, NOx controls result in increased ozone levels, particularly in the urban cores of large cities. The assessment of ozone impacts due to biodiesel must therefore include the effects of the fuel on regional ozone and ozone transport as well as the effects within urban areas. The ozone air quality modeling conducted as part of this study therefore takes into account both urban-scale and regional-scale ozone formation through the use of high-resolution (4 - 5-km) urban-scale modeling of the cities under study as well as coarser-scale (12-km) regional-scale modeling.

The 1-hour ozone National Ambient Air Quality Standard (NAAQS) has a threshold of 0.12 ppm (124 ppb) that is not to be exceeded more than once per year over three consecutive years (i.e., with complete data capture a violation occurs if the fourth highest daily maximum 1-hour ozone concentration at a monitor exceeds 0.12 ppm). More recently EPA has promulgated a more stringent 8-hour ozone standard that is based on a three-year average of the fourth highest annual daily maximum 8-hour ozone concentration with a threshold of 0.08 ppm (84 ppb). EPA is currently formulating the implementation policy for the 8-hour ozone NAAQS.

The assessment of the impacts of biodiesel use on ozone concentration is made with respect to both 1-hour and 8-hour ozone concentrations (Morris, Mansell, Jia, and Wilson, 2002). An analysis of daily peak ozone concentrations in each urban area is made along with displays of spatial distributions of daily maximum ozone concentrations. These results are used to evaluate the effects of biodiesel use on the 1-hour and 8-hour ozone concentrations and attainment of the NAAQS. As part of the assessment, ozone exposure metrics are also calculated and evaluated as a measure of the biodiesel impacts on ozone air quality and human health.

The EPA 2007 State Implementation Plan (SIP) Call emissions inventory was used for the eastern United States and the baseline (standard diesel) scenario with the MOBILE5 mobile source emissions was updated to incorporate some of the MOBILE6 emission effects.

A new SoCAB database for the August 3-7, 1997 Southern California Ozone Study (SCOS) episode was used for ozone modeling of Southern California.

The California Air Resources Board (CARB) latest emissions inventory for 1997 based on the EMFAC2000 mobile source emissions model was used for the baseline (standard diesel) emissions scenario.

EFFECTS OF BIODIESEL USE

The incorporation of biodiesel effects in the emission inventory used in this study was accomplished by applying the 1995 version of the Emission Modeling System (EMS95) for the eastern US and the ARB's Gridded Emissions Model (GEM) for the SoCAB. Biodiesel effects were accounted for in the HDDV fleet only, and only the effects of B20 were considered. Under Task 1 of the NREL study, engine test data were analyzed and the average effects of using biodiesel rather than a standard diesel fuel on HDDV tailpipe emissions of ozone precursors were estimated as shown in Table 2-1 (Lindhjem and Pollack, 2002).

Table 2-1. Overall average change in mass emission effects due to use of biodiesel fuels in HDDVs over using a standard diesel fuel.

Biodiesel Fuel	**NO_x**	**CO**	**VOC**
B20	+2.4%	-13.1%	-17.9%
B100	+13.2%	-42.7%	-63.2%

Three emission scenarios were analyzed for 2007 in the eastern United States and 1997 for the SoCAB:

- Standard diesel baseline scenario;
- 100% penetration in the HDDV fleet of a B20 biodiesel fuel scenario; and
- 50% penetration in the HDDV fleet of a B20 biodiesel fuel scenario.

EMISSION SUMMARY RESULTS

Table 2-2 summarizes the on-road mobile source NOx, VOC, and CO emission inventory in terms of the fractional contribution to the total inventory, the fractional contribution to the anthropogenic component, and the fraction of the on-road mobile inventory due to HDDV for the Lake Michigan and Northeast Corridor high-resolution (4-km) modeling domains, the 12-km eastern United States OTAG domain, and the SoCAB high-resolution (5-km) domain. While the on-road mobile component represents a considerable percentage of the overall inventory, the

The resulting changes in the emission inventory for a representative episode weekday are presented in Table 2-3 for the two biodiesel emission scenarios and for the Lake Michigan, Northeast Corridor, eastern United States, and SoCAB domains. The use of biodiesel fuel with the HDDV fleet is estimated to cause a very small change (<1%) in all ozone precursor emissions.

