Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California – Biodiesel Characterization and NO_x Formation and Mitigation Study

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Statement of Significance

Renewable fuels are one potentially important strategy to reduce petroleum dependency, air pollution, and greenhouse gases. California has established AB1007 to develop plans to increase the use of alternative fuels in California and has also established greenhouse gas reduction goals. Biodiesel provides potential benefits towards meeting all of these goals. There are a number of limitations in the currently available information about biodiesel, including the true impact on NO_x emissions, how to mitigate NO_x emissions, the potential impact relative to California in-use fuels, the effect of different feedstocks, and the effects for different operating conditions, such as chassis and engine dynamometer testing. CARB is conducting some preliminary work with CE-CERT to evaluate the differences in biodiesel effects for different blend levels and California and EPA fuels. The proposed work will expand on this preliminary study and to investigate the effects of biodiesel under different modes of operation including engine dynamometer, chassis dynamometer transient and steady state, and will a much broader range of biodiesel blended or derived fuels.

Abstract

Increasing the use of biodiesel in the California fleet provides benefits for the enhanced use of alternative fuels and in meeting greenhouse gas reduction targets. This work will build on preliminary testing that is currently being planning to provide a more comprehensive test program for NO_x emissions, and studying different operating conditions, feedstocks, and blend levels. The program will involve engine dynamometer testing and chassis dynamometer testing under transient and steady state conditions. This study will also seek to better understand the mechanism via which NO_x emissions are formed and to find ways to mitigate NO_x emissions from biodiesel use. Testing will include at least 2 different biodiesel feedstocks to evaluate the effects of these differences on emissions and blend levels ranging from B5 to B100. Several potential strategies for reducing NO_x emissions will be investigated including the possibility of match blending or controlling fuel specifications for biodiesel blends, the use of fuel additives, and the new renewable diesel fuels that incorporate biodiesel feedstocks into the refinery process. Intercomparisons will also be made between similar operating conditions on the chassis and engine dynamometer.

Project Background and Objectives

Project Background

The legislature passed AB1007 that requires the ARB and CEC to develop a plan to increase alternative fuels use in California to reduce oil dependency and air pollution. Also, the governor has established aggressive greenhouse emission reduction targets for which the ARB has identified potential strategies such as biodiesel. Biodiesel is an alternative diesel fuel that has the potential to reduce greenhouse gas emissions, other pollutants, and can partially offset our use of petroleum-based fuels. However, knowledge gaps exist and further research is needed in characterizing the impact biodiesel has on NO_x emissions, the effects various feedstocks have on air emissions, and the effect biodiesel has on emissions from off road and post 1997 on road diesel engines. This research is needed to conduct lifecycle analyses and to determine the potential health and environmental benefits and disbenefits of biodiesel. Additionally, for the conditions under which NO_x is found to increase, it is important to identify methods which can mitigate the NO_x increases.

The US EPA published a draft technical report that evaluates the impact of biodiesel on pre 1997 engines. Most of the studies cited in the report were on soy-based biodiesel and its effect on criteria pollutants. A US EPA tier 1 emissions study on criteria and toxic emissions and a tier 2 health effects study were conducted as part of the US EPA fuel registration process. Again, these studies were limited to soy-based biodiesel. Also, a Montreal transit bus study evaluated both criteria and toxic emissions. NREL is currently conducting a study on newer engines. Most of these studies are limited in their direct application to CA because soy-based biodiesel may not be the major feedstock used in CA and or because exhaust emissions from diesel engines fueled with biodiesel were not compared to these engines fueled with CARB diesel. Additionally, most of the available literature has been obtained from engine dynamometer tests, whereas more recent studies have indicated that biodiesel fuels may behave differently in chassis dynamometer or types of tests.

