Attachment 6

Reviews of Renewable Diesel Assessment Reports and Supporting Documents (7)

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b) Tracey Holloway, Ph.D. - University of Wisconsin - Madison
c) An Li, Ph.D. - University of Illinois - Chicago
d) Stephen Nesnow, Ph.D. - Stephen Nesnow Consulting
e) Lisa A. Rodenburg, Ph.D. - Rutgers University
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January 7, 2014

Gerald W. Bowes, Ph.D.
Manager, California Environmental Protection Agency
Scientific Peer Review Program
Office of Research, Planning, and Performance

Dear Dr. Bowes:

I have reviewed the **Staff Report: Multimedia Evaluation of Renewable Diesel** including 10 appendices. My expertise is microbial engineering that is applied to biodegradation of organic contaminants, transport and fate of bacteria in soil and aquifers, biofilm reactors, and contaminated sediments. I am providing external scientific peer review comments below mainly for the two sections on Water Evaluation and Soil and Hazardous Waste Evaluation.

Water Evaluation. The chemical properties and composition of renewable diesel without additives are similar to that of petroleum diesel (CARB diesel), so I agree with the conclusion that there are likely to be minimal additional risks to the waters of California from the use of renewable diesel. A general tendency is that liquid products from biomass are highly biodegradable under the proper conditions. For example, most liquid petroleum hydrocarbons (e.g., gasoline, diesel, jet fuel, and oils) can be biodegraded under aerobic conditions by many different species of bacteria. Several of these species of bacteria capable of petroleum hydrocarbon biodegradation are commonly found in rivers, lakes, and oceans and in the subsurface. Consequently, these liquid products tend not to persist for long periods when they are released to the environment. The biodegradability of renewable diesel and CARB diesel will be similar, so there is not an expected increase in risk from the use of renewable diesel in comparison to CARB diesel when they come in contact with surface waters or groundwaters.

The one factor that "clouds" the above conclusion is that additives are likely to be introduced in almost all renewable diesel blends. These additives address issues of oxidation, corrosion, foaming, cold temperature flow properties, biodegradation during storage, and water separation. As long as the expectation holds that renewable diesel will employ additives similar to those used currently in CARB diesel, then it follows that the health and environmental impacts of the two mixtures will be similar. If different additives are employed that might make the renewable diesel mixture either more toxic or less biodegradable, then additional studies will need to be conducted to demonstrate the environmental health and safety of the renewable diesel mixture planned for use.

Soil and Hazardous Waste Evaluation. Essentially, the same analysis provided for the Water Evaluation above applies for this topic. The similar chemical properties and composition for renewable diesel and CARB diesel means that the transport and fate of the two products should be similar if they are released to the subsurface. Consequently, there is not likely to be an increased risk to the environment with the use of renewable diesel. The limited knowledge regarding the additives that will be used for renewable diesel does add uncertainty to this conclusion. If such additives are different from the ones used for CARB diesel, then there is potential for the renewable diesel mixture to behave differently in the environment, such as increased toxicity or reduced biodegradability. If different additives are used for renewable diesel, then additional studies are recommended to properly document the new transport and fate properties.

In addition to the above comments for the major conclusions offered by the Staff Report, I provide following comments on specific sections of the report:

1. The Opening Glossary should contain CARB. The opening section does not define CARB diesel (page 4). CARB diesel is defined later in the report. If a reader starts with the opening section as I did, it will be confusing to not have a definition of CARB diesel up front. I believe that "conventional petroleum diesel" or simply "petroleum diesel" is another term that is synonymous with CARB diesel. The broader community is likely to be more familiar with the term conventional petroleum diesel or petroleum diesel in comparison to CARB diesel.

2. Add CARB to the list of acronyms on page 8 of Appendix A. ARB is listed, but not CARB.

3. In Appendix C on pages 10 and 11, the figure captions should be modified. The phrase "relative to CARB diesel" implies that the data are normalized to the CARB diesel value. Such normalized values are not plotted. The results for each of the test conditions are plotted to make an easier visual comparison between the CARB Diesel and the R20, R50, and R100 values. As an example, the Graph 1 caption should read "PM Emissions of R20, R50, R100, and CARB Diesel". The data points connected by lines on pages 10 and 11 imply that there is a predictive relationship between the different blends and the CARB Diesel. It is recommended that the data be plotted as a stacked column or bar chart to convey the data visually to avoid using a line plot.

4. On page A-52 in Appendix G, there is a Section 8 with header Environmental Transport and Fate of Renewable Diesel. The second paragraph on page A-52 has a poorly worded opening sentence regarding the environmental behavior of renewable diesel and conventional ULSD. I agree with the first theme that the chemical composition of renewable diesel is similar to conventional ULSD, so that behavior of these two products in aquatic and soil systems will be similar. The second theme of the opening sentence is poorly worded. I believe the intent of the sentence is to state that existing models and measurements are not able to reliably predict any differences in the behavior of renewable diesel and conventional ULSD. The suggested text better supports the conclusion that the use of renewable diesel does not pose a significant adverse impact on public health or the environment relative to CARB diesel.

5. The Staff Report on Multimedia Evaluation of Biodiesel indicates that there are material compatibility issues between biodiesel and CARB diesel. There is limited discussion

about material compatibility with renewable diesel on page A-41 of Appendix G because of limited data. As stated on page A-52, the chemical composition of renewable diesel is similar to that of CARB diesel. It should then follow that few material incompatibilities are expected for renewable diesel in comparison to CARB diesel. A few sentences to strengthen the discussion of compatible materials will be helpful.

6. As acknowledged thoroughly in the report, the presence of additives in the renewable diesel is a source of uncertainty for the chemical and physical properties of the renewable diesel (e.g., page A-54 in Appendix G). It would be helpful to provide some documentation on whether or not existing stocks of renewable diesel are likely to contain the same additives used in CARB Diesel. The database might be limited, but any evidence to support a statement about identical or similar additives will be helpful to support a conclusion that renewable diesel is just as acceptable as CARB diesel.

7. Typos: Appendix G, page A-52: line 5 from the bottom: "lease" should be "least".

Sincerely,

Edward J. Bouwer, Ph.D.
Abel Wolman Professor of Environmental Engineering
Department Chair

Review of

"Staff Report: Multimedia Evaluation of Renewable Diesel"
Prepared by the Multimedia Working Group

Tracey Holloway, Ph.D.
University of Wisconsin--Madison

The California Air Resources Board (ARB) is proposing the development of new regulation for renewable diesel. Like biodiesel, renewable diesel is made from vegetable and animal oil feedstocks, but produced through different processing, and with different chemical composition. Renewable diesel is considered a potentially desirable fuel alternative, given the lower carbon intensity relative to petroleum diesel fuel and other possible benefits. In this report, all conclusions about renewable diesel are given relative to diesel fuel meeting ARB specifications, referred to in the report as "CARB diesel."

This review follows the topical areas of the MMWG report:

1. Renewable Diesel

Overall, the conclusions of the staff report are supported by the California Renewable Diesel Multimedia Evaluation (Final Tier I and III reports; there was no Tier II) from researchers at UC Davis and UC Berkeley. In particular, the major conclusion that "the use of renewable diesel in California...does not pose a significant adverse impact on public health or the environment relative to CARB diesel" is in line with the findings of the Multimedia Evaluation.

Although the report uses nomenclature of R20, R50, and R100 to reflect blending levels, where R20 = a 20% by volume blending of renewable diesel with CARB diesel, Appendix A defines only B5 and B20 and does not provide similar definitions of R20, etc.

a. Air Emissions Evaluation

The conclusion that "the use of renewable diesel does not pose a significant adverse impact on public health or the environment from potential air quality impacts" is supported by the Multimedia Evaluation and discussion in the staff report. This conclusion is based on an analysis of criteria pollutant emissions (including ozone precursor emissions), toxic air emissions, and greenhouse gas emissions.

