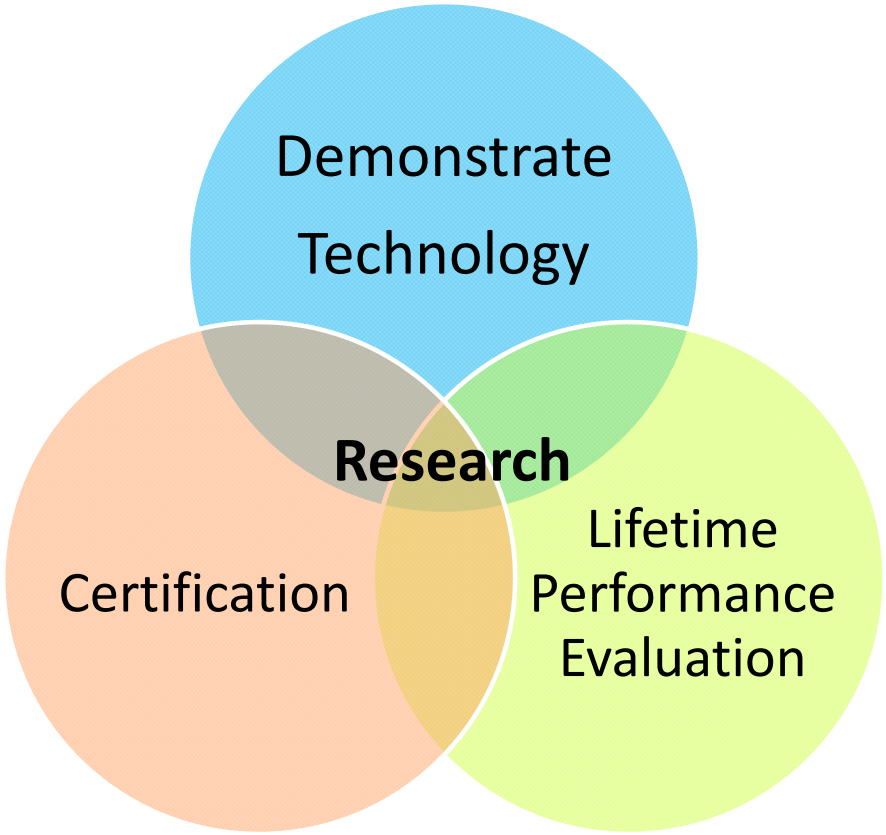
Update on Vehicle Emissions Research

California Air Resources Board

Board Hearing, April 23rd 2015

Research Underpins
ARB's Mobile Source Program

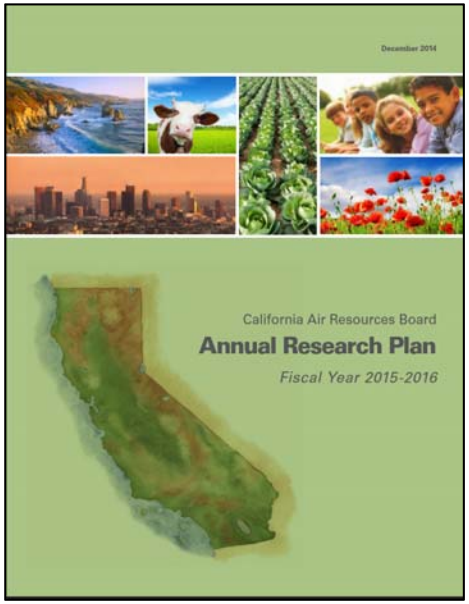
Emissions Testing at ARB



Research is critical and benefits all program areas

Resources

- Staff expertise
- In-house laboratories and field measurements
- Research contracts



Research Plan

PEMS

Mobile Measurements

Dynamometers

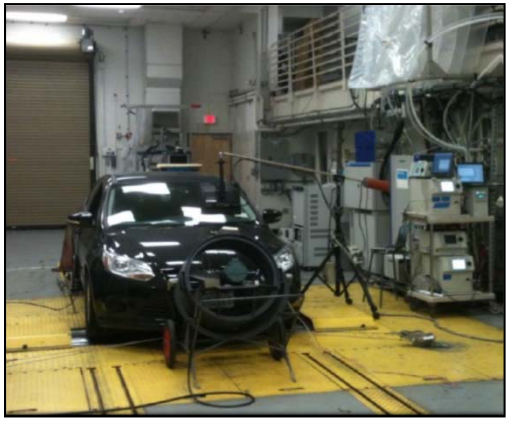
Determining Priorities

1. *Identify ARB program priorities and develop appropriate research*
2. *Investigate emerging issues*

