

# Ethanol and Ground Level Ozone

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Photo from 2001, published in The Denver Post, July 20, 2020

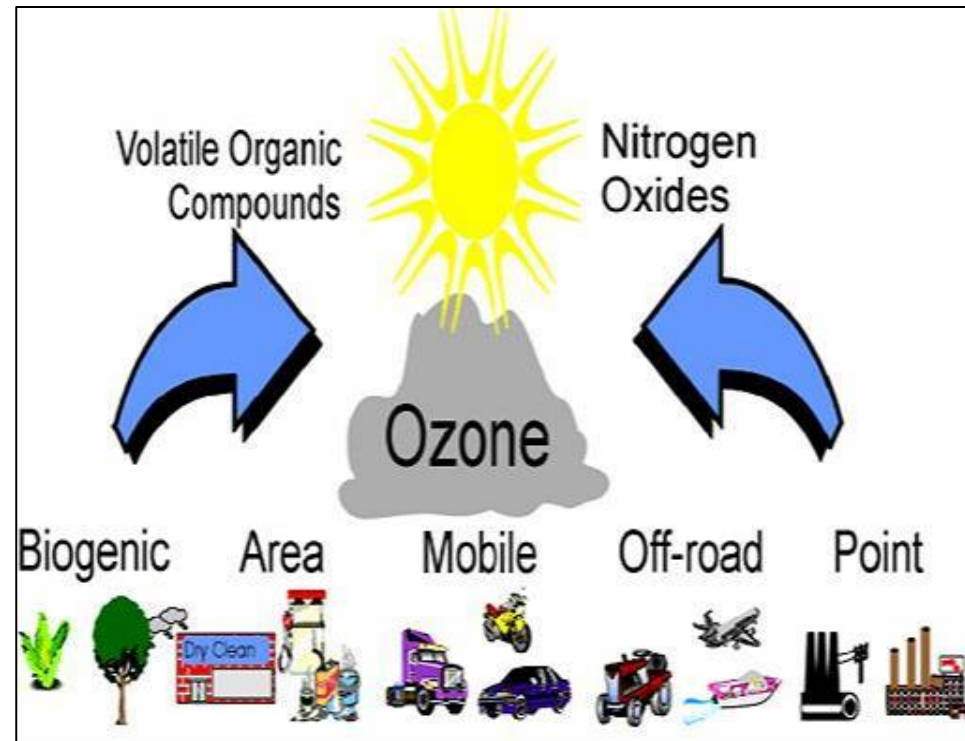
# The Basics

- **Smog** is visible pollution. It can include ozone, nitrogen oxides, sulfur oxides, smoke or particulates
- **Stratospheric ozone** (around 10 km above the earth) naturally occurring and beneficial – we don't want a hole in it because the ozone layer protects us from dangerous levels of UV radiation.



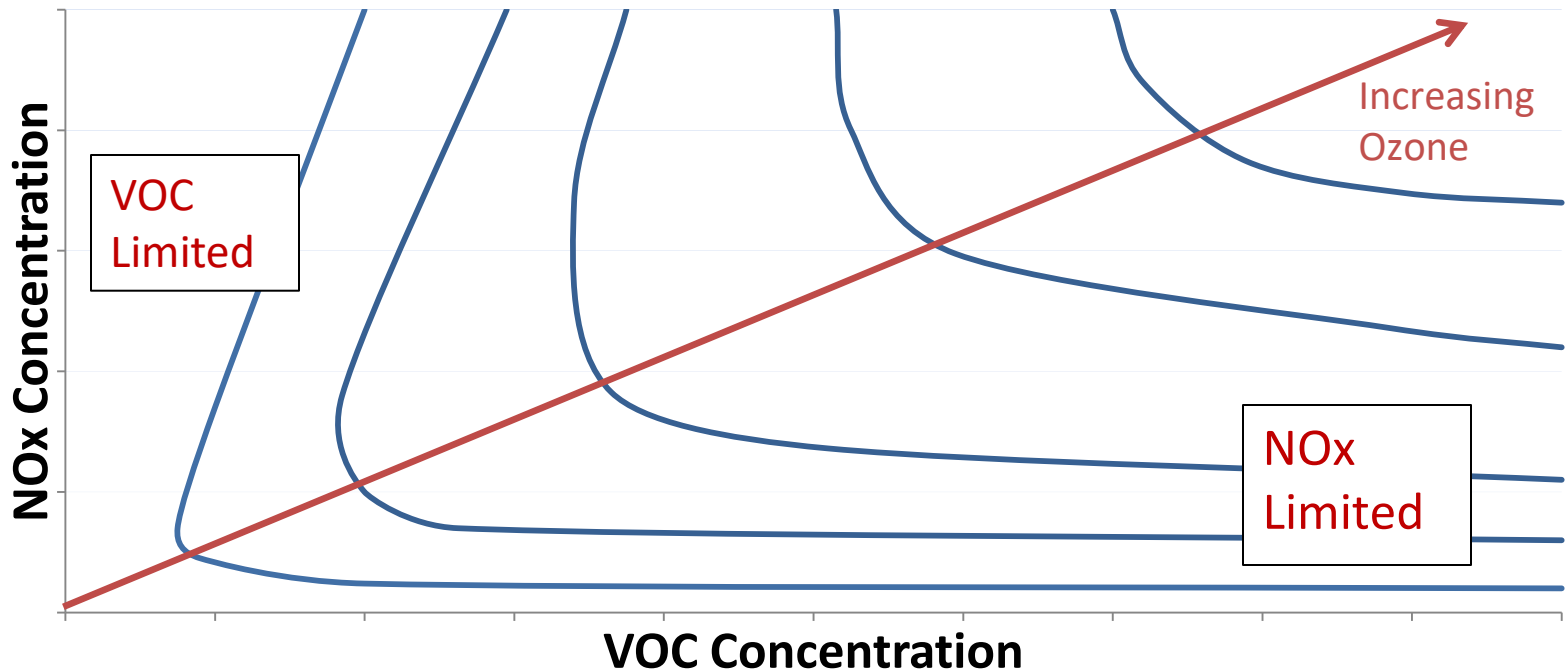
Ground level ozone is not emitted but forms in the presence of:

1. Oxides of nitrogen (NO<sub>x</sub>)
2. Volatile organic compounds (VOC)
3. Sunlight



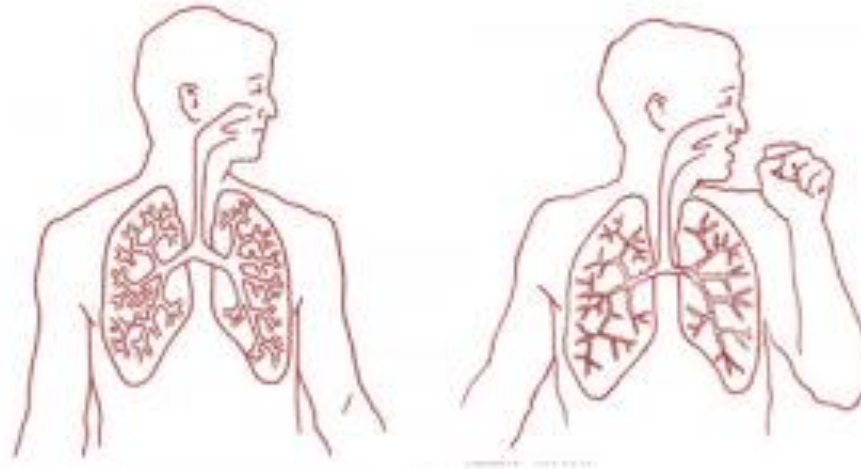
# Ozone Isopleths

(Blue Lines Represent Constant Ozone Level)



Based on Dodge, M.C., Combined use of modeling techniques and smog chamber data to derive ozone-precursor relationships, Proc. Int'l Conf. on Photochemical Oxidant Pollution and Its Control, Vol II, B. Dimitriadis, ed EPA-600/3-77-001b, pp. 881-889. cited in Zannetti, P. Air Pollution Modeling, 1990.

Ozone causes the muscles in the airways to constrict preventing the movement of air in and out of the lungs



- Make it more difficult to breathe deeply and vigorously.
- Cause shortness of breath, and pain when taking a deep breath.
- Cause coughing and sore or scratchy throat.
- Inflammation and damage the airways.
- Aggravate lung diseases such as asthma, emphysema, and chronic bronchitis.
- Increase the frequency of asthma attacks.

# Ozone Forming Potential

- Not all VOCs are the same: need to consider how fast the organic compound will react and how many molecules of ozone it will create when fully reacted
- Less reactive VOCs may leave the area before forming any ozone
- MIR – Maximum Incremental Reactivity - most commonly used approach. Reflects total ozone yield over a simulated 24 hour day at low base level of VOCs and high level of NO<sub>x</sub>.

