Response to Charge Question

What is the most effective way to determine the improvement in ambient air quality from requiring non-road diesel construction equipment to install retrofit technology and how do we quantify the health benefit to the worker and surrounding population (community) from requiring said retrofits?

Summary Report

of the

NJDEP Science Advisory Board

Dr. Judith Weis, Ph.D. (chair)
Clinton J. Andrews, Ph.D., P.E.
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Raymond A. Ferrara, Ph.D.
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Robert J. Lippencott, Ph.D.
Nancy C. Rothman, Ph.D.
Emile D. DeVito, Ph.D.
Anthony J. Broccoli, Ph.D.
Mark G. Robson, Ph.D., M.P.H.
David A. Vaccari, Ph.D., P.E.

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The following report has been issued by the Science Advisory Board to the Commissioner of the New Jersey Department of Environmental Protection

Response to the Charge Question:

What is the most effective way to determine the improvement in ambient air quality from requiring non-road diesel construction equipment to install retrofit technology and how do we quantify the health benefit to the worker and surrounding population (community) from requiring said retrofits?

A report was initially prepared by the Climate and Atmospheric Sciences Standing Committee and sent to the Science Advisory Board for review.
The Science Advisory Board forwards this approved report.

Members of the CAS Standing Committee include:

Anthony Broccoli, Ph.D. Chairperson
Mark J. Chopping, Ph.D.
Maurie Cohen, Ph.D.
Paul J. Croft, Ph.D.
Joann L. Held, M.S.
Philip K. Hopke, Ph.D.
Robin Leichenko, Ph.D.
William E. McMillin, M.E.E., P.E.
Gregory A. Pope, Ph.D.
David A. Robinson, Ph.D.
Alan Robock, Ph.D.
Joseph A. Spatola, Ph.D.

In addition the following SAB Members contributed to the Report:

Robert J. Laumbach, M.D., M.P.H.
Paul J. Lioy, Ph.D.

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Science Advisory Board, Standing Committee on Climate and Atmospheric Sciences

Executive Summary

A Diesel Work Group (Work Group) was formed from the membership of the Science Advisory Board (SAB) Climate and Atmospheric Sciences Standing Committee (Standing Committee) to address the question: "What is the most effective way to determine the improvement in ambient air quality from requiring non-road diesel construction equipment to install retrofit technology and how do we quantify the health benefit to the worker and surrounding population (community) from requiring said retrofits?"

The Standing Committee, through its Work Group and assisted by NJDEP (the Department) staff, gathered information, held a series of discussions via conference calls, and developed findings and recommendations, which are summarized below.

Given the demonstrated health risks associated with Diesel Particulate Matter (DPM) and the demonstrated effectiveness of the retrofit technology in reducing DPM emissions, there is little doubt that retrofitting construction equipment will lead to improvements in air quality and the health benefits for citizens in the state. The Committee recommends that a simple analysis of expected emission reductions should be conducted to demonstrate the effectiveness of the proposed retrofit of diesel construction equipment.

If, however, the Department disagrees with the above recommendation and feels it is imperative to develop additional support for these reductions, then the Committee would recommend the use of a variety of approaches to estimating the air quality and public health impacts of the retrofit program, where practically feasible,

1. Direct measurement to estimate the effects of retrofits on air quality and public health would be facilitated by a demonstration project that could eliminate or reduce some of the uncertainty associated with variability in amounts of DPM arising from equipment that can be retrofitted, the dispersion of that DPM, and background levels of nonspecific DPM markers. Such measurements could be part of a demonstration project designed for the purpose of assessing the impacts of retrofits on air quality as it affects workers and off-site exposures. As discussed below, direct measurement may have serious practical limitations.

2. Air quality dispersion modeling with US Environmental Protection Agency's (EPA) widely used and validated model AERMOD could be used to estimate expected local reductions in DPM. Any modeling plan must be carefully conceived to account for variability in local land use and site activity as well as topographical and meteorological variability.

3. Additional modeling approaches, if deemed practically feasible, could include an analysis based on NATA results and also a Monte Carlo approach used with AERMOD (discussed below).