There is a small typo, in that p. 6, paragraph 3 refers to the Tier II report from the UC multimedia assessment, whereas the renewable diesel evaluation only included Tier I and III reports.

Conclusions are drawn primarily from emission tests conducted at UC Riverside and at ARB test facilities. All emissions types decrease, except for a small increase in CO emissions under certain operating conditions. These emission reductions suggest benefits to renewable diesel as a substitute for CARB diesel. Appendix C is especially helpful in presenting these results graphically.

The findings of the air emissions evaluation are also presented in the health evaluation, Section C1 (p. 8-13). It would be useful to integrate Section A and C more clearly, and separate the emission test results for renewable fuels (which belong in Section A) from the toxicity and health impacts (which belong in Section C).

Section A1. (p. 6) is labeled "Criteria Pollutants." This section should begin with a discussion of what pollutants fall into this category, and which are evaluated here for renewable diesel. As written, Section A1 includes PM, nitrogen oxides (NO_x = NO + NO_2), total hydrocarbons (THC), carbon monoxide (CO) and brake specific fuel consumption (BSFC). However, THC and BSFC are not criteria pollutants and do not belong in this section. SO_2 is a criteria pollutant that is not discussed here, but is referenced in the "Renewable Diesel Background Information" on p. 4. Section A1 should report should comment on all criteria pollutant emissions (or precursor emissions) in some way, and omit discussion of metrics that are not criteria pollutants.

Section A3 (p. 7) discusses "Ozone Precursors." Because ozone is a criteria pollutant, this section would seem to be a better fit with Section 1 and/or follow directly afterward. For the benefit of readers unfamiliar with ozone chemistry, some brief comment should be added explaining that THC and NO_x emissions create ambient ozone.

Section A4 (p. 7) reports on Greenhouse Gas Emissions. This section would benefit from a number of changes. First, clarifying which greenhouse gas emissions have been evaluated - it appears only CO_2. It would also benefit from more detail on what steps in the lifecycle were considered. In particular, it would be helpful to note that the 80% reduction in GHG emissions would arise from tallow feedstock use, whereas the 15% reduction in GHG emissions would arise from soybean production in the Midwestern U.S. Detail on this point is provided in Appendix C, but a brief comment in the main report would improve clarity.

In the main discussion of renewable diesel lifecycle assessment in Appendix C (p. 12), more detail would also be useful. Table 8 presents two of the four scenarios based on tallow, which is assumed to have no indirect carbon intensity. Some comment should be included on the source of the tallow, and whether it is assumed to be a waste product.

b. Water Evaluation

The MMWG concludes that renewable diesel is equivalent to CARB diesel in terms of aquatic toxicity, compliance with underground storage tanks, biodegradability, and other factors. These conclusions are consistent with the UC multimedia evaluation.

c. Public Health Evaluation

Overall, the public health evaluation seemed to be provided with too much detail to clearly assess main points. Also, the content was somewhat redundant with the air emissions evaluation.

Conclusions that health-relevant air emissions are reduced with renewable diesel are well supported. Conclusions about emissions toxicity are uncertain due to limited testing. This result is consistent with the Tier III report, but should be stated more clearly.

d. Soil and Hazardous Waste Evaluation

Hazardous waste is outside the expertise of this reviewer. However, the discussion overall was clearly presented and seemed consistent with findings from the Multimedia Evaluation.

Review Comments

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Submitted to Dr. Gerald W. Bowes (Gerald.Bowes@waterboards.ca.gov) on January 7, 2014

Document Reviewed: Staff Report: Multimedia Evaluation of Renewable Diesel by the Multimedia Working Group (MMWG), California Environmental Protection Agency, November 2013

Topic/Area Reviewed: Surface and Ground Water Quality

Summary Comments

The document reviewed here is a Staff Report prepared by MMWG of CEPA for the California Environmental Policy Council (CEPC), which will determine whether the proposed regulation on commercialization of new alternative diesel fuels poses significant adverse impact on public health or the environment. This is part of the process towards legally accepting and commercializing alternative diesel fuels in California.

The assignment to this reviewer is to help determine whether the scientific portions, particularly in the water quality section, of the MMWG Staff Report are based upon sound scientific knowledge, methods, and practice. The sections regarding water quality are mostly based on the evaluation by the State Water Resources Control Board (SWRCB) (Appendix D). The scientific knowledge is provided primarily in the Final Tiers I and III Reports (Appendix G).

I have read the main Staff Report and its Appendices A, D, and G. I consider the tiered multimedia evaluation well designed, and the Tiers Reports (Appendix G) were well written. In Tier I, the key knowledge gaps were identified through literature search, and a work plan was built, reviewed and revised. Tier II provided new experimental data showing the reduced emissions of most air pollutants including PM, CO, most PAHs, and, in contrast to biodiesel, NOx, from blended renewable diesels. Tier III is a summary of all the work with qualitative risk assessment in some sections. The Proposed Regulation Order (Appendix A) specifies the stages for commercializing new alternative diesel fuels.

Provided below are my Overall comments, Comments on water quality impact assessment, and Document specific minor comments.

Overall Comments

1. Within the scopes of my review and my expertise, I do not found the major flaws in the scientific knowledge, methods, and practice presented in the main Staff Report and its Appendices A, D and G.
2. The major MMWG conclusion – renewable diesel specifically evaluated within the scope of the evaluation will not cause a significant adverse impact on public health or the environment – is reasonable given the similarities and advantages of renewable diesel when compared with petroleum based CARB diesel. The chemistry and the technology (e.g. hydrocracking) for producing renewable diesel from the intended feedstock are basically the same as those petroleum industry has been using

for many decades. The advantage and benefits of adopting renewable diesel outweigh the slightly lowered fuel efficiency and the potential risks.

3. I suggest summarizing the limitations of this multimedia evaluation in the main Staff Report, section I-C. Some limitations are well described in the Tiers Reports, but are absent in the Staff Report. The limitations are different from the conditions in section IV Recommendations part 2 (page 17).
4. The definition of R20 (similarly Rxx) is a bit confusing to this reviewer. It seems both blended (20% R100 + 80% CARB diesel) and co-processed (manufactured by co-processing petroleum and some bio-source, such as tallow as in the case shown in Tier-I Report pages A-36 to A-38) renewable diesels are called R20. A clarification somewhere can be helpful. If the "Rxx" is based on chemical composition of the final product regardless its production methods (blended or co-processes), please say so.
5. No comparison between renewable diesel and biodiesel was made. The advantages of each over the other are quantitatively or qualitatively mentioned. According to UOP (2005), renewable diesel has a lower environmental impact than biodiesel and requires less capital investment to produce. This is in agreement with what I learned from reading the documents provided. However, I failed to find answers to the questions whether biodiesel is indeed needed and why biodiesel is being proposed as the first alternative diesel fuel in California, given the apparent advantages of the renewable diesel.
6. The assessment of the supply and demand is not within the scope of this multimedia assessment. According to Hill et al. (2006), even dedicating all U.S. corn and soybean production to biofuels would meet only 12% of the gasoline and 6% of diesel demands in the country. Even with R20 or lower blends, whether all the available resources would meet the demand is unclear.
7. In the near future, the major feedstock could be soybeans grown in the US Midwest, as mentioned in Tier III report, page 7. Various adverse impacts on the ecosystem in the Midwest states have already been reported. Although a complete evaluation of the impact outside California is beyond this work, a summary of available information on the impacts of the upstream processes (feedstock production, extraction, blending, etc.) on the environment and human health will be helpful and could have been included.