Table 2-2. Summary of on-road mobile and HDDV emission contributions.

2007 SIP Call Base Case and Eastern US OTAG 12-km Domain			
	NOx	**VOC**	**CO**
Mobile % of Total Inv.	30%	2.2%	49%
Mobile % of Anthro.	37%	17%	49%
HDDV % of Mobile Inv.	35%	4.7%	4.5%

[redacted]

[redacted]

Table 2-3. Summary

fuel in HDDVs. In the Lake Michigan region, the maximum increase and decrease in daily maximum ozone concentrations anywhere in the modeling domain for the 100% B20 emissions scenario are +0.09 and –0.53 ppb, respectively. The maximum increases and decreases in daily maximum ozone concentrations in the Northeast Corridor are +0.20 and –0.25 ppb, respectively. Similar numbers for the SoCAB are +0.22 and –1.20 ppb. Thus, the maximum changes in daily maximum 1-hour and 8-hour ozone concentrations due to the introduction of biodiesel fuels in the HDDV fleet in the Lake Michigan, Northeast Corridor, and SoCAB regions are very small.

The use of a 100% or 50% penetration in the HDDV results in very small changes, both increases and decreases, in the peak daily maximum 1-hour and 8-hour ozone concentrations in the SoCAB and Northeast Corridor, Lake Michigan, and other cities in the eastern United States (see Morris, Mansell, Jia, and Wilson, 2002). The changes in 1-hour and 8-hour ozone peaks due to use of the biodiesel fuel are always < 1 ppb.

Table 2-4. Maximum increases and decreases in daily maximum 1-hour ozone concentrations (ppb) in the Lake Michigan, Northeast Corridor, and South Coast Air Basin regions.

	50% B20 Biodiesel (ppb)		**100% B20 Biodiesel (ppb)**	
Date	**Max Increase**	**Max Decrease**	**Max Increase**	**Max Decrease**
2007 Lake Michigan Domain				
July 11, 1995	+0.03	-0.16	+0.05	-0.33
July 12, 1995	+0.07	-0.10	+0.09	-0.19
July 13, 1995	+0.05	-0.12	+0.09	-0.24
July 14, 1995	+0.07	-0.09	+0.09	-0.18
July 15, 1995	+0.04	-0.26	+0.08	-0.53
2007 Northeast Corridor Domain				
July 11, 1995	+0.06	-0.08	+0.11	-0.14
July 12, 1995	+0.07	-0.12	+0.13	-0.25
July 13, 1995	+0.12	-0.06	+0.15	-0.07
July 14, 1995	+0.15	-0.04	+0.20	-0.09
July 15, 1995	+0.10	-0.10	+0.18	-0.20
1997 South Coast Air Basin Domain				
August 4, 1997	+0.09	-0.48	+0.17	-0.95
August 5, 1997	+0.10	-0.56	+0.19	-1.1
August 6, 1995	+0.11	-0.60	+0.22	-1.2
August 7, 1995	+0.13	-0.49	+0.26	-0.98

Table 2-5. Maximum increases and decreases in daily maximum 8-hour ozone concentrations (ppb) in the Lake Michigan, Northeast Corridor, and South Coast Air Basin regions.

	50% B20 Biodiesel (ppb)		**100% B20 Biodiesel (ppb)**	
Date	**Max Increase**	**Max Decrease**	**Max Increase**	**Max Decrease**
2007 Lake Michigan Domain				
July 11, 1995	+0.02	-0.14	+0.04	-0.28
July 12, 1995	+0.03	-0.09	+0.07	-0.17
July 13, 1995	+0.04	-0.11	+0.09	-0.21
July 14, 1995	+0.03	-0.09	+0.07	-0.18
July 15, 1995	+0.03	-0.20	+0.07	-0.40
2007 Northeast Corridor Domain				
July 11, 1995	+0.05	-0.07	+0.10	-0.13
July 12, 1995	+0.05	-0.10	+0.11	-0.20
July 13, 1995	+0.07	-0.04	+0.12	-0.07
July 14, 1995	+0.07	-0.04	+0.14	-0.07
July 15, 1995	+0.06	-0.04	+0.15	-0.08
1997 South Coast Air Basin Domain				
August 4, 1997	+0.06	-0.34	+0.12	-0.68
August 5, 1997	+0.07	-0.39	+0.15	-0.77
August 6, 1995	+0.08	-0.48	+0.15	-0.96
August 7, 1995	+0.08	-0.42	+0.15	-0.83