Given the limited scope of the proposed construction diesel retrofit program, decisions about the level of resources to commit to reduce uncertainty in estimates of improvement in air quality and public health are policy decisions, not scientific decisions. Uncertainty in the estimated benefits of the construction diesel retrofit program are in part due to its limited scope; the smaller the scope of the retrofit project, the more difficult it is to precisely and accurately define a diminishing, but real, benefit from reduced DPM emissions.

Background

Emissions from diesel engines have been identified as a major health concern (U.S. Environmental Protection Agency 2000), for workers and others who are exposed to diesel emissions (Woskie, et al., 2002, Pronk, et al., 2009). Diesel exhaust is a complex mixture that contains hundreds of compounds, including several that are regulated as air toxics and compounds known or suspected to cause cancer. The International Agency for Research on Cancer (IARC) considers diesel engine exhaust to be "probably carcinogenic to humans." USEPA has also determined that Diesel Engine Exhaust is “Likely to be carcinogenic to humans.” In New Jersey and elsewhere in the US, diesel particulate matter (DPM) is a major component of urban ambient and near-roadway particulate matter, which has been associated with increased risk of exacerbation of asthma and COPD, and increased sickness and premature death from pulmonary and cardiovascular disease. Using estimated DPM concentrations from the National-scale Air Toxics Assessment (NATA) and the California Office of Environmental Health Hazard Assessment (OEHHA) unit risk factor for quantifying cancer risk for DPM, NJDEP estimated that lifetime cancer risk for DPM among residents of New Jersey ranges from 39 in a million in Sussex County, to 916 in a million in Hudson County, with a statewide average of 324 in a million. Recognizing the increased risks to human health posed by DPM and other components of diesel exhaust, the Department has prioritized efforts to reduce diesel emissions.

NATA (2005) estimated 53% of DPM emissions within the state of New Jersey come from non-road mobile sources. These non-road sources include construction, commercial, industrial, rail, agricultural, and lawn and garden equipment, and commercial marine vessels. The Department is considering strategies to reduce emissions from non-road diesel construction equipment. In several cases, stakeholders have requested that air monitoring be conducted in communities surrounding sites where significant diesel reduction efforts will be implemented in order to document the health and environmental benefits of said reductions.
These stakeholder requests led the Department to develop the charge question noted above. The Department developed additional questions to help guide the response(s) from the Committee and full SAB when answering the overall question as stated above. These additional questions are:

1. Is there sufficient science to support ambient air quality monitoring to quantify the environmental benefits of installing retrofit technology on non-road diesel construction equipment?
2. If ambient monitoring is conducted, what parameters should be measured and at what frequency?
3. How many monitoring sites would be required and what should be the duration of the monitoring program?
4. What should be done to minimize potential confounding factors such as other sources in the study area, dust, and variable weather conditions?
5. Are there any data that should be collected concurrent with the ambient monitoring program (e.g., meteorological data)?
6. What constraints, if any, regarding the conclusions that can be drawn based on monitoring data, should the department be aware of if such a program were to be implemented?
7. How do we collect, analyze and present the data in a way that is meaningful to stakeholders?
8. If ambient monitoring is not the best approach, how should the Department address community concerns regarding quantifying the effects of retrofit efforts? Other options include quantifying the amount of diesel emissions reductions from applying retrofits to construction equipment by either using EPA emission factors or testing the exhaust of engines with and without retrofits. These data could then be used to conduct air quality modeling of several construction projects to estimate public exposure to diesel exhaust with and without retrofits. The modeling could also be used to quantify the affect of other diesel emission reduction measures at the construction sites.

Diesel Work Group's Activities and Findings

The Standing Committee formed a Diesel Work Group to focus on this question. The Diesel Work Group (Work Group) consisted of Tony Broccoli, Chair of the Standing Committee, Rob Laumbach of the SAB, and Joann Held and Phil Hopke of the Standing Committee. Providing technical support to the Work Group were DEP staff including Linda Bonanno and Mike Aucott of the Office of Science; Charlie Pietarinen, Chief, Bureau of Air Monitoring; Peg Hanna and Tony Iavarone, Diesel Risk Reduction Program; and Alan Dresser, Greg John, and Olga Boyko of the Bureau of Technical Services.