Some studies have also examined mechanisms via which biodiesel might be impacting NO_x emissions. Researchers have suggested a number of explanations including chemical structure (McCormick et al., 2001; Ban Weiss et al., 2005), such as fatty chain length and number of double bonds, or an advancement in timing which could be related to bulk modulus (Szybist et al., 2003 a,b). Some research has also suggested that the impact of biodiesel on NO_x emissions can depend on operating conditions or engine configuration (McCormick et al., 2006). If biodiesel blends are determined to increase NO_x emissions then it is important to find mitigation strategies that make biodiesel NO_x neutral or better when compared to CARB diesel use. It is known that the properties of diesel fuel can affect the emissions of NO_x as well as other emission components (Miller, 2003). It is possible that the fuel specifications of diesel fuel can be altered such that any negative impacts of the biodiesel in the blend could be overcome or such that the properties of the biodiesel blend could be made such that the blend would have the same properties as a typical diesel fuel. Biodiesel could potentially even be incorporated into more traditional petroleum refinery processes as a feedstock. The use of additives and cetane improvers has also shown some potential for reducing NO_x emissions from biodiesel blends (McCormick et al., 2005; Sharp, 1994).

CARB and CE-CERT are conducting a preliminary study to better investigate biodiesel emissions with an emphasis on comparison of biodiesel fuels with CARB diesel fuels. Since much of the emphasis in previous studies has been comparisons with EPA diesel fuel formulations, it is important to better understand the benefits/liabilities relative to California diesel fuels, which tend to have more tightly constrained fuel properties. As part of this program, the emission effects of biodiesel relative to both a CARB diesel fuel and an EPA diesel fuel will be investigated. For this preliminary study, it is planned to test two biodiesel feedstocks with a variety of blend levels. The engine planned for this preliminary study is also expected to be used as one of the primary engines for the present study.

Under this proposed work, this preliminary study will be significantly expanded to investigate a wider range of issues relating to emissions from biodiesel fuels including differences in the effects of biodiesel under different operating conditions. Part of this effort will also focus on better understanding of the principle NOx formation mechanism in biodiesel blends. Research will also be conducted to find ways to mitigate NO_x emissions from biodiesel use including changes in fuel specifications, incorporating biodiesel as a feedstock in the petroleum refinery process, and using additives to reduce NO_x from biodiesel use. Testing will be conducted on an engine dynamometer and on a chassis dynamometer under transient and steady state conditions. Operating conditions will include the FTP, UDDS, and or other potential cycles where cross correlations between chassis and engine dynamometer conditions can be evaluated. For this testing, three biodiesel feedstocks will be utilized with blend levels ranging from B5/10 to B100. A total of up to 6 different engine configurations will be tested under this test program.

Project Objectives

The objective of this program is to provide a comprehensive program to study the effects of biodiesel as a function of type of feedstock, blend level, operating condition/test method, and engine type. A primary emphasis of this program will be understanding the effects of biodiesel on NO_x emissions. Methods by which NO_x emissions from biodiesel blends can be mitigated will also be investigated. Another important objective will be to better understand the effects of differences in operation on biodiesel emissions by comparisons between chassis, on-road, and engine dynamometer testing. Testing will be conducted on at least one engine in a vehicle that will be tested on a chassis dynamometer and have the engine removed for engine dynamometer test so that changes over the different dynamometer conditions. Operating conditions will include the FTP, UDDS, and or other potential cycles where cross correlations between chassis and engine dynamometer conditions can be evaluated. For this testing, at least biodiesel feedstocks will be utilized with blend levels ranging from B5/10 to B100, as well as other specialty blends with unique fuel blending, refinery processing, or the addition of additives. A total of up to 6 different engine configurations will be tested under this test program.

Detailed Work Plan

Overview of Approach

The primary focus of this program will be the testing of different biodiesel feedstocks and blend levels over different operating conditions on an engine dynamometer and a chassis dynamometer under transient and steady state conditions and for different engine types. The scope of work will essentially be divided into nine tasks: Task 1 – program planning and fuel and engine acquisition;

Task 2 – sample media organization and storage; Task 3 – chassis dynamometer testing; Task 4 – engine dynamometer testing for biodiesel characterization; Task 5 – engine dynamometer testing for NO_x mitigaton; Task 6 – Testing of off-road engines at the CARB Stockton facility; Task 7 – Toxicity and Biological Testing; Task 8- Compilation of Speciation, Toxicity, and Biological Testing data; and Task 9 – Reporting