Comments on Surface and Ground Water Quality Assessment

1. Within the scope of this multimedia evaluation, the SWRCB conclusion – there are minimal additional risks to beneficial uses of California waters posed by renewable diesel than that posed by CARB diesel alone – is reasonable given the similarities in chemical composition (including the needed additives) of renewable diesel when compared with petroleum based CARB diesel.
2. However, the impact of additives is not considered, which constitutes a major concern. Some conclusions, particularly those concerning water quality and toxicity, were made based only on the similarities in fuel properties and chemical compositions between the renewable diesel and CARB diesel, without conducting any laboratory experiments or model simulations.
3. Main Staff Report, pages 7-8, section II-B: Compared with other sections in chapter II, the summary for water quality impact is very brief. It reads more like conclusions rather than a summary, and may not be sufficient for CEPC review. I suggest adding sufficient information to allow an understanding on the assessment methods and the results, with references. Take part 1 Water Impacts as an example, where and when was the aquatic toxicity test conducted? What type(s) of aquatic toxicity was tested with what test species and what method? Was the test on R100 or any blends? Do the data show higher or lower toxicity compared with CARB diesel? … For all 4 parts of this summary, references of

the data sources and major scientific knowledge should be cited. The data source information is needed here because, based on my understanding from reading Tier III report page 12 paragraph 1, Tier II experiments were not conducted for toxicity and fate and transport.

4. Page 15, section III-B: This paragraph may be improved by including more specific information, which could come from page 8. The last several words need to be changed from "public health or the environment" to "the quality of surface water and groundwater in California".

Document Specific Minor Comments

Main Report (20 pages)

Table of Contents: I suggest changing II title from "Summary" to "Section Summaries" or "Summaries of Reports from Participating State Agencies", in order to avoid confusion with the summary of this Main Report.

Page 1, section A: There are three bulleted lines for air, water and wastes, respectively. It is not clear why public health is not included here. Risk assessment on the public health focuses on human, in contrast to those on environmental media. The same can be said for the bulleted lines in Page 2, section 2.

Page 5, section C: I suggest including one brief sentence on line 4 indicating that CARB diesel is conventional petroleum based ultra-low sulfur diesel, along with a brief time line. One or more references should be helpful, directing readers to information on CARB diesel development and adoption, quantity of use in the state, its environmental and human health impacts, etc. This is especially helpful to stakeholders who reside outside California and are unfamiliar with the phrase "CARB diesel".

Page 7, section 4 Greenhouse Gas Emissions, line 1: Please check if the word "decreased" should be "increased". The word "decreased" appears to conflict with the statement in page 6, last sentence.

Appendix A – Proposed Regulation Order (36 page)

Page 4, (a), (1): If ADF means any non-CARB diesel fuel that does not consist solely of hydrocarbons, a question arises whether "renewable diesel" as defined in the 3-tier multimedia evaluation is an ADF. The renewable diesel, to my understanding, consists of predominantly hydrocarbons.

Page 5, (8): The definition for "CARB Diesel fuel" in this proposed regulation appears different from that for "CARB Diesel" used in the 3-tier multimedia evaluation. The former includes 5%v of FAME, while the latter is a pure ultra-low-sulfur diesel (ULSD) derived from petroleum.

Page 22, top lines: The definition of NBV is repeated.

Page 22, Table A.2. "Limit" column: The sign "≥" for both total aromatics and polycyclic aromatic hydrocarbons could be "≤".

Page 30, Table A.9, column "fuel Specifications", row 4 for PAHs w%: The 10% maximum seems incorrect for PAHs in a reference fuel. Please check.

Appendix D – SWRCB Submittal (5 pages)

Relevant to this review is Attachment #2 (2 pages).

Most part of Attachment #2 is the same as presented in the main Staff Report. Thus, same comments as explained above are applicable.

Appendix G – Final Tier III Report (19 pages)

Following the excellent summaries of Tier I (chapter 2) and Tier II (chapter 3), it is logical and helpful to have a chapter providing details on the work executed in Tier III stage. How was the risk assessment carried out? Which model(s) was used? A description of the protocol and a result summary would be very helpful to interested stakeholders. In the current version of this report, chapter 4 gives conclusions and recommendations, but it is not clear on what was done and how.

Page 12: The 2nd paragraph should be deleted. It should not be under 3.1, and repeats the first two sentences in 3.2. Also, "(Citation)" needs to be changed to the reference information.

Page 16, 5th line from bottom: "will be become" should be "will become".

Appendix G, Appendix – Tier I Report (65 pages optional)

The only comment is that references should be cited at places. For example, the numbers used in the last three paragraphs on page A-40 need references.

Literature Cited

Hill, J. et al. 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. PNAS 103 (30), 11206–11210. (http://www.pnas.org/content/103/30/11206.abstract)

UOP, 2005. Opportunities for Biorenewables in Oil Refineries. Final Technical Report. DE-FG36-05GO15085. Des Plaines, Illinois. http://www.osti.gov/scitech/biblio/861458

Peer Review of Staff Report: Multimedia Evaluation Renewable Diesel (Renewable Diesel Staff Report)

Prepared by:

Stephen Nesnow, Ph.D.
Stephen Nesnow, Consulting
Chapel Hill, NC

January 6, 2014

1. Preface

The purpose of this document is to review The Staff Report: Multimedia Evaluation of Renewable Diesel to determine whether the scientific portions of the MMWG staff report are based upon "sound scientific knowledge, methods, and practices." The Staff Report: Multimedia Evaluation of Renewable Diesel is based on three previous documents the California Renewable Diesel Multimedia Evaluation Final Tier I, II and III Reports that contain data and analyses from government reports, literature documents, and from reports of studies commissioned by the CARB.

2. General comments

Emissions from diesel fueled engines are a complex mixture consisting of both gaseous and particulate components. The gaseous phase contains ozone, sulfur oxides and the criteria pollutants, carbon monoxide, particulate matter, nitrogen dioxide and ozone. Many organic compounds are also present, such as acetaldehyde, acrolein, benzene, 1,3-butadiene, ethylbenzene, toluene, formaldehyde, polycyclic aromatic hydrocarbons and nitro-polycyclic aromatic hydrocarbons. Particulate matter, benzene, 1,3-butadiene, formaldehyde and benzo[a]pyrene are carcinogenic in experimental animals and are classified as human carcinogens and acetaldehyde, ethylbenzene and a number of other polycyclic aromatic hydrocarbons and nitro-polycyclic aromatic hydrocarbons have been classified as probably or possibly carcinogenic to humans by the International Agency for Research on Cancer (IARC, 2013). Toluene is not classifiable as to its carcinogenicity to humans (IARC, 2013). The particulate phase also contains trace metals such as lead, manganese arsenic and chromium and metals from the catalyst after treatment system, vanadium, copper and iron. Arsenic and arsenic inorganic compounds and chromium VI are classified as human carcinogens by IARC while lead and inorganic lead compounds as classified as probably or possibly carcinogenic to human, respectively by IARC. Moreover, diesel engine exhaust, diesel exhaust particles, diesel-exhaust condensates, and organic solvent extracts of diesel-engine exhaust were genotoxic. Increases in bulky DNA adducts were detected the lung tissues of rodents exposed to whole diesel exhaust and in workers exposed to diesel exhaust. In addition to lung cancer, diesel exhaust exposure in humans has been linked to lung inflammation, cardiovascular disease and cardiopulmonary disease (Madden et al., 2011).

The biological and toxicological information available for renewable diesel emissions are extremely limited compared to the rich compendium available for diesel emissions and many of the biological and toxicological measures available for conventional diesel are not available for renewable diesel. Therefore, surrogate measures need to be employed to make meaningful comparisons between the emission types. These measures include chemical and physical analyses of the renewable diesel emissions and to a limited extent some toxicological data on the renewable diesel emissions.