The Work Group found that NJDEP has successfully completed air modeling of diesel emission sources at two locations: a rail yard in Raritan Borough (New Jersey Department of Environmental Protection 2008), and the Ports of Newark and Elizabeth (New Jersey Department of Environmental Protection 2009). In order to estimate diesel particulate emissions at the Ports, data were supplied by the Port Authority of NY/NJ and its consultant on the number and types of vehicles used at the Port. These vehicles include trucks that pick up and drop off containers and other cargo; many types of cargo-handling equipment such as cranes, fork lifts, and terminal tractors; trains operating on Port property; commercial marine vessels such as tugboats; and ocean-going vessels while docked and in transit to the Port. Data were obtained or estimated on locations of cargo handling equipment, idling trucks, and ships at berth; heights of emission sources such as ship stack heights and crane stack heights; and model years of drayage trucks picking up containers and cargo. NJDEP used USEPA's published emission rates for the types of engines in each of these vehicle categories.

The Work Group also learned that the California Air Resources Board (CARB), in cooperation with the Bay Area Air Quality Management District, conducted a modeling study to estimate the health risks from diesel exhaust in West Oakland. The Port of Oakland and the Union Pacific Railroad provided information on their local marine and rail operations for this risk assessment. The West Oakland Community risk assessment (California Air Resources Board 2008) estimated the lifetime cancer risk and other health impacts from diesel PM exposure in 2005 using computer models to estimate the concentration of diesel PM in the West Oakland Community. Similar studies were conducted for the Roseville Rail Yard (California Air Resources Board 2004) and the Ports of Los Angeles and Long Beach (California Air Resources Board 2006).

The Work Group evaluated several options for determining the improvement in air quality from retrofitting diesel construction equipment. These options fall into 3 general categories.

1. Air quality measurement
2. Air quality modeling
3. Health benefits assessment

Consensus was obtained on the following items.

1. **Air quality measurement**

The Committee considered the possibility of collecting ambient air concentrations at one or more construction projects to determine the improvement in air quality from retrofitting some pieces of equipment on specific project(s). The committee also considered the measurement of worker exposure by personal breathing zone sampling or area sampling within the site, and measurement of potential for exposure by fixed or mobile ambient air sampling at locations surrounding the site. A basic experimental design that could be used to compare community air quality with and without retrofits would be to measure markers of DPM at various locations within and surrounding the site, first prior to and then after retrofitting. This measurement-based approach will require extensive sampling to estimate differences in air quality before and after retrofitting.

Firstly, measurement of any marker for DPM (EC, BC, PM) will have a large and highly variable component from background sources of DPM, as well as from other non-DPM sources of these markers, none of which is specific to DPM. Secondly, there will be large variability in the component of any marker measurement coming from the construction equipment that would be retrofitted, as DPM emissions are likely to change over short periods of time due to changes in site activity and the mix of retrofitted and un-retrofitted equipment. These sources of variability will be exacerbated at DOT construction projects where the equipment is used on or near active roadways, and where activities are likely to be highly variable over location and time. For example, during a road grading and paving project, the diesel equipment could potentially be slowly moving up a long length of road over an extended period of time or across multiple seasons. Other sources of variation include the other pieces of diesel equipment (generators, heating, industrial, vehicles) in the area that have not been retrofitted; the type of worksite (e.g., while building a road, equipment moves through an area with variable terrain); the equipment that is being used; how that equipment is being used (changes in activities). Seasonality (e.g., summer and winter) and other changing meteorological factors (wind speed and direction, vertical mixing, etc.) will be additional sources of variability in the concentration of markers measured at any particular sampling point in space and time.

The resultant expected high degree of variability in monitoring data will require a very extensive sampling campaign in order to have sufficient statistical power to detect a real difference in air quality from the retrofits. The number of samples required to detect a specified mean difference between retrofitted and un-retrofitted conditions, with a reasonable degree of power (e.g. 0.80) and level of statistical significance (eg. $P<=0.05$), can be estimated by statistical power calculation using reasonable, conservative estimates of the variability of specific markers at similar construction sites (by literature search if available, or by limited sampling). The specified mean difference that is considered to have significance for public health or welfare will be somewhat arbitrary, but it is important to determine what amount of change "makes a difference" in advance of any sampling. In any case, this question would arise after sampling when evaluating the results.