Task 1 Program Planning and Fuel and Engine Acquisition

CE-CERT will work in conjunction with the ARB and appropriate stakeholders to identify test fuels for the program. The test fuels will include a CARB ultralow sulfur diesel (ULSD) and two biodiesel feedstocks. The specific biodiesel feedstocks will be determined as part of the planning process, but will likely include a soy-based biodiesel and a yellow-grease biodiesel. Additionally, a number of different blend stocks will be formulated to evaluate the potential for NO_x mitigation. A summary of the expected approaches for NO_x mitigation is as follows:

Fuel specifications: Fuel specifications will be evaluated to determine if specifications such as distillation and density can be adjusted to result in a NO_x neutral biodiesel fuel. Match blending will be evaluated as part of this effort. Match blending is where the diesel portion is adjusted so that the biodiesel blend has the same physical properties as diesel.

Refinery Processing: The potential of developing a new generation of renewable fuels will be evaluated. These fuels would incorporate biodiesel feedstocks into the refinery process to produce non-oxygenated feedstocks that can be used to produce diesel fuel.

Fuel Additives: The potential impact of fuel additives on reducing NO_x emissions will be evaluated. Promising fuel additives will be utilized in various biodiesel fuels against CARB ULSD fuel.

Funds for the purchase of all fuels are included in the budget. If it is found that fuels can be obtained through in-kind contributions, the monies will be redirected to the testing effort.

Fuel analyses will be conducted on the CARB ULSD (D975) and each of the neat biodiesels (D6751). Fuel analyses will also be conducted on the finished blends at levels of B5, B20, B50, and B100 to ensure/evaluate the quality of the blending.

Several options will be examined for acquisition of testing engines include the Engine Manufacturers Association (EMA) and other interested stakeholders. The costs associated with engine acquisition are planned to be covered under separate funding of $50,000 from the South Coast Air Quality Management District, and as such are not included in the budget for this program.

For the purposes of this study, a technical advisory board will be convened. The technical advisory panel will consist of experts from government, industry, and academia. This could include, but will not be limited to, representatives from the Coordinating Research Council and the National Renewable Energy Laboratory. CE-CERT will work in conjunction with ARB and appropriate stakeholders to review the relevant literature with respect to the impacts of biodiesel on NO_x emissions. CE-CERT will work in conjunction with the ARB and the technical advisory board to develop a test matrix and matrix of fuel properties, blends, or additives for testing. It is expected that experts from the petroleum industry will provide significant input into this process. A test plan will be developed for the test program and will be provided for CARB approval prior to the initiation of testing. In particular, it is recognized that the technical advisory will provide considerable expertise in the development of a test plan and in the various formulation strategies for the NO_x mitigation portion of the study.

Task 2 Sample Media Organization and Storage

CE-CERT will work in conjunction with the ARB to organize the sample media for collection of samples for subsequent chemical analyses of 1,3 butadiene, VOCs, carbonyls, PAHs, elements, OC/EC, as well as a range of other species. CE-CERT will provide for sample storage and shipping to appropriate laboratories for analysis and to CARB for their use.

Task 3. Chassis Dynamometer Testing at the CARB LA Test Facility

Testing at the CARB chassis dynamometer facility in Los Angeles will be conducted on several vehicles on a CARB base fuel and various blends of the biodiesel feedstocks. The test matrix for a single vehicle is provided in the table below and is expected to be the same or very similar for all vehicles. The blends will range from B5/10 to B100. Test cycles will include the UDDS and another transient test cycle or steady state conditions to be determined. To the extent possible, all testing on a particular vehicle will be conducted over the same period to ensure the most consistent and repeatable data set.

Table 1. Los Angeles CARB Chassis Dynamometer Test Matrix For each Test Vehicle

	UDDS	Cycle TBD
CARB	3	3
SoyB10	3	3
SoyB20	3	3
Soy[illegible]	3	3
SoyB100	3	3
CARB	3	3
YGB10		
YGB20	3	3
YGB50		
YGB100	3	3
Sub-total	24	24

Total 48

A total of three vehicles is anticipated for this program. Each will repeat the same test matrix. For one of the three vehicles, it is planned to have the vehicle equipped with a diesel particulate filter. For this vehicle, the test matrix will be repeated with and without the DPF. The option to test up to two more vehicles on the chassis dynamometer will be considered during the planning process depending on test cell availability and costs.