The Staff Report bases the comparisons (chemical, physical and toxicological) of the renewable diesel fuel emissions to those properties of CARB diesel emissions. The crux of each document's conclusion is that the selected parameters (chemical, physical and toxicological) examined were lower (with some exceptions) in emissions from engines fueled with renewable diesel compared to CARB diesel. Thus, the public health risk would not be greater than that already established for CARB diesel. The underlying premise is that lower levels of specific emissions will equate to lower human health risk or adverse health effects. This premise is generally consistent with the quantitative results from many studies in animals and in human populations of each specific constituent as well as studies in animals and human populations exposed to whole diesel exhaust emissions. Much of the data on emissions from the combustion of renewable diesel fuel is from quantitative chemical analysis and that is used to equate to lower toxic or adverse effects in exposed humans. The agents selected for comparison are from the group of EPA criteria pollutants and from selected VOCs commonly found in diesel exhaust and in ambient air. Each exhibits its own toxicity profile. Genotoxicity evaluations were based on organic extracts of particulates or the vapor phase fraction using bacterial tests for mutagenic activity. Some genotoxicity data in mammalian cells in culture were also available as well as bioassays for cytotoxicity, oxidative stress, inflammation and apoptosis. There are a number of toxicological evaluations of the particulate matter. There no studies in whole animals exposed to complete exhaust emissions and there are no studies that I know of in humans exposed to complete exhaust emissions from renewable diesel.

The MMWG concludes that the use of renewable diesel fuel in California, as specified in the renewable diesel multimedia evaluation, does not pose a significant adverse impact on public health or the environment relative to CARB diesel.
Based on the results of the renewable diesel multimedia evaluation and the information provided in the UC final report, "California Renewable Diesel Multimedia Evaluation Final Tier III Report" (McKone, T.E. *et al.*, April 2012), the MMWG makes the overall conclusion that renewable diesel specifically evaluated within the scope of the renewable diesel multimedia evaluation will not cause a significant adverse impact on public health or the environment relative to CARB diesel. The MMWG based their conclusion on each individual agency's assessment of the multimedia evaluation. (Renewable Diesel Staff Report, Chapter 3)

Public Health Evaluation. OEHHA staff concludes that PM, benzene, ethylbenzene, and toluene in combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel are significantly lower than combustion emissions using CARB diesel. OEHHA staff evaluated potential human health impacts from the use of renewable diesel and made conclusions based on their analysis of toxicity testing data and combustion emissions results. (Renewable Diesel Staff Report, Chapter 2 and 3)

3. Peer review of the scientific issues

The basic premise of the conclusion: "that renewable diesel specifically evaluated within the scope of the renewable diesel multimedia evaluation will not cause a significant adverse impact on public health or the environment relative to CARB diesel" is based in large part on the measurements of the levels of key toxic components of emissions from renewable diesel and CARB diesel and to a minor degree on some toxicological measurements of these emissions.

Some of the issues of concern include: Are the metrics used to compare the levels and toxicity of individual or groups of pollutants of renewable diesel to CARB diesel appropriate, relevant, specific, sensitive and accurate?; Are the CARB renewable diesel results consistent with those reported by others in the literature?; Are all of most toxic components known to be present in diesel exhaust being measured in the CARB renewable diesel studies?; Is the toxicological dataset detailed, compete and extensive?; Are the selected indicators of adverse human health accurate and comprehensive?; Are there additional markers that could be included?

In general, there is a very limited body of information about the combustion emissions of renewable diesel compared to diesel as the data cited in the Report comes from studies commissioned by the CARB and reported in Durbin et al. (2011) and from three peer-reviewed publications. Comparisons of the Durbin et al. (2011) results to those published by others can be made but the results vary given the different fuel types, blends, engines, catalysts, and test cycles used in the studies.

The conclusion that the use of renewable diesel compared to diesel reduces the amount of particulate matter is supported by a majority of studies cited in the Report in that under specific experimental conditions the use of renewable diesel reduces the levels of particulate matter. The results of these studies comparing the levels of particulate matter from renewable diesel to diesel showed a variety of results (equal, greater than and less than) in levels of particulate matter between the two fuel types depending on fuel, blend, engine type, cycle and the presence or absence of a catalyst. To reinforce this point, a recent study by Westphal et al. (2013) who used a heavy duty diesel engine combusting hydrotreated vegetable oil reported an 8% decrease in particulate matter compared to the combustion of diesel fuel. Therefore, the conclusion of lower particulate matter from renewable diesel engines is not applicable to all exposure scenarios.

The conclusion that benzene, ethylbenzene and toluene levels are lower in emissions from renewable diesel fueled vehicles compared to those vehicles using CARB diesel are from the Durbin et al (2011) report who collected data from several engines under several test cycle protocols. There are no other sources of this data to verify these results.

The toxicological evaluation of emissions from renewable diesel fueled vehicles compared to those vehicles using diesel is limited. The assays and methods selected to determine the genotoxicity, oxidative stress, cytotoxicity, inflammation and apoptosis induced by the emissions are well accepted as measures of these endpoints. The conclusions and interpretations drawn from the data are acceptable.

The mutagenic activities of extracts of particulate matter and/or vapor phase fraction collected from diesel engines combusting renewable diesel and diesel were based on two studies cited in the Report and by Westphal et al. (2013) who reported that mutagenic activities of particulate extracts and condensates were lower in the hydrotreated vegetable emissions compared to diesel fuel emissions. Several of these studies used *Salmonella typhimurium* strains TA98 and TA100 for the analyses, while one study only used TA98. Overall, the studies showed different extents of reduction in mutagenic activities, or under some experimental conditions, no mutagenicity.

The genotoxicity, oxidative stress, cytotoxicity, inflammation and apoptosis data comparing emissions of renewable diesel to diesel are based on two studies (Durbin et al. (2011). The inflammation and oxidative stress analyses showed that renewable diesel produced lower responses in the HO-1, IL-8, and CYP1A1 assays in U937 macrophages and no differences in the CYP1A1, MUC5A and COX-2 assays in NCI-H441 lung Clara cells. The comet assay in U937 cells gave no differences between renewable diesel and CARB diesel. The other study used particulate matter from a diesel engine fueled hydrotreated vegetable oil renewable diesel or conventional diesel with, and without, a catalyst. Cytotoxicity and apoptosis assays using these cells showed no differences between the two fuels. Also reported were effects of the particulate matter samples from an engine combusting the two fuels on the release of cytokines that mediate inflammation using mouse macrophage cells. Some differences were noted in the absence of a catalyst while no significant difference was noted when a catalyst was used. In the same study the Comet assay results showed that the particulate matter from a diesel engine without a catalyst combusting hydrotreated vegetable oil diesel showed decreased DNA damage in a macrophage cell line (RAW264.7) compared to the particulate matter using conventional diesel. With a catalyst no significant differences were observed between the two fuels.

Specific comments: There are several duplications of text: P12, 2nd para is the same text as P13, 4th para (an analyses of Jalava et al. (2012)). P12, 3rd para has much of the same text as P13, 5th para but with the opposite interpretation of the Comet assay results with respect to HVORD fueled engine particulate matter vs. EN590 fueled engine particulate matter in the absence of a DOC/POC. The data in Jalava et al. (2012) clearly show DNA damage in mouse macrophage RAW264.7 cells treated in vitro with HVORD-fueled engine particulate matter was decreased compared to cells treated with EN590-fueled engine particulate matter in the absence of a DOC/POC.

A major shortcoming in the existing toxicology dataset is that there are no data from in vivo or ex-vivo studies of emissions of renewable diesel, a data need.

4. The Big Picture

It is noted that the levels of the constituents cited above have not been determined for the many different combinations of engine types (heavy and light duty) technology (old, new, catalyst type, test cycle and load), feed stock sources (plant and animal based) and mixture blends therefore, some caution needs to be exercised in accepting these conclusions without further data on the most prevalent combinations. Decisions on the impact of the toxicity of emissions from the multitude of combinations should be revisited after more data is available.

The data base on the physical, chemical and toxicological endpoints for renewable diesel is not as robust at that for biodiesel or diesel. The basis for the conclusion that particulate matter in combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel are significantly lower than combustion emissions using diesel is based on a several studies, while some other studies show generally equal or slightly lower levels.