- Annual meetings between research and program staff to develop annual research plan and research priorities
- Active in scientific community
- Meet with state and federal partners and major industry groups to understand research needs and emerging issues
- Respond to direct requests from program staff

Light Duty Research Priorities

- Guide the transition to zero emission vehicles
- Evaluate emissions of current fleet
- Expand understanding of emissions



Results will inform several important decisions by the Board on our light duty program

Research Focused on Transitioning to Zero Emission Technologies

Zero Emission Vehicles are here today:

- Factors affecting choice to purchase PHEV and ZEVs?
- PHEV usage patterns and emission implications?
- What happens to ZEVs and PHEVs in the secondary market?
- How to maximize the benefits of incentives?

Research will inform the Midterm Review

Evaluate Emissions from the Current Fleet

Research confirms emissions continue to decline

- Portable Emissions Measurements Systems (PEMS) studies
- Roadside measurements
- Remote sensing

99% reduction in light duty emission rate over 20 years

Car exhaust control technology becoming increasingly durable

Expand our Understanding of Emissions

Use novel measurement techniques in the controlled laboratory environment

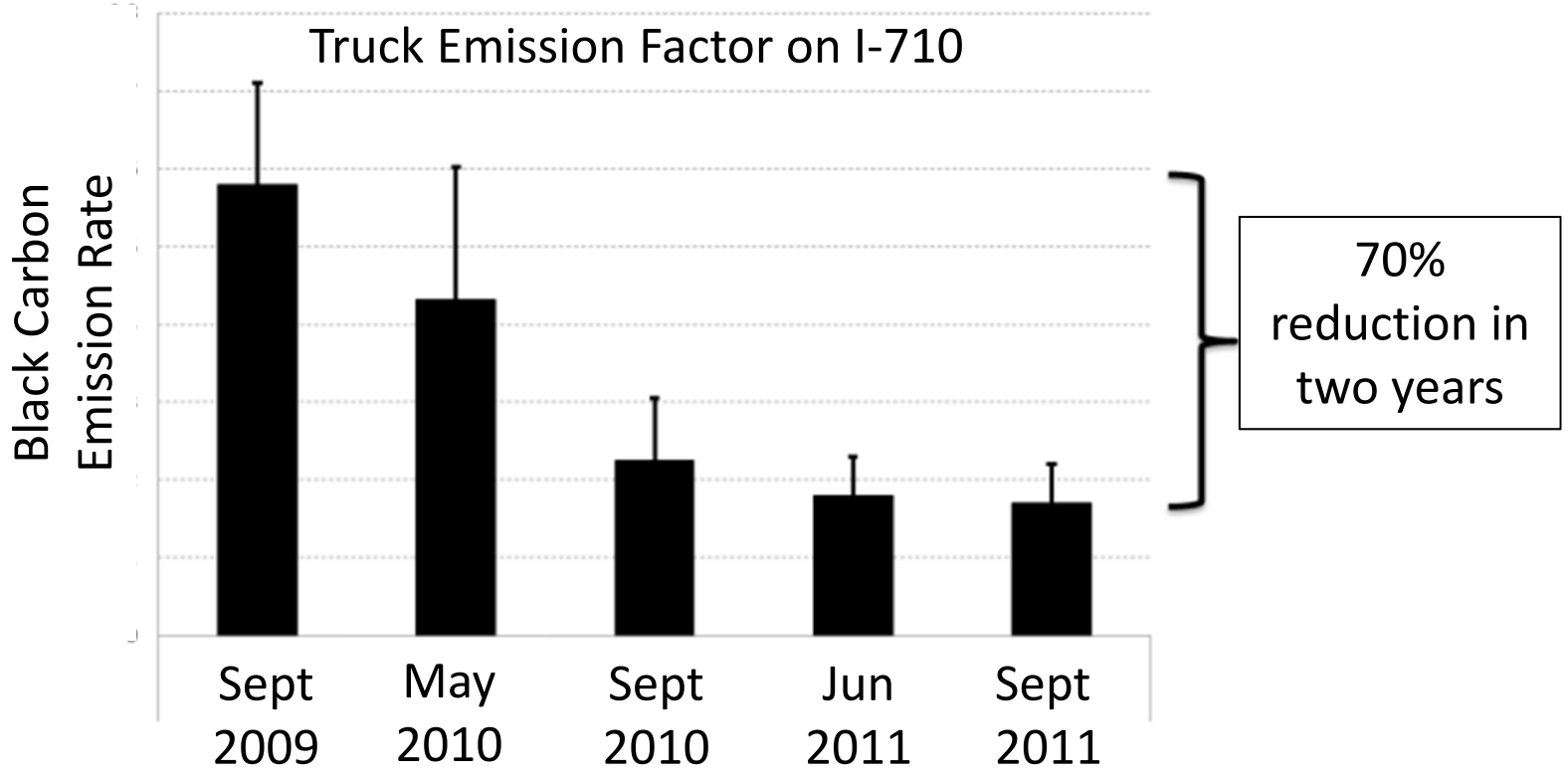
- Properties of light duty PM – implications for low mass measurements
- Emissions of air toxics and ultrafine PM reduced, often by more than 95%, over the last 25 years
- Newest control technology eliminate gases that condense to form secondary PM