For at least one vehicle tested on the chassis dynamometer, the engine will be utilized for cross comparisons on an engine dynamometer. This engine will be removed from the vehicle and then utilized in task 4 below. This same engine will also be utilized as part of a pilot project that will be conducted at UC Riverside prior to the chassis dynamometer testing. In conjunction with the chassis dynamometer testing, data on the engine load and rpm will be collected during the ARB transient cycle. These data will be used for subsequently developing an engine dynamometer test cycle to provide operating conditions as similar as possible to those found on the chassis dynamometer.

Task 4. Engine Dynamometer Testing – Biodiesel Characterization Test Matrix

Two engines will be tested over a test matrix that includes blends ranging from B5/10 to B100 for three biodiesel feedstocks. Engine tests will be performed in CE-CERT's Engine Dynamometer Test Laboratory. At least one of the engines will be the same as that being used for chassis dynamometer testing at CARB's chassis dynamometer test facility in Los Angeles. The engine removal will be performed by a local outside repair facility that CE-CERT works with on a regular basis.

Test cycles will include the FTP and a UDDS cycle performed at two different loads. The UDDS cycles will be based on the engine parameters gather during the chassis dynamometer testing at the CARB facility. The UDDS cycles will be programmed into the engine dynamometer computer program. The software for the dynamometer computer will be upgraded to allow the addition of different cycles with different transient conditions.

A proposed sample test matrix that will be used for both engines is provided in the table below. The test matrix includes replicates for the CARB diesel fuel to provide a measure of long-term repeatability. The engine tests will be performed over the same testing period to the extent possible, to allow the best comparability over the set of fuels to be tested. For each test matrix point, 6 test cycle iterations will be performed in a single test day.

Table 2. Engine Dynamometer Test Matrix for each Engine

	Engine 1		
	FTP	UDDS (Load 1)	UDDS (Load 2)
CARB	6	6	6
SoyB5/10	6	6	6
SoyB20	6	6	6
SoyB50	6	6	6
SoyB100	6	6	6
CARB	6	6	6
YGB5/10	6	6	6
YGB20	6	6	6
YGB50	6	6	6
YGB100	6	6	6
Sub total	60	60	60
Total			180

Samples for chemical analysis for assays, PAHs, and nitroPAHs will be collected for tests number in parentheses for the FTP test cycle iteration, but only for a single engine. This represents a total of 27 samples. Samples for detailed hydrocarbons C_1-C_{12} and carbonyls will be collected for the tests noted in parentheses and shaded in turquoise, but for both engines. This represents a total of 48 samples.

Since it is planned that one of the two test engines planned for this portion of the testing will be utilized, a portion of the testing shown in this test matrix could potentially be performed during the preliminary study. This could include, for example, the testing associated with the FTP test cycles for the base fuel and the different blend levels on the Soy-based biodiesel fuel. If such cost saving are realized, the test matrix could potentially be expanded to evaluate other test parameters of interest.

Task 5. Engine Dynamometer Testing – NO_x Mitigation Test Matrix

The test matrix for the engine testing is designed around testing two engines over a range of different potential feedstock/additive combinations. The different biodiesel blend formulations or additive combinations are generically termed blend formulations 1-6 in the test matrix below. The specific combinations of blend or additive formulations will be determined in conjunction with the technical advisory committee. This also provides flexibility in the number of biodiesel blends that will be specified in either the fuel specification, match blend, refinery blend, or additive categories. For each blend formulation, two variations are included in the test matrix, as denoted as "a" and "b". This will allow for the testing of two applications of a formulation that shows promise, be it two levels of biodiesel blend or two levels of an additive. The test matrix includes replicates for the CARB diesel fuel to provide a measure of long-term repeatability. For each test matrix point, 6 test cycle iterations will be performed in a single test day.