In summary, it is in principle possible to detect the expected real difference in air quality attributable to retrofitting off-road construction equipment at a particular site, or over multiple sites. However, with increasing variability in before- and after-retrofitting measurements and/or decreasing size of the mean effect size of retrofitting, an increasing number of samples will be required. In theory, the limitations on obtaining an estimate of the mean effects of retrofitting are practical, not scientific. In other words, assuming unlimited resources, there is no scientifically defensible argument against measurement, if it is done correctly with a sufficient number of samples to avoid a Type II error. Besides cost and resource utilization, some examples of other practical issues are the difficulty in siting long-term monitoring locations (e.g., space, power, security).

In addition to the difficulty in obtaining internally valid measurements of the air quality impact of retrofits at one or more constructions sites, external validity, or the application of results from some limited number of sites is similarly challenging. Here again, there is a great deal of variability in conditions between construction sites, and statistical approaches can be used to estimate the number of sites at which sampling would be required to obtain estimates of the mean impact of retrofits at sites across the state. Due to variability between sites, this is likely to require sampling at a very large number of sites, depending on the desired degree of confidence. Again, this approach is scientifically feasible, but it appears unlikely to be economically or practically feasible.

One potential approach to reducing the variability of measurements at any particular site would be to control conditions to the extent feasible. Conditions that could be controlled include activities at the site, which may require simulation, and perhaps rapidly removing and reinstalling retrofit equipment to obtain an 'ABABAB…' crossover experimental design. It will not be possible to control meteorological and background source variables, but fewer samples would be required. This "demonstration project" approach would greatly reduce the number of samples needed to detect a specified effect. It will require cooperation and collaboration with industry, and it may not be practically feasible due to costs involved in controlling or simulating construction activities. Also the results may lead to additional questions about external validity and representativeness compared to "real-world" conditions.

2. Air quality modeling

In addition to direct measurement, several forms of modeling can produce estimates of air quality improvement. Modeling could be used alone or in conjunction with measurement. Modeling is likely to be more practical and cost effective than air quality measurement, for reasons described below. However, all models are simplifications of actual highly complex conditions and processes, and the model results are therefore subject to error that is difficult to assess without comparison to measured results.

The simplest model would be the application of known emission reduction factors to an inventory of diesel emissions. Emission reduction calculations using USEPA-approved emission factors and retrofit effectiveness values approved by USEPA/CARB are accepted standards among government and industry alike for estimating mobile source emissions in small and large projects. This model can be used to quantify reductions in emissions that can be assumed to have definite, but unquantifiable, air quality and public health benefits at state-funded construction sites across the state.

Air quality dispersion modeling

Air quality dispersion modeling can estimate improvement in ambient air quality from requiring off-road diesel construction equipment retrofits under various scenarios. Predicted air concentrations from the modeling can be used to quantify the health benefits to both the workers and surrounding populations (the community). An advantage of modeling vs. measurement is that the model's input(s) can be altered to produce estimates of air quality improvement at various sites under various conditions with relatively little cost/resources. Furthermore, modeling can control for variables that cannot be controlled during an air sampling campaign, such as the impact from varying meteorological conditions or off-site emissions.

Modeling could be done for two types of land use, urban and rural, and for as many different types of construction projects as needed. The best model to use for this purpose appears to be AERMOD. AERMOD has been USEPA's regulatory model since December 9, 2005 (U.S. Environmental Protection Agency 2005). As such, it has undergone extensive validation for many different source types and source configurations. It has generally been found to produce reasonably accurate model predictions (Perry et al. 2005).

Limited near-field monitoring at a stationary site to help evaluate the model

This approach was initially considered useful by the Work Group. However, upon further discussion with the full SAB, it was decided that, as with community-scale and construction site-scale monitoring (discussed above), so many variables (meteorology, site-specific conditions, etc.) exist that there can be little if any confidence that results would be useful.