Heavy Duty Research Priorities

- Effect of Drayage and Truck and Bus rules for on-road emissions
- Support regulation to reduce on-road PM and NOx
- Expand understanding of emissions
- Inform the introduction of ZEVs in heavy duty applications

Results will inform several important decisions by the Board on our heavy duty program

Black Carbon Emissions from Trucks in California

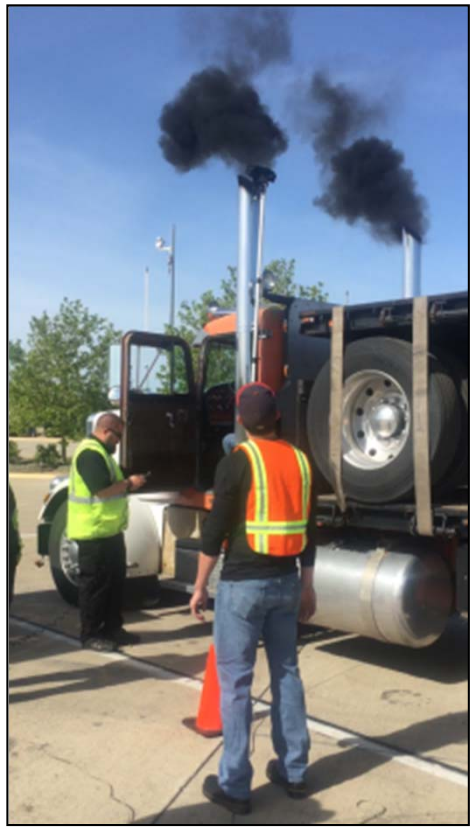


Kozawa et al. (2014) Verifying Emissions Reductions from Heavy-Duty Diesel Trucks Operating on Southern California Freeways, *Environmental Science and Technology,* 48(3), 1475-1483.

On-Road PM Emissions

ARB funded research measures on-road emission factors:

- PM filters, or DPFs, virtually eliminate PM
  - Thousands of trucks measured
  - Multiple locations statewide
  - Several different techniques used
  - Multi-year studies
- Small fraction of on-road PM filters not well maintained or tampered with



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Improving Compliance for Filters

Develop ability to quickly identify compromised DPFs

Detailed testing and repair of high-emitting trucks

Design Inspection &Maintenance program to improve compliance

NO_X Emissions

- ARB research identified off-cycle NO_X from modern diesel engines as a possible concern in 2009
- Subsequent research has provided additional insight
- Working with engine manufacturers – improvements have been made

Environ. Sci. Technol. 2009, 43, 5928–5933

Effect of Advanced Aftertreatment for PM and NO_x Control on Heavy-Duty Diesel Truck Emissions

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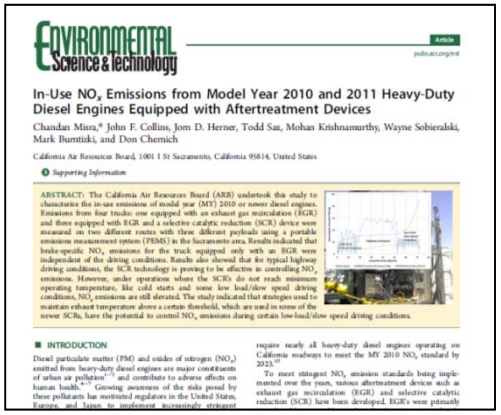
Emissions from four heavy-duty and medium-duty diesel vehicles were tested in six different aftertreatment configurations using a chassis dynamometer. The aftertreatment included four different diesel particle filters (DPF) and two prototype selective catalytic reduction (SCR) devices for NO_x control. The goal of the project was to fully characterize emissions from various in-use vehicles meeting the 2007 particulate matter (PM) standard for the United States and California and to provide a snapshot of emissions from 2010 compliant vehicles. The aftertreatment devices all worked as designed, realizing significant reductions of PM and NO_x. The DPF realized >95%

duty diesel (HDD) emissions in the late 1980s and have since tightened the emissions standards periodically as new diesel technology has made it possible to lower emissions while retaining the high thermal efficiency characteristics of diesel engines. The most sweeping reduction in the emissions standards from heavy-duty diesel engines is a 90% reduction of PM and NO_x effective as of 2007 and 2010, respectively.