The basis for the conclusion that benzene, ethylbenzene and toluene in combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel are significantly lower than combustion emissions using CARB diesel is based on a single study using a single engine, albeit using multiple blends and several test cycle protocols.

The available toxicological data comparing the emissions from renewable diesel and diesel is quite limited and contains no data from in vivo or ex-vivo studies of emissions of renewable diesel which is a concern.

In my opinion, the conclusions and scientific portions of the multimedia evaluation were based upon sound scientific knowledge, methods, and practices. However, it is noted that the conclusion that the use of renewable diesel fuel in California, as specified in the renewable diesel multimedia evaluation does not pose a significant adverse impact on public health or the environment relative to CARB diesel is based on data limited in scope, breadth and content.

References:

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January 7, 2014

External scientific peer review of the Multimedia Working Group's assessment of the renewable diesel multimedia evaluation

As reviewers we're specifically asked to evaluate the following statements:

A. **Air emissions evaluation. ARB staff concludes that the use of renewable diesel does not pose a significant adverse impact on public health or the environment from potential air quality impacts.**
I find that this conclusion of the report is based on sound scientific knowledge, methods, and practices. The tier two investigations indicate that changes in emissions of most air pollutants including total hydrocarbons carbon monoxide, NOx, and particulate matter are minimal. Because there are many possible types of renewable diesel and only a few were tested, any changes in emissions of these types of pollutants are not necessarily statistically significant. However these tests do suggest that renewable diesel is no worse than regular diesel.

B. **Water evaluation. SWRCB staff concludes that there are minimal additional risks to beneficial uses of California waters posed by renewable diesel than that posed by CARB diesel alone.**
I find that this conclusion of the report is based on sound scientific knowledge, methods, and practices. Because the chemical composition of renewable diesel is so similar to regular diesel the impacts on water resources are almost identical.

C. **Public health evaluation. OEHHA staff concludes that PM, benzene, ethylbenzene, and toluene in combustion emissions from diesel engines using hydro treated vegetable oil renewable diesel are significantly lower than combustion emissions using CARB diesel.**
I find that this conclusion of the report is based on sound scientific knowledge, methods, and practices. While the chemical composition of renewable diesel is very similar to that of regular diesel, the emissions tests performed as part of the tier II assessment do show what appear to be significant decreases in emissions of some of these hazardous air pollutants vs. regular diesel.

D. **Soil and hazardous waste evaluation. DTSC staff concludes that renewable diesel is free of ester compounds and as low aromatic content. The chemical compositions of renewable diesel are almost identical to that of CARB diesel. Therefore, the impacts on human health and the environment in case of a spill to soil, groundwater, and surface waters would be expected to be similar to those of CARB diesel.**

I find that this conclusion of the report is based on sound scientific knowledge, methods, and practices. The characterization of renewable diesel has been very thorough and state of the art. While it is not possible to characterize every chemical component of either regular diesel or renewable diesel, the characterization that was performed is conclusive. The conclusion that the impacts on human health and the environment from spills of renewable diesel and regular diesel will be indistinguishable is reasonable.

In addition, as a reviewer I have been asked to evaluate the following statement.

The MMWG recommends that the California environmental policy council find that the use of biodiesel and renewable diesel, as specified in the respective multimedia evaluations, does not pose a significant adverse impact on public health or the environment.

I find that this conclusion is based on sound scientific knowledge, methods, and practices. As noted in the report, renewable diesel maybe formed from many sources. It is not possible to characterize all of those sources. However, because renewable diesel is so chemically similar to regular diesel, the conclusion that renewable diesel may be used without significant adverse impact on public health and the environment is sound. As opposed to the use of biodiesel, the use of renewable diesel is less likely to require changes in the materials used in tanks and pipelines used to store and transport the fuel, changes in the types of additives used in the fuel, or the construction of new facilities for production of renewable diesel.

As a reviewer, and also been asked whether there are additional scientific issues that are not described in the report.

Additional comments.

Staff Report

Page 6. Here and elsewhere, the report states that the renewable diesel emits less PM, NOx, THC, and CO, but that the BSFC is lower. It is important to explain to the reader that the emissions of criteria pollutants are expressed as g per hour or g per distance, such that differences in fuel consumption are already factored in.

Tier I Final Report

Pages A24-25 and table 2.1 on page A-25. The emission factors are on a grams per gallon basis. Because the different fuels have different mpg ratings, it would be useful to include a statement about whether their relative emission factors would change if they were expressed on a grams per vehicle mile travelled basis.

Appendix C: Air Resources Board: Impact Assessment of Renewable Diesel on Exhaust Emissions from Compression Ignition Engines

Page 9, tables 5, 6, & 7. Units are missing. Are these expressed on a g/bhp-hr basis as in the biodiesel report? Do values in bold represent those that are significant ($P < 0.05$)? Again, it would be useful to stress in the narrative that these units have already taken differences in fuel efficiency into account.

Appendix G: California Renewable Diesel Multimedia Evaluation Tier I Final Report

Page A-19 In comparing the production volumes across ConocoPhillips, Nest, and Petrobras, it would be helpful if all could be expressed in the same units, either metric tons per year of barrels per day. For Petrobras, the tons per year is presumably metric tons?

Page A-25 Table 2.1. Again, it would helpful to point out how fuel efficiency affects the emissions factors. If I'm not mistaken, ethanol's relatively poor mpg rating means that on a vehicle miles travelled basis, renewable diesel and biodiesel both look even better.

Page A-29 typo: avvegetable

Page A-30 top of page. Establishment of dedicated facilities for renewable diesel production will be problematic in terms of land use. This should be factored into the LCA if it becomes clear that these new facilities will, in fact, be required.

Page A-36 Unless I am mistaken, the sulfur content should be reported as less than 15 ppm, not 15%.

Pages A-49 and A-53 typo: missing symbol in 200 ?g/ml.

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External Peer Review of "Multimedia Evaluation of Renewable Diesel"

Re-statement of Objectives –

External peer reviewers are instructed to evaluate the scientific portions of the Multimedia Working Group (MMWG) report, and ensure that they are based on "sound scientific knowledge, methods and practices".

This review is primarily focussed on the *Public Health Evaluation* by the Office of Environmental Health Hazard Assessment (OEHHA), as well as additional components of the evaluation that relate to the toxicological hazards of biodiesel and biodiesel emissions (e.g., results of aquatic toxicity tests). The review encompasses the MMWG Staff Report "Multimedia Evaluation of Renewable Diesel", as well as the Tier I and Tier III reports, and related documents (e.g., *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California*).

Recap of Scientific Conclusions to be addressed by Peer Reviewers (Renewable Diesel) –

(1) ARB staff concludes that the use of renewable diesel does not pose a significant adverse impact on public health or the environment from potential air quality impacts.
(2) SWRCB staff concludes that there are minimal additional risks to beneficial uses of California waters posed by renewable diesel than that posed by CARB diesel alone.
(3) OEHHA staff concludes that PM, benzene, ethyl benzene, and toluene in combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel are significantly lower than combustion emissions using CARB diesel.
(4) DTSC staff concludes that renewable diesel is free of ester compounds and has a low aromatic content. The chemical compositions of renewable diesel are almost identical to that of CARB diesel. Therefore, the impacts on human health and the environment in case of a spill to soil, groundwater, and surface waters would be expected to be similar to those of CARB diesel.

Evaluation of MMWG Conclusions –

Despite the fact that the MMWG did not review the literature pertaining to emissions from diesel engines fuelled with pure plant oils (PPO), this reviewer ***supports the ARB and OEHHA conclusions listed above*** (i.e., 1 and 3). However, since the MMWG's evaluation is restricted to hydrotreated vegetable oils, it would be prudent to ***explicitly restrict the concluding statements to this type of renewable diesel***. With respect to the SWRBC and DTSC conclusions, this reviewer's limited analysis of the presented information did not reveal any problems or inconsistencies.