Other modeling to help characterize uncertainty

The Work Group's recommended approach is air quality dispersion modeling with AERMOD (discussed above). Additional modeling approaches were discussed to support the results of AERMOD. Among such modeling approaches that were considered are the use of EPA's National-scale Air Toxics Assessment (NATA) modeling results. The change in health impacts due to the retrofit program could be estimated by taking NATA's predicted concentrations and ratioing them by the change in the off-road diesel emissions before and after installation of the retrofits. A Monte Carlo simulation of air quality changes based on expected distributions of emissions of diesel equipment at a statewide level before and after retrofits was also considered. Insofar as quantification of health benefits to workers are concerned, the Standing Committee notes that there is a body of literature on the use of mathematical models to estimate occupational exposure to chemicals that may be of use to the Department (Armstrong, 2009).

3. Health Benefits Assessment

Improvements in air quality determined by measurement and/or modeling could be translated into estimates of public health improvement by applying unit risk factors or reference doses to estimated incremental statewide reductions in measured or modeled pollutant concentrations. For cancer risk, the unit risk factor from the CA OEHHA could be applied to an estimated incremental average reduction in exposure to DPM on a statewide basis to derive an estimate of potential lives saved. The estimated decrease in statewide DPM emissions could also be applied directly to the DEP's existing estimates of statewide cancer risk from DPM, using the simplifying assumption that the decrease in emissions is proportional to a decrease in cancer risk. Valid assessment of reduction in heart attacks and sudden cardiac death, and asthma attacks, and hospitalization and death from respiratory disease may be especially challenging as short term changes in DPM exposure are likely to be important metrics for risk of acute effects. It should be recognized that all estimates of statewide health benefits of the diesel retrofit program will be highly uncertain, due to uncertainty in estimates of exposure, estimates of distribution of exposure in the population, and estimates of the potency of exposure relative to any particular health outcome.

Recommendations Summary

The Standing Committee considered various approaches to measuring and modeling improvements in air quality from the retrofitting of diesel construction equipment. Given the demonstrated health risks associated with DPM and the demonstrated effectiveness of the retrofit technology in reducing DPM emissions, there is little doubt that retrofitting construction equipment will lead to improvements in air quality and health benefits for citizens in the state. The question before the SAB is how best to quantify these effects.

In general, from a scientific point of view, the Committee recommends that a simple analysis of expected emission reductions should be conducted to demonstrate the effectiveness of the proposed retrofit of diesel construction equipment.

If, however, the Department disagrees with the above recommendation and feels it is imperative to develop additional support for these reductions, then the Committee would recommend the use of a variety of approaches to estimating the air quality and public health impacts of the retrofit program, where practically feasible, as each approach has relative strengths and weaknesses, and each may inform the others: (1) Direct measurement to estimate the effects of retrofits on air quality and public health would be facilitated by a demonstration project designed for the purpose of assessing the impacts of retrofits on air quality as it affects workers and off-site. (2) Air quality dispersion modeling with EPA's widely used and validated model AERMOD. The Committee recommends that any modeling plan be carefully conceived to account for variability in local land use and site activity as well as topographical and meteorological variability. (3) Additional modeling approaches, if deemed practically feasible, could include an approach based on NATA results and a Monte Carlo approach used with AERMOD (see above).

Test results have demonstrated that emission control technologies have the ability to reduce DPM mass emissions by as much as 85% depending on what is technologically feasible (California Air Resources Board, 2012; U.S. Environmental Protection Agency, 2012). As discussed above, accurate assessment of the air quality and public health impacts will require considerable resource commitment due to a number of factors that increase the variability in amounts of DPM arising from equipment that can be retrofitted, the dispersion of that DPM, and background levels on nonspecific DPM markers.

Given the limited scope of the proposed construction diesel retrofit program, decisions about the level of resources to commit to reduce uncertainty in estimates of improvement in air quality and public health are policy decisions, not scientific decisions. Uncertainty in the estimated benefits of the construction diesel retrofit program are in part due to its limited scope; the smaller the scope of the retrofit project, the more difficult it is to precisely and accurately define a diminishing, but real, benefit from reduced DPM emissions.

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