CONCLUSIONS

Measured ozone is typically reported to EPA's AIRS ozone compliance database to the nearest 1 ppb. The maximum estimated increase and decrease in daily maximum 1-hour or 8-hour ozone concentrations due to the use of either a 100% or 50% penetration of a B20 fuel in the HDDV fleet in any of the areas studied is +0.26 ppb and –1.20 ppb for 1-hour ozone and the 100% B20 fuel scenario in the SoCAB region. As the maximum ozone increase (+0.26 ppb) is well below 1 ppb, the use of biodiesel is estimated to have no measurable adverse impact on 1-hour or 8-hour ozone attainment in Southern California and the Eastern United States.

3. BIODIESEL EFFECTS ON AMBIENT CO CONCENTRATIONS

INTRODUCTION

Carbon monoxide (CO) air pollution is generated by a variety of combustion processes ranging from industrial sources, to household heating, to motor vehicles. Due to the sheer number of automobiles, the vast majority (typically 90%) of area-wide CO emissions in congested urban areas come from on-road motor vehicles. Numerous urban centers in the western United States have experienced elevat area (> 90%), the HDDV fraction contributes less than one percent (0.7%) to the total on-road mobile CO emissions. The percent reduction in CO emissions due to the 100% B20 and 50% B20 biodiesel emissions scenarios from the 2001 standard diesel base case for the HDDV, on-road mobile, and total emissions are shown in Table 3-2. Although the biodiesel results in substantial reductions in CO emissions from the HDDV fleet (7%-13%), because the HDDV contributes such a small fraction of the total CO emissions, the CO reductions from on-road mobile sources (0.08%-0.19%) and total emissions in the LVV area (0.09-0.18%) are quite small.

Table 3-1. Base year 1996 and base year 2001 CO emissions by emission component for the Las Vegas Valley.

	Emissions (tons/day)			
Emissions Component	**December 9**		**December 20**	
	1996	**2001**	**1996**	**2001**
Area	12.7	14.3	12.7	14.3
Surface Points	22.6	22.6	22.6	22.6
Elevated Points	2.1	2.1	2.1	2.1
On-Road Mobile	415.2	366.6	511.8	451
Total	452.6	405.6	549.2	490

Table 3-2. Reductions from base year 2001 CO emissions by emission component for the Las Vegas Valley due to a 100% and 50% penetration of a B20 biodiesel fuel in the HDDV fleet.

	Emissions Reductions (%)			
Emissions Component	**December 9**		**December 20**	
	50% B20	**100% B20**	**50% B20**	**100% B20**

Table 3-3. Peak estimated 1-hour and 8-hour CO concentrations in the Las Vegas Valley for the 2001 Base Case, 100% B20, and 50% B20 emission scenarios and the differences in CO concentrations between the biodiesel fuel scenarios and standard diesel base case.

	Std. Diesel	**50% B20**		**100% B20**	
Episode	**Peak (ppm)**	**Peak (ppm)**	**Difference (ppm)**	**Peak (ppm)**	**Difference (ppm)**
1-Hour CO Dec 8-9	17.90	17.89	-0.01	17.87	-0.02
8-Hour CO Dec 8-9	9.39	9.38	-0.01	9.37	-0.02
1-Hour CO Dec 19-20	18.38	18.36	-0.02	18.35	-0.03
8-Hour CO Dec 19-20	13.73	13.72	-0.01	13.71	-0.02

4. BIODIESEL IMPACTS ON PM CONCENTRATIONS

There are several areas in the United States that are currently in nonattainment for particulate matter of 10 µm or less (PM_{10}). The PM_{10} NAAQS consists of an annual standard of 50 $\mu g/m^3$ that is not to be exceeded and a 24-hour average standard of 150 $\mu g/m^3$ that is not to be exceeded more than once per year over three consecutive years (i.e., fourth highest in 3 years). In addition, there is a new fine particulate matter ($PM_{2.5}$) standard that will result in new areas being in nonattainment for PM. The form of the $PM_{2.5}$ standard is similar to the PM_{10} standard with annual and 24-hour average thresholds of 15 and 65 $\mu g/m^3$, respectively. The use of biodiesel is estimated to reduce several precursors to PM (e.g., PM, SO_2, and VOC), but increase others (NOx). Thus, the net affect of biodiesel fuel use on ambient PM levels is unclear based on analyzing changes in emissions alone, so it was assessed using air quality modeling.