This reviewer also supports the MMWG's recommendations to the California Environmental Policy Council (i.e., "that the use of renewable diesel, as specified in the multimedia evaluations, does not pose a significant adverse impact on public health and the environment"). **However, as noted above, the statements should be restricted to hydrotreated vegetable oils.**

In this reviewer's opinion, a comprehensive evaluation of renewable diesels should include PPOs and/or heated plant oils, in addition to hydrotreated oils. Consequently, to provide a comprehensive evaluation of the MMWG documents, this reviewer collected, reviewed, and evaluated the publicly-available scientific information pertaining to the relative toxicological activity of pure plant oil (PPO) emissions relative to petroleum diesel emissions. This review, which is contained in the *Peer Review of the MMWG Evaluation and Related Documents* provided below, is based on the scientific information summarised in a series of appended tables (i.e., Appendix I). Although the publicly-available information is limited, there is some evidence to support the assertion that PPO-fuelled engines emit more PM; and moreover, that the mutagenic hazards of the particulate emissions are greater than those of conventional diesel.

Peer Review of the MMWG Evaluation and Related Documents

First and foremost, it is important to note that the ***overall quality of the MMWG report on renewable diesel***, as well as the associated Tier I and III reports, are far superior to the analogous biodiesel reports. For the most part, they are well written, clear and comprehensive, and the interpretation is informed and balanced. With respect to the MMWG reports, renewable diesel is defined as hydrotreated vegetable oil (e.g., NExBTL HVO), and the authors have done a thorough job assessing the state of knowledge regarding the toxicological properties of HVO emissions. The MMWG reports document the chemical similarities of HVO and ULSD; noting that the former is chemically distinct from biologically-derived fatty acid esters (i.e., biodiesel). The chemical similarity, particularly between 20% v/v renewable diesel in ULSD and 100% ULSD, suggests that, as asserted by the MMWG, additional studies on the relative toxicological activity of renewable diesel blends, and/or emissions from engines fuelled with renewable diesel blends, are not necessary. This appears to be a sound assertion.

Few studies have examined the relative toxicological activity of emissions from renewable diesel fuelled engines, relative to conventional diesel. Indeed, the publicly-available scientific literature contains only 3 studies that employed cultured mammalian cells (e.g., mouse macrophages) to examine the toxicological activity of emissions from HVO-fuelled engines, relative to conventional diesel emissions. As noted by the MMWG, the Jalava et al (2010 and 2012) studies showed that the magnitude and direction of changes in cytotoxicity and the ability to induce inflammatory signalling (expressed per mg PM) vary according to fuel formulation and exhaust aftertreatment. Nevertheless, despite some indication of enhanced cytotoxicity and inflammatory signalling (Jalava et al, 2012), emissions of HVO-fuelled engines are generally associated, as noted by the MMWG, with reductions in cytotoxicity, genotoxicity and inflammatory signalling in murine cells exposed *in vitro*. A study by Ihalainen et al (2009), which was not reviewed by the MMWG, also showed reductions in inflammatory signalling for HVO emissions, relative to conventional diesel. Finally, the Durbin et al (2011) analyses clearly shows reductions in inflammatory signalling in human cells (i.e., macrophage and Clara cell lines) exposed to organic extracts of HVO DEP (diesel exhaust particulates), relative to extracts of conventional diesel DEP. Observed reductions in the oxidative stress response (as HO-1) were even more pronounced.

A study by Westphal et al (2013), which was also not reviewed by the MMWG, noted that the mutagenic activity of SVOCs and extracts of DEP from HVO emissions are markedly lower (unit not provided) than that observed for conventional diesel.

Despite the fact that the MMWG defines renewable diesel as a fuel from a “non-petroleum renewable resource”, the MMWG reports do not review the admittedly limited scientific literature on emissions from engines fuelled with unaltered or heated pure plant oils. In this reviewer’s opinion, it would be useful (i.e., for the reader) for the MMWG to review the few published studies on emissions from PPO-fuelled engines. Since the external peer review process provides the latitude to include any scientific information that is deemed to be pertinent, this reviewer also examined publicly-available information pertaining to “pure plant oils”. **A detailed summary of the information is presented in a series of appended tables (i.e., Appendix I).**

It is important to note that this reviewer does acknowledge the information presented in the Tier I report (e.g., p. A-19) suggesting that unaltered plant oils are not likely to become popular fuels for compression-ignition engines. As indicated, although pure plant oils can provide reliable short-term performance, long term use can contribute to undesirable engine fouling

Several noteworthy studies, such as those by Bunger et al (2007), Krahl et al (2007) and Krahl et al (2009), examined the mutagenic activity of organic extracts from plant oil DEP (i.e., RSO or heated RSO), and noted that the potency expressed per L of exhaust is greater than that of samples from conventional diesel. Kooter et al (2011) noted similar increases (unit not provided) for PPO-fuelled engine emissions. The Krahl et al studies also noted that combustion of RSO is associated with an increase in PM emission rate (per kWhr). Thus, there is evidence that PPO-fuelled engines emit more PM; and moreover, that the mutagenic hazards of the particulate emissions is greater than that of conventional diesel.

One study examined the ability of organic extracts of DEP from PPO emissions, relative to conventional diesel, to induce oxidative stress and reductions in the viability of mouse macrophages (Kooter et al, 2011). The results indicate that extracts of PPO DEP are less cytotoxic, with no appreciable differences in induction of oxidative stress signalling.

The MMWG reports clearly outline the relative differences in emission rates of criteria air pollutants and air toxics between HVO and conventional diesel. It is quite clear from the Durbin et al (2011) work that R100 (i.e., 100% HVO) is associated with reductions in the emission rates of PM, CO, NOx and HCs, relative to conventional diesel. Additional analyses showed declines in PAH, nitro-PAH and V OC emissions rates; moreover, that PAH and nitro-PAH emission rates declined with increasing blending levels. Importantly, emission rates for toxic aldehydes such as acrolein were not significantly different between HVO and conventional diesel emissions. These results are generally consistent with published information showing reduced PM and PAH emission rates for HVO relative to conventional diesel (Westphal et al, 2013; Ihalainen et al., 2009; Jalava et al, 2010; Jalava et al., 2012). Nevertheless, as noted in the MMWG report, the PAH emission rate from engines equipped with DOC/POC aftertreatment has been shown to be elevated for HVO exhaust, relative to conventional diesel.

Studies of pure plant oils (e.g., Kooter et al, 2011) have also recorded declines in the emission rates of PAHs, oxy-PAHs and nitro-PAHs, relative to conventional diesel.

Miscellaneous Editorial Comments –
Durbin et al (2011), pages 222 and 224: “Marcophage” should be macrophage.

MMWG Evaluation of renewable diesel, p. 13: Third paragraph “was noted” appears twice in same sentence. Firth paragraph – “reactive production” should be relative production. There are many similar editorial issues throughout the documents.

Renewable diesel Tier 1 report, page A-49: Why do the authors cite a presentation by Vogel et al? All the information is presumably presented in the Durbin et al report.

Renewable diesel Tier 1 report, page A-49: Penultimate line – should be μg/mL. Same on p. A-53.

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APPENDIX I: Summary of Published Information Regarding the Relative Toxicological Properties of Renewable Diesel and Petroleum Diesel Emissions.