The two engines to be utilized for testing will be the same engines utilized for a companion project with CARB for the characterization of biodiesel. The will provide synergies and costs savings between the two programs in terms of replication and engine set-up. One of these engines will also be utilized in testing at the CARB LA chassis dynamometer test facility, as part of the companion biodiesel characterization project. Test cycles will include the FTP and a UDDS cycle similar to the cycles used in the biodiesel characterization project. The UDDS cycle will be performed at only a single load point, however.

Samples for chemical analysis for assays, PAHs, and nitroPAHs, detailed hydrocarbons C_1-C_{12} and carbonyls will be collected for tests number in parentheses for the FTP test cycle iteration on a single engine. This represents a total of 12 samples.

Table 3. Engine Dynamometer Test Matrix for each Engine

	Engine 1	
	FTP	UDDS
CARB	6 (3)	6
Blend formulation #1a	6 (3)	6
Blend formulation #1b	6	6
Blend formulation #2a	6 (3)	6
Blend formulation #2b	6	6
Blend formulation #3a	6 (3)	6
Blend formulation #3b	6	6
CARB	6	6
Blend formulation #4a	6	6
Blend formulation #4b	6	6
Blend formulation #5a	6	6
Blend formulation #5b	6	6
Blend formulation #6a	6	6
Blend formulation #6b	6	6
CARB	6	6
Sub total	**90**	**90**
Total		**180**

Task 6. Testing of Off-Road Engines at the CARB Stockton Facility

Testing is planned for two off-road engines at the Stockton facility. CE-CERT will provide oversight for this testing, but the actual testing and sampling will be conducted by CARB representatives. At the Stockton chassis dynamometer facility, tests will be conducted on the CARB base fuel and various blends with two biodiesel feedstocks. The blends will range from B5/10 to B100. The steady state 8 mode test will be used for the test cycle. A sample test matrix is provided below. Samples for chemical analysis will be collected at the test points denoted in pink.

Table 4. Stockton CARB Chassis Dynamometer Test Matrix for each Off-Road Test Vehicles

	Chassis 6– Off road 8 mode	Chassis 7– Off road 8 mode
CARB	3	3
[illegible]	3	3
[illegible]	3	3
[illegible]	3	3
[illegible]	3	3
CARB	3	3
[illegible]		
[illegible]	3	3
YGB50	3	3
YGB100	3	3
Total	54	54

Task 7 Detailed Speciation, Toxicity and Biological Analyses

Speciation of toxics and biological testing of the biodiesel exhaust will primarily be carried out by researchers at UC Davis including PAH/nitro-PAHs, carbonyls, and biological tests. In conjunction with this, researchers at CE-CERT will make some measurements of volatile organic compounds.

From the test matrix provided above, 36 carbonyl and C_1-C_{12} VOC samples will be collected during the biological characterization portion of the engine testing, with an additional 12 carbonyl and C_1-C_{12} VOC samples collected during the NO_x mitigation portion of the engine testing. Provisions are provided for an additional 9 carbonyl and C_1-C_{12} VOC samples, which will be used for some combination of tunnel or trip blanks or repeat tests, however there is limited knowledge on the concentration of some of these carbonyls because some of these carbonyls have not been previously measured in diesel exhaust, some of the carbonyl samples may need to be used for range finding to ensure the amount of carbonyls collected in the samples are not outside the range of the sample collection media.

From the test matrix provided above, 24 samples for biological assays, PAH and nitroPAH analyses will be collected during the biological characterization portion of the engine testing, with an additional 12 samples for biological assays, PAH and nitroPAH analyses will be collected during the NO_x mitigation portion of the engine testing. Provisions are provided for an additional 9 biological assays, PAH and nitroPAH samples, which will be used for some combination of tunnel or trip blanks or repeat tests.

(A) Sample Preparation

UCD personnel will prepare media used for sampling. Media includes filters to collect PM, and XAD to collect volatile/semivolatile compounds for PAH/nitro-PAH analyses and biological tests, and aqueous solution to collect carbonyls. Filters and XAD will be pre-cleaned by solvents (hexane, acetone, and/or dichloromethane). Filters will be pre-weighed and sampling cartridges will be assembled. Mist chambers and collection tubes for carbonyl analysis will be prepared.