PM MODELING APPROACH

The SoCAB region of southern California was selected to assess the effects of biodiesel use because: (1) it is currently a PM_{10} nonattainment area; and (2) ammonium nitrate (for which NOx is a precursor) is a major component of the PM. Thus, the SoCAB would provide a conservative (i.e., tending toward overstating any adverse effects) assessment of the impacts of biodiesel fuel on PM because the one PM precursor that biodiesel fuel increases (NOx) is a precursor to ammonium nitrate, which is a major component to PM in the SoCAB. Outside of California, ammonium nitrate is usually a minor contributor to ambient PM. The CAMx photochemical and PM grid model were applied to the SoCAB for an April 1998 through March 1999 annual modeling period to estimate the effects a 100% and 50% penetration of B20 in the HDDV fleet has on ambient PM levels. The effects of biodiesel were separately assessed for particulate sulfate, nitrate, ammonium, elemental carbon (EC), organic carbon (OC), other fine particulate, coarse matter, total PM_{10} mass, total $PM_{2.5}$ mass, and exposure to PM_{10} and $PM_{2.5}$ (Morris and Jia, 2002).

PM MODELING RESULTS

The average effect of using a B20 and B

Table 4-2 summarizes the NOx, VOC, SOx, and PM emissions in the SoCAB domain for the standard diesel and 100% B20 biodiesel emission scenarios and for the summer and winter periods. The difference between the 50% B20 and standard diesel scenario are half that of the 100% B20 scenario. For the standard diesel base case, on-road diesel vehicles account for 22.0%, 0.5%, 0.4%, 7%, and 0.7% of the NOx, VOC, CO, SOx, and PM emissions in the SoCAB, respectively. The change in total NOx, VOC, CO, SOx, and PM emissions in the SoCAB from all sources due to the 100% B20 scenario are, respectively, +0.5%, -0.1%, -0.1%, -1.3%, and –0.1%.

Table 4-2. Summary of domain-wide total on-road diesel (Total DSL), area plus point sources, and total NOx, VOC, CO, SOx, and PM emissions in the SoCAB (tons per day) for the 1997 standard diesel Base Case and 1997 100% penetration of B20 biodiesel scenarios.

	1998 Summer Baseline					**1998 Summer 100% B20 Biodiesel**				
	NOx	**TOG**	**CO**	**SOx**	**PM**	**NOx**	**TOG**	**CO**	**SOx**	**PM**
Total DSL	336.5	13.5	35.3	7.7	8.0	344.5	11.3	30.9	6.2	7.3
On-Road	932.9	860.5	6912.3	38.1	23.7	940.9	858.2	6907.8	36.6	23.1
Area+Point	571.1	1489.3	1466.9	73.3	1076.0	571.1	1489.3	1466.9	73.3	1076.0
Total	1504.0	2349.8	8379.2	111.4	1099.7	1512.0	2347.5	8374.8	110.0	1099.1
						% Change				
Total DSL						2.38	-16.57	-12.55	-19.30	-8.30
Total						0.53	-0.10	-0.05	-1.33	-0.06
	1999 Winter Baseline					**1999 Winter 100% B20 Biodiesel**				
Total DSL	364.1	14.8	31.7	5.4	7.9	372.7	12.4	27.7	4.3	7.3
On-Road	1009.4	944.5	6204.4	26.7	23.6	1018.0	942.0	6200.4	25.7	23.0
Area+Point	503.7	1484.3	1528.4	72.1	1070.7	503.7	1484.3	1528.4	72.1	1070.7
Total	1513.1	2428.8	7732.8	98.8	1094.3	1521.7	2426.3	7728.8	97.8	1093.7
						% Change				
Total DSL						2.36	-16.58	-12.53	-19.31	-8.30
Total						0.57	-0.10	-0.05	-1.05	-0.06