In the past, engine manufacturers have realized reductions in PM and NO_x emissions for HDD engines with engine design modifications and combustion process improvements. While the new PM and NO_x standards are technology neutral, it is widely expected that sophisticated aftertreatment technologies will be required to meet the limits, namely, diesel particulate filters (DPF) for PM and selective catalytic reduction (SCR) and exhaust gas recirculation (EGR) for NO_x. DPFs and SCRs, in addition to filtering soot and converting NO_x, change the character of the diesel engine emissions qualitatively by acting as chemical reactors that create varying degrees of either oxidizing or reducing conditions with associated effects on other exhaust gas species (*11*–*13*). The extent to which this happens depends on the individual characteristics of the DPF or SCR. While epidemiological evidence exists linking $PM_{2.5}$ mass with adverse health effects (*14*–*18*) and, therefore, a reduction is beneficial, it still remains to be shown directly that the toxicity of the treated exhaust is also reduced (*19*, *20*).

The primary goal of this study is to investigate the effectiveness and effects of advanced emission control technologies. Effectiveness is defined as reductions of the targeted pollutants PM mass and NO_x. Effects include those on other criteria pollutants, SO_2(g), particle number, volatility, toxicity, mutagenicity, toxic gas−phase compounds, ozone



Environmental Science & Technology

Article

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In-Use NO_x Emissions from Model Year 2010 and 2011 Heavy-Duty Diesel Engines Equipped with Aftertreatment Devices

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Supporting Information

ABSTRACT: The California Air Resources Board (ARB) undertook this study to characterize the in-use emissions of model year (MY) 2010 or newer diesel engines. Emissions from four trucks: one equipped with an exhaust gas recirculation (EGR) and three equipped with EGR and a selective catalytic reduction (SCR) device were measured on two different routes with three different payloads using a portable emissions measurement system (PEMS) in the Sacramento area. Results indicated that brake-specific NO_x emissions for the truck equipped only with an EGR were independent of the driving conditions. Results also showed that for typical highway driving conditions, the SCR technology is proving to be effective in controlling NO_x emissions. However, under operations where the SCRs do not reach minimum operating temperature, like cold starts and some low load/slow speed driving conditions, NO_x emissions are still elevated. The study indicated that strategies used to maintain exhaust temperature above a certain threshold, which are used in some of the newer SCRs, have the potential to control NO_x emissions during certain low-load/slow speed driving conditions.

INTRODUCTION

Diesel particulate matter (PM) and oxides of nitrogen (NO_x) emitted from heavy-duty diesel engines are major constituents of urban air pollution[1−3] and contribute to adverse effects on human health.[4−6] Growing awareness of the risks posed by these pollutants has motivated regulators in the United States, Europe, and Japan to implement increasingly stringent

require nearly all heavy-duty diesel engines operating on California roadways to meet the MY 2010 NO_x standard by 2023.[10]

To meet stringent NO_x emission standards being implemented over the years, various aftertreatment devices such as exhaust gas recirculation (EGR) and selective catalytic reduction (SCR) have been developed. EGRs were primarily

ARB's Freight Strategy includes actions to address these issues

NO_x Research Informing How Low New Engine and In-Use Standards Can Be Set

Demonstrate ability to meet a 90% reduction in NO_x standard

Lower engine NO_x standards

Remote sensing to understand in-use emissions

Measure NO_x from real world driving using PEMS

Activity as a function of vocation

Improve in-use certification

Expand Understanding of Emissions

- Diesel PM from modern trucks is reduced by 99%, but is still diesel PM
- Emissions of toxic compounds and ultrafine diesel soot PM reduced by 95-99% over the last 20 years
- Toxicity screening also show major reductions

Inform the Introduction of Hybrids, Battery and Fuel Cells in Heavy Duty

- Research to record duty cycle of trucks in various vocations:
  - Determine the right technology for the right use
  - Develop test procedures and certification programs for new technologies
- Data collection and analysis to evaluate performance of ARB funded demonstrations

Next Steps

- Support conversion to zero emission light duty vehicles
- Emulate light duty success and transition heavy duty fleet to zero emissions
- Quantify the rate of on-road emission reductions as lower emitting vehicles enter the fleet and control technology becomes more durable

Continue to provide the scientific underpinnings of programmatic goals