(B) Sample collection

UCD personnel will setup high volume air sampling system with filter+XAD for PAH/nitro-PAH analyses and biological tests, and mist chambers for carbonyl analysis, and conduct sampling. After sampling, post-sampling weight of filters will be determined in a temperature and humidity controlled weighing room, Filter and XAD samples will be shipped to the UCD lab. Trapping and derivatizing solution for carbonyls will be transferred to vials and shipped to the lab in Arizona State University (ASU). Blue ice and insulated shipping containers will be used for shipping samples.

In conjunction with each test for which a carbonyl sample is collected, CE-CERT researchers will collect a sample for C_1-C_{12} detailed hydrocarbons in Tedlar bags.

(C) Sample analysis

UCD lab staff will extract filter and XAD samples for biological tests and PAH/nitro-PAH analyses. Human lung and macrophage cell assays will be conducted for filter samples by UCD, and the Comet assay will be conducted for filter samples by UCD in collaboration with USEPA. Mutagenicity test (Salmonella/microsome microsuspension assay) and PAH/nitro-PAH analyses will be conducted for filter and XAD samples at UCD. Extraction of mist chamber solutions and analysis of carbonyls will be conducted at ASU. The target compound list for the carbonyl and PAH analyses is provided in Table 5.

At CE-CERT, Tedlar bag samples for C_1-C_{12} hydrocarbons will be analyzed using a GC-FID and protocols consistent with those used in earlier Auto-Oil related programs, with some additional provisions for the sampling of diesel exhaust.

Table 1. Target compounds for chemical analyses (PAHs requested by ARB are highlighted)

Carbonyls	PAHs
Saturated aldehydes	NitroPAHs
acetaldehyde	1-nitronaphthalene
propanal	5-nitroacenaphthene
butanal	2-nitrofluorene
pentanal	9-nitroanthracene
3-methylbutanal	3-nitrofluoranthene
hexanal	1-nitropyrene
heptanal	6-nitrochrysene
octanal	7-nitrobenz(a)anthracene
2-methylpropanal	6-nitrobenzo(a)pyrene
Unsaturated aldehydes	Alkylated PAHs
acrolein	1-methylnaphthalene
crotonaldehyde	2-methylnaphthalene
3-methyl-2-butenal	2,6-dimethylnaphthalene
2-hexenal	2,3,5-trimethylnaphthalene
2-heptenal	1-methylphenanthrene
	3-methylcholanthrene
Aromatic aldehydes	2-methylfluoranthene
benzaldehyde	5-methylchrysene
o,m-tolualdehyde	7,12-dimethylbenz(a)anthracene
p-tolualdehyde	
2-ethylbenzaldehyde	Unsubstituted PAHs
3,4-dimethylbenzaldehyde	naphthalene
4-methoxybenzaldehyde	acenaphthylene
1-naphthaldehyde	acenaphthene
	fluorene
Diones	phenanthrene
2,3-butanedione	anthracene
2,3-pentanedione	fluoranthene
3,4-hexanedione	pyrene
2,4-pentanedione	chrysene
2,3-hexanedione	benz[a]anthracene
	benzo[b]fluoranthene
Other compounds	benzo[j]fluoranthene
glyoxal	benzo[k]fluoranthene
methyl glyoxal	benzo[e]pyrene
2-furaldehyde	benzo[a]pyrene
nopinone	perylene
pinonaldehyde	indeno[1,2,3-cd]pyrene
	dibenz[a,h]anthracene
	dibenzo[a,e]pyrene
	dibenzo[a,h]pyrene
	dibenzo[a,l]pyrene
	dibenzo(a,i)pyrene

Task 8 –Compilation of the Chemical Analysis Data

Samples collected and analyzed by researchers from UC Davis will be analyzed and confirmed by UC Davis using established QA/QC criteria. The data will be reduced to chemical mass per cycle. Statistical analysis including ANOVA, Student's t-tests and regression analysis will be conducted by UC Davis for biological data to compare biological response among samples, blank, positive and negative controls, and to correlate response to concentrations. CE-CERT will compile these results into a single file to provide a comprehensive database for the program. Additional statistical analyses will be conducted by CE-CERT to compare the results for chemical analyses between the different biodiesel feedstocks and blend levels to be used in the test matrix.