Table 1. Summary of the published *in vitro* studies in cultured animal cells

Engine	Fuels Examined	Exposure System	Endpoint(s) Examined	Results Obtained	Reference
Kubota 1.123L D1105-T diesel engine (EPA Tier I), ISO C1 cycle, with or without DOC/POC, DEP collected using HVCI.	ULSD, HVO and RME	RAW264.7 mouse macrophage cells exposed to DEP suspension for 24 h	Production and release of proinflammatory cytokine TNF-α.	At 150 µg/mL decreased response for RME, relative to DF. HVO similar to DF. When based on per kW-hr exposures, reduced response for RME, especially with DOC/POC. Small reduction for HVO, relative to DF, without aftertreatment only. PM emission rates reduced for RME and HVO, relative to DF. Aftertreatment reduced PM emissions rates by 50-60%.	[1]
Kubota 1.123L D1105-T diesel engine (EPA Tier I), ISO C1 cycle, with or without DOC/POC, DEP collected using an HVCI with downstream polyurethane foam (PUF) and Teflon®-coated membrane, ultrasonic extraction with methanol.	ULSD, HVO and RME	RAW264.7 mouse macrophage cells exposed to 5–300µg/mL DEP extract and suspension of insoluble material for 24 h	DNA strand breaks by comet assay, proinflammatory cytokine production (Tnf-α, Mip-2), MTT reduction for cytotoxicity, apoptosis by flow cytometric analysis.	All samples yielded a significant concentration-related increase in cytotoxicity and DNA strand breaks. No difference in cytotoxicity across fuels types and aftertreatment. DOC/POC aftertreatment significantly reduced RME response only. ULSD and HVO elicited larger inflammatory response than RME. DOC/POC increased oxidative potential on a per mass basis; aftertreatment reduced PM emission rates by more than 50%.	[2]
2005 Scania 6-cylinder 11.7L Euro 4 engine with EGR, Braunschweig (bus) cycle, with or without DOC/POC (for LSDF and HVO 100 only), DEP collected on Teflon® filter, ultrasonic extraction with methanol.	LSDF, RME (B100 and B30), HVO (B100 and B30)	RAW264.7 mouse macrophage cells exposed to 15–300µg/mL DEP extract and suspension of insoluble material for 24 h	MTT reduction for cytotoxicity, proinflammatory cytokine production (Tnf-α, Mip-2), apoptosis, cell cycle and membrane permeability by flow cytometry. DNA strand breaks by comet assay.	Little differences in cytotoxicity across the fuels and aftertreatment conditions examined. Higher inflammatory response for HVO samples; lowest for RME. Little differences in apoptosis across conditions examined; some indication of higher levels for HVO. DOC/POC greatly reduced PM emission rate and PAH content of PM.	[3]

Engine	**Fuels Examined**	**Exposure System**	**Endpoint(s) Examined**	**Results Obtained**	**Reference**
Six cylinder 12L Euro III truck, no DOC, with or without DPF, 13-mode ESC, DEP collected on Teflon®-coated GFFs, ethanol/DCM (1:1) sonication extract	DF, B100, B5, B10, B20, PPO	RAW264.7 mouse macrophage cells exposed to DEP extract for 24 h	Cytotoxicity via LDH release, oxidative stress as *Ho-1* gene expression.	Biodiesel blends and PPO elicited less cytotoxicity relative to DF; B100 significantly more cytotoxic (unit unknown). No differences in *HO-1* expression. Biodiesel associated with reductions in PM (g/kWh), PAHs and oxy-PAHs (µg/kWh).	[4]
2000 Caterpillar C15 six cylinder 14.6L engine, 2007 MBE 4000 six cylinder 12.8L engine with EGR and DOC/DPF combination, chassis dynamometer UDDS and HHDDT, DEP collected on Teflon®-filters, PFE extraction with DCM followed b y DCM/Tol, SVOCs on PUF/XAD cartridges, DCM extraction.	CARB DF, SME and AFME blends, renewable (NExBTL HVO)	Human U937 macrophages and NCI-H441 Clara cell line (exposure details not provided)	Expression of oxidative and inflammatory stress markers (CYP1A1, COX-2, IL-8, HO-1, MUC5AC). Details not provided. DNA damage by comet.	For C15, some evidence of declines in oxidative stress and inflammatory responses (per engine mile) for biodiesels relative to DF. Strong declines in oxidative stress for HVO (R100). For MBE 4000 some evidence for increase in oxidative stress and inflammatory signalling (SME and AFME only). No appreciable changes in DNA damage (all blends). Nevertheless, some indication of declines for HVO and SME relative to DF, reverse for AFME.	[5]

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Table 2. Summary of published *in vitro* analyses of naked DNA exposed to diesel exhaust particulate extract

Test Article	Fuels Examined	Exposure System	Endpoint(s) Examined	Results Obtained	Reference
2003 4.5L Cummins ISBe4 engine and 2007 Zetor Euro 3 engine, ESC, WHSC and NRSC driving cycles. DEP collected with a high-volume sampler, DCM extract.	DF, RME (B100) and RSO	Incubation of Calf thymus DNA with DEP extract for 24 h with and without rat liver S9.	Frequency of stable, bulky DNA adducts by ^{32}P-postlabelling.	Significant concentration-related increases in adduct frequency for all samples; higher responses with S9. Potency per mg PM similar for two engines, and similar across fuel types, diesel higher for WHSC. Similar potency trend per kWh.	[6]

Table 3. Summary of published results of Salmonella mutagenicity analyses of diesel exhaust particulate extracts

Test Article	Fuels Examined	Salmonella Strains[a]/Test Version	Results Obtained	Reference
DEP and exhaust condensate from a Mercedes-Benz Euro 3 6.37L, 6-cylinder engine, 13-mode ESC, Teflon®-coated GFFs, DCM Soxhlet extract of DEP	DF, RSO, RME, GTL	TA98 and TA100, standard plate-incorporation assay, PB/5,6BF-induced rat liver S9	All samples elicited significant positive responses. Potency (per L exhaust) higher without S9 for TA100 only. DEP extracts for RSO and heated RSO fuels yielded the highest potency samples (9.7- to 59 fold greater than DF for TA98 and 5.4- to 22.3-fold for TA100). DEP extracts for RME also significant higher than DF. Condensate samples for RSO and heated RSO also significantly elevated relative to DF (up to 13.5-fold).	7
DEP from 3 diesel engines, 1.686L, 4-cylinder light-duty, 10.8L, 6-cylinder heavy-duty with DPF and SCR, 10.52L, 6-cylinder, heavy-duty with DPF, DEP collected on GFF, DCM Soxhlet extract	DF and plant oils (peanut, rapeseed, soy, sunflower)	TA98, TA100, TA Mix, fluctuation assay (Xenometrics)	All samples in the range of the negative control with no evidence of differences in activity between the fuels.	8
DEP and SVOCs from a Mercedes-Benz, 6.37L, 6-cylinder engine, 13-mode ESC. DEP collected on Teflon®-coated GFFs, DCM Soxhlet extract, and condensates from gas phase collected at 50 °C	DF, RME, GTL, RSO, modified RSO	TA98 and TA100, standard plate-incorporation assay, PB/5,6BF-induced rat liver S9	DEP extract for RSO yielded the highest potency values (9.7- to 17-fold higher than DF on TA98 and 5.4- to 6.4-fold higher than DF on TA100). Modified RSO potency 2.4- to 3.5-fold higher than RSO. RSO condensate samples also yielded the highest potency values (up to 3-fold DF). Modified RSO 3- to 5-fold higher than RSO. Few differences between DEP extracts for DF, RME and GTL, although RME significantly greater than DF on TA98 with S9 and TA100 without S9.	9, 10
DEP from a Mercedes-Benz 6.37L, 6-cylinder and an IVECO 5.9L, 6-cylinder diesel test engine with SCR, 13-mode ESC. DEP collected on Teflon®-coated GFFs, DCM Soxhlet extract.	DF, RME, RSO, SMDS, B5 RME in SMDS, DF/RME/GTL blend.	TA98 and TA100, standard plate-incorporation assay, PB/5,6BF-induced rat liver S9	For the Mercedes engine, no significant difference in potency (per L exhaust gas) between DF, RME, SMDS and DF/RME/GTL blend. RO yielded significantly elevated potency (approximately 10-fold), also highest PM output in g/kWh. For the IVECO engine, SCR significantly reduced mutagenic potency, no difference between DF and RME, after 1000hrs SCR less effective. RME associated with reduced PM emissions (g/kWh).	11, 12