Table 4-3 summarizes the estimated maximum increases and decreases in total PM_{10} and $PM_{2.5}$ mass and PM components due to a 100% penetration of a B20 fuel in the HDDV fleet. The results for the 50% B20 penetration are approximately half those of the 100% B20 penetration scenario. The maximum increases and decreases in $PM_{2.5}$ and PM_{10} mass concentrations are extremely small. The largest PM ions are

Table 4-3. Estimated maximum increases and decreases in PM concentrations (µg/m^3) in the SoCAB due to a 100% penetration of B20 biodiesel in the HDDV fleet.

	Annual Average	Maximum 24-Hour Average
P		

5. IMPACTS OF BIODIESEL FUEL ON AIR TOXICS AND RISK

Diesel particulate matter has been declared a toxic substance by the state of California, and reports from the EPA have also identified it as a toxic compound. In the recent MATES-II study in the SoCAB of Southern California, 70% of the air toxic risk in the SoCAB was identified as being associated with diesel PM (SCAQMD, 2000). The use of biodiesel not only reduces the level of diesel PM mass emissions, but also reduces their toxicity. The impacts from the use of biodiesel in the HDDV fleet on air toxics and risk is discussed below.

EFFECTS OF BIODIESEL ON DIESEL PM EMISSIONS MASS AND TOXICITY

An analysis of engine test data has found that B20 fuel reduces tailpipe diesel PM emissions by approximately 9% and reduces the toxicity of the diesel PM by approximately 5% (Lindhjem and Pollack, 2002). These eff [illegible]

Table 5-1. Diesel particulate matter emissions in SoCAB modeling domain for the three emission scenarios (lb/day).

Source Category	**Standard Diesel (lb/day)**	**100% B20 Biodiesel**		**50% B20 Biodiesel**	
		(lb/day)	**(%)**	**(lb/day)**	**(%)**
HDDV	23239.6	21171.3	(-8.9)	22205.4	(-4.4)
Other On-Road	1668.9	1668.9	(0.0)	1668.9	(0.0)
Other Diesel	19061.1	19061.1	(0.0)	19061.1	(0.0)
Total	43969.6	41901.3	(-4.7)	42935.4	(-2.4)

The air toxics modeling accounted for six air toxics compounds: diesel PM, four organic air toxics (benzene, 1, 3-butadiene, formaldehyde, and acetaldehyde) and hexavalent chromium. According to the MATES-II study, these six air toxic compounds accounts for over 90 percent of the risk associated with exposure to air toxic compounds in the SoCAB (SCAQMD, 2000).

EFFECTS OF BIODIESEL FUEL ON AIR TOXICS RISK

As used in the MATES-II study, species-dependent unit risk factors (URFs) were applied to the air toxics estimates to estimate the one in a million risk of premature death due to long-term

Table 5-2. Average risk (out of a million) of premature death due to exposure to air toxics for the standard diesel base case and the 50% and 100% penetration of B20 biodiesel in the HDDV fleet emission scenarios calculated with no indoor/outdoor (I/O) effects and accounting for I/O effects on an annual average and hourly basis.

	Std Diesel	**50% B20 Fuel**		**100% B20 Fuel**	
Scenario	**Risk**	**Risk**	**(%)**	**Risk**	**(%)**
No I/O Effects	1,950	1,910	(-2.1)	1,835	(-5.9)
Annual I/O Effects	1,284	1,261	(-1.8)	1,216	(-5.3)
Hourly I/O Effects	1,257	1,235	(-1.8)	1,191	(-5.3)

In conclusion, the use of a B20 fuel in the HDDV fleet is estimated to reduce the per million risk of premature death due to exposure to air toxics in the SoCAB by approximately 2% and 5% for the 50% and 100% HDDV fleet penetration B20 scenarios, respectively.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB NO. 0704-0188*

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE May 2003	3. REPORT TYPE AND DATES COVERED Subcontract Report September 16, 1999–January 31, 2003

4. TITLE AND SUBTITLE

Impact of Biodiesel Fuels on Air Quality and Human Health [illegible] 4.4d (p)TAX06 Tw 941408 0 0 9- 0 Td (u)408 0 0