Task 9 –Reporting and the Final Report

A final report will be prepared for CARB incorporating the results from the engine dynamometer testing. The final report will include a description of the experimental procedures used, all relevant test data for PM and regulated emissions, and analysis of the test results. All reduced data will be made available to CARB investigators in an appropriate format. Summary plots will be prepared for the primary emissions results. The results will also be compared to previous studies and assessed in that context.

The draft report will be provided to CARB for review. The schedule incorporates 1 month for CARB to provide comments on the draft final report and 1 month for CE-CERT to incorporate any changes based on the CARB comments. Upon approval by CARB, the findings will be jointly reported for peer-review and publication.

In addition to the comprehensive final report, summary reports will be provided for the results of different tasks or subtasks. In particular, separate summary reports for the regulated and unregulated emissions for the biodiesel emissions study and the NO_x mitigation study.

Bimonthly progress reports will also be prepared throughout the course of the program. CE-CERT and UC Davis researchers will also be available as needed for conference calls relating to program planning or results presentations. The budget also includes travel for 4 trips to Sacramento for data presentation/planning, as needed.

Deliverables

The results will be summarized in a final report prepared under task 9. Data from the emissions testing for regulated and speciated emissions, as well as biological and toxicity testing will be compiled and put into an electronic format. Electronic copies of all data collected, pictures, data logs, and any other appropriate information shall be provided to CARB in a suitable format.

Project Schedule

A project schedule is provided below for the major tasks. The schedule is based on number of months based from the point of authority to proceed. It is anticipated that this project will be completed within a 24 month period.

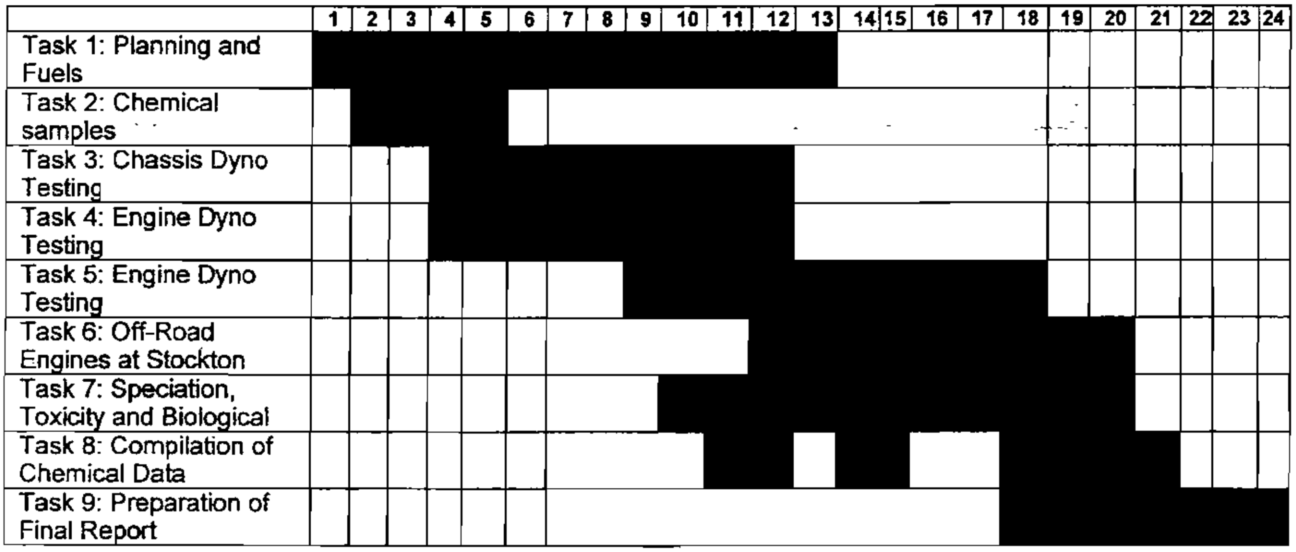

Table 1 Schedule of major milestones for the project.