Table 3. Summary of published results of Salmonella mutagenicity analyses of diesel exhaust particulate extracts

Test Article	Fuels Examined	Salmonella Strains[a]/Test Version	Results Obtained	Reference
DEP from a 12L 6 cylinder Euro III truck, no DOC, with or without DFP, 13-mode ESC, DEP collected on Teflon®-coated GFFs, ethanol/DCM (1:1) sonication extract	DF, B100, B5, B10, B20, PPO (pure plant oil)	TA98 and YG1024, YG1029. Standard plate incorporation version, Aroclor-induced rat liver S9	No significant response in the presence of S9 for any sample. For TA98, significant response for B20 and PPO only. For YG1024, significant responses for B10, B100 and PPO only. Maximum responses on YG1024 for B100 and PPO (per µg PM). Biodiesel associated with reductions in PM (g/kWh), PAHs and oxy-PAHs (µg/kWh).	[4]
DEP and SVOCs from a heavy-duty, 6-cylinder 6.4L Mercedes-Benz OM 906 LA Euro 3-compliant engine, ESC steady state cycle. DEP collected on Teflon®-coated GFFs, DCM Soxhlet extract, SVOC on chilled surface	DF, HVO, RME, JME	TA98, TA100 standard plate incorporation assay, with and without S9 (source not indicated)	Stronger responses for SVOC samples, relative to DEP extracts. SVOC samples and PM extracts for RME and JME elicited similar or greater responses on TA98 (unit not indicated), relative to DF. HVO responses much lower. RME and JME responses on TA100 substantial greater than DF. PM emission rates (g/kWhr) for RME and JME substantially lower than DF. HVO slightly lower. PAH emission rates (ng/test) substantially lower for biodiesels, relative to DF with HVO being the lowest.	[13]
2000 Caterpillar C15 six cylinder 14.6L engine, 2007 MBE 4000 six cylinder 12.8L engine with EGR and DOC/DPF combination, chassis dynamometer UDDS and HHDDT, DEP collected on Teflon®-filters, PFE extraction with DCM followed b y DCM/Tol, SVOCs on PUF/XAD cartridges, DCM extraction.	CARB DF, SME and AFME blends, renewable (NExBTL HVO).	TA98, TA100, microsuspension preincubation version, rat liver S9	C15 engine DEP extracts, for both TA98 and TA100, general decline in potency (per engine mile) with increasing concentrations of biodiesel. For SVOCs, appreciable decline for HVO only. For MBE4000 samples, appreciable decline in potency for SME blends only.	[5]

[a]YG1021 – TA98 with plasmid pYG216, nitroreductase overproducing strain. YG1024 – TA98 with plasmid pYG219, *O*-acetyltransferase overproducing strain. YG1041 – TA98 with plasmid pYG233, nitroreductase and *O*-acetyl transferase overproducing strain. YG1026 – TA100 with plasmid pYG216, nitroreductase overproducing strain. YG1029 – TA100 with plasmid pYG219, *O*-acetyl transferase overproducing strain. YG1042 – TA100 with plasmid pYG233, nitroreductase and *O*-acetyl transferase overproducing strain.

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Review of
Staff Report: Multimedia Evaluation of Renewable Diesel

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The staff report, prepared by the Multimedia Working Group (MMWG), provides an overall assessment of potential adverse impacts on public health and the environment that may result from the production, use, and disposal of renewable diesel, which is produced from non-petroleum resources and is not a mono-alkyl ester. Renewable diesel consists of hydrocarbons and meets ARB motor vehicle fuel specifications of California. The report concludes that the use of renewable diesel fuel in California does not pose a significant adverse impact on public health or the environment relative to California Air Resources Board (CARB) diesel. The conclusion was made largely based on the results of the "California Renewable Diesel Multimedia Evaluation Final Tier III Report" from the researchers at University of California. As requested, this reviewer provides the following assessment and determination of whether each of the conclusions that constitute the basis of the staff report is based on sound scientific knowledge, methods, and practices, and if additional issues need to be addressed.

Overall Comments on the reports

The Staff Report is based on a cascade of studies conducted by University of California (UC) researchers. The PIs are known scientists in the field. The evaluation procedure, as outlined in their final Tier III report, is sequential and logic. Literature cited in their reports is quite complete and up to date. Experiments were well designed and conducted. Data were carefully collected and analyzed. Therefore, this reviewer would conclude that the UC final Tier III report and the Staff Report are based on sound scientific knowledge, methods, and practices. And consequently, the conclusions of the Staff Report are acceptable.

Comments on specific conclusion statements

1. Air Emissions Evaluation. Air Resources Board (ARB) staff concludes that the use of renewable diesel does not pose a significant adverse impact on public health or the environment from potential air quality impacts.

Based on engine and vehicle emissions testing on multiple blends of renewable diesel compared to the baseline CARB diesel fuel, the report concludes that for use of renewable diesel would reduce emissions of most criteria pollutants, ozone precursors, toxic pollutants, and greenhouse gases (including PM, NOx, CO, and THC in diesel exhaust), and therefore does not pose a significant adverse impact on public health or the environment. This reviewer in general agrees with the findings of the evaluation studies that focused on the use of renewable diesel. If renewable diesel is going to be produced in state, additional studies are encouraged to evaluate the impact on air quality from collection, storage, and transport of large amount of biological feedstock for renewable diesel production.

2. Water Evaluation. State Water Resources Control Board (SWRCB) staff concludes that there are minimal additional risks to beneficial uses of California waters posed by renewable diesel than that posed by CARB diesel alone.

Water evaluation focused on aquatic toxicity and risks associated with fuel production, transport, storage, and disposal. Renewable diesel is refined in a similar way as for petroleum diesel with almost an identical chemical composition, and uses the same additives. Based on studies conducted by UC researchers, the report concluded that the use of renewable diesel in California poses minimal adverse impact on public health and the environment. Similar to the air emissions evaluation, the study does not include the effect of growing, collection, storage, and transportation of large amount of biological feedstock, if some of the renewable diesel is produced in the State of California using local resources.

3. Public Health Evaluation. Office of Environmental Health Hazard Assessment (OEHHA) staff concludes that PM, benzene, ethyl benzene, and toluene in combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel are significantly lower than combustion emissions using CARB diesel.

Impact of renewable diesel on public health was assessed by comparing the combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel against that with petroleum based diesel fuel. Data show that there is a significant reduction in PM, benzene, ethyl benzene, and toluene using the tested renewable diesel. Tests on emissions toxicity also indicated that there is no significant difference between the tested renewable diesel and CARB diesel. Conclusions made by the OEHHA staff are acceptable based on the limited studies. Again, the report did not address the impact of growing, storage, and transportation of large amount of biological feedstock for local production of renewable diesel.

4. Soil and Hazardous Waste Evaluation. Department of Toxic Substances Control (DTSC) staff concludes that renewable diesel is free of ester compounds and has low aromatic content. The chemical compositions of renewable diesel are almost identical to that of CARB diesel. Therefore, the impacts on human health and the environment in case of a spill to soil, groundwater, and surface waters would be expected to be similar to those of CARB diesel.

Because the chemical composition of renewable diesel is similar to that of CARB diesel and renewable diesel has a lower content of aromatic hydrocarbons than CARB diesel, I agree with the DTSC staff on that the impacts on soil, surface water and groundwater of renewable diesel are similar to or less severe than that of CARB diesel. As pointed out by the DTSC Staff Report, the chemical composition and additives may vary with different feedstock and production processes. Large amount of biological feedstock also needs to be transported, stored, and processed should certain renewable diesel be produced locally. Therefore, additional studies may be needed in the future for regulatory purposes.