Project Management Plan

The figure below is an organizational chart for this project. Drs. Tom Durbin and Wayne Miller will serve as the co-Principal Investigators. Dr. Durbin will be the primary point of contact for CARB staff for all planning and execution of project activities. He will also be primarily responsible for communication, resolution, and overall coordination of activities. Dr. Miller will assist with the oversight and development of the overall program, and assist in the preparation of reports/manuscripts documenting the results. The PIs will be assisted by Kent Johnson and Dave Martis who manage the engine dynamometer testing facilities at CE-CERT. Mrs. Kathalena Cocker will also assist Dr. Durbin with the VOC analyses that will be done at UC Riverside.

The main portion of the toxics and biological testing will be performed by researchers from UC Davis. Dr. Reiko Kobayashi will serve as PI for this portion of the work. She will be responsible for sample preparation, sample collection, sample shipping, extraction of filter and XAD samples for biological tests and PAH/nitro-PAH analyses, and quantitative chemical analyses of PAH/nitro-PAHs. Dr. Norman Kado (UCD) will serve as the Co-PI and will be responsible for mutagenicity tests and for Comet assay in collaboration with Dr. Mike Madden (USEPA). He will also help sampling setup and sample collection. Dr. Fumio Matsumura (UCD) will oversee studies using human cell and macrophage cell assays. Dr. Chris Vogel (UCD), will be responsible for selecting proper primers for each marker selected, guide the technical staff for the use of the lightcycler (RT-PCR) and oversee the actual human lung and macrophage cell assays and data analyses. Dr. Patrick Wong (UCD) will be responsible for culturing cells, characterization of markers, media selection, maintenance of low passage cultures for human cell and macrophage assays, and the quantitative RT-PCR. Dr. Thomas M. Cahill (ASU) will be responsible for extracting and analyzing carbonyls. He also will provide the sampling team with the protocol for sampling method (using mist chambers) for carbonyl analyses.

Biographies of all key personnel are presented after the figure.

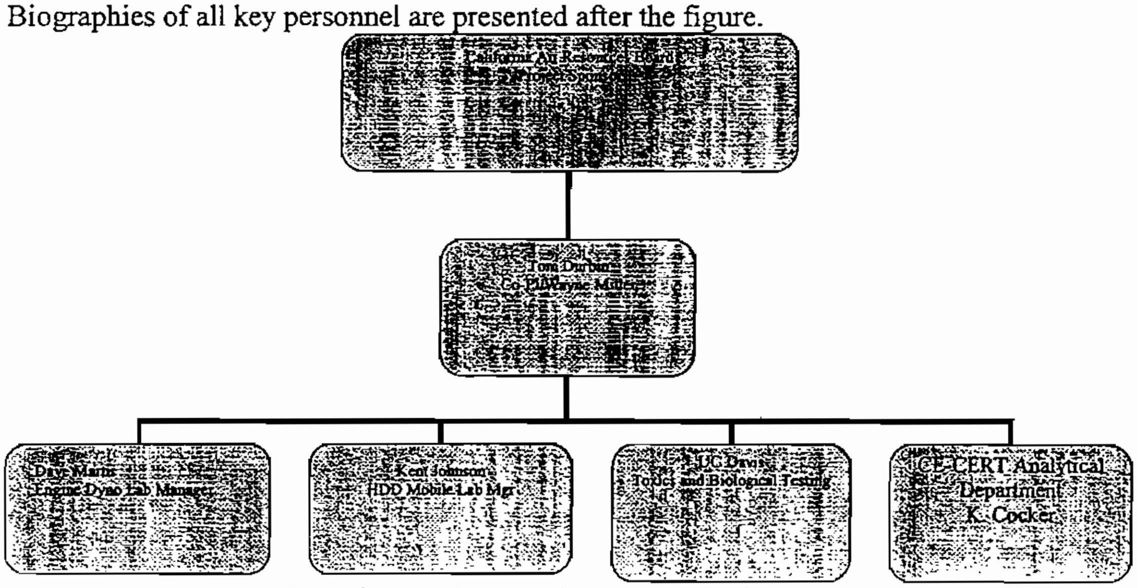

Figure 1 Organization Chart for the Key People Involved in the project