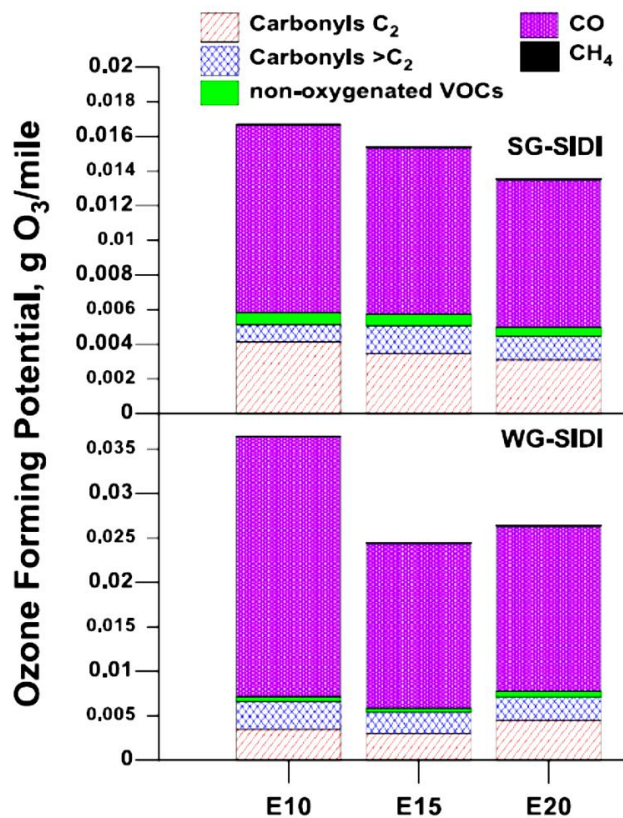
# MIR

MIR (g of ozone/g of compound)	
Methane	0.014
Ethane	0.26
Ethene	8.76
Benzene	0.69
Acetaldehyde	5.5
Ethanol	1.45
Carbon monoxide	0.053
CARB gasoline evap. emissions <a href="https://www.arb.ca.gov/fuels/gasoline/premodel/pmdevelop.htm">https://www.arb.ca.gov/fuels/gasoline/premodel/pmdevelop.htm</a>	Approx. 3

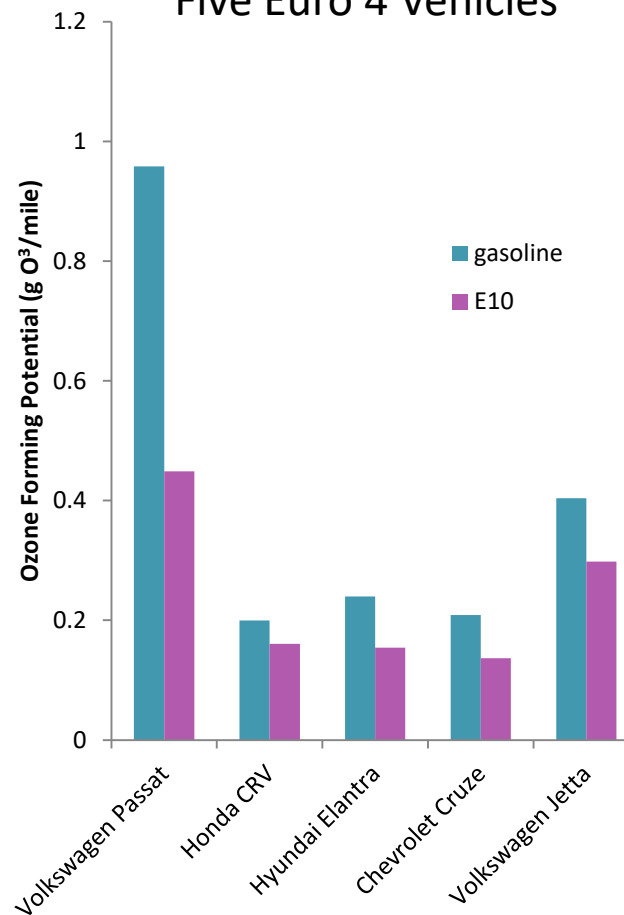
Carter, W. P. L., Updated Maximum Incremental Reactivity Scale and Hydrocarbon (2006) Bin Reactivities for Regulatory Applications, prepared for CARB, June 22, 2009, [www.arb.ca.gov/research/reactivity/mir09.pdf](http://www.arb.ca.gov/research/reactivity/mir09.pdf).

# Ozone Forming Potential from use of Ethanol-Containing Fuels

Two U.S. 2012 Vehicles  
(Tier 2/Tier 3)



Five Euro 4 Vehicles



# Test Results: Tailpipe Emissions E15 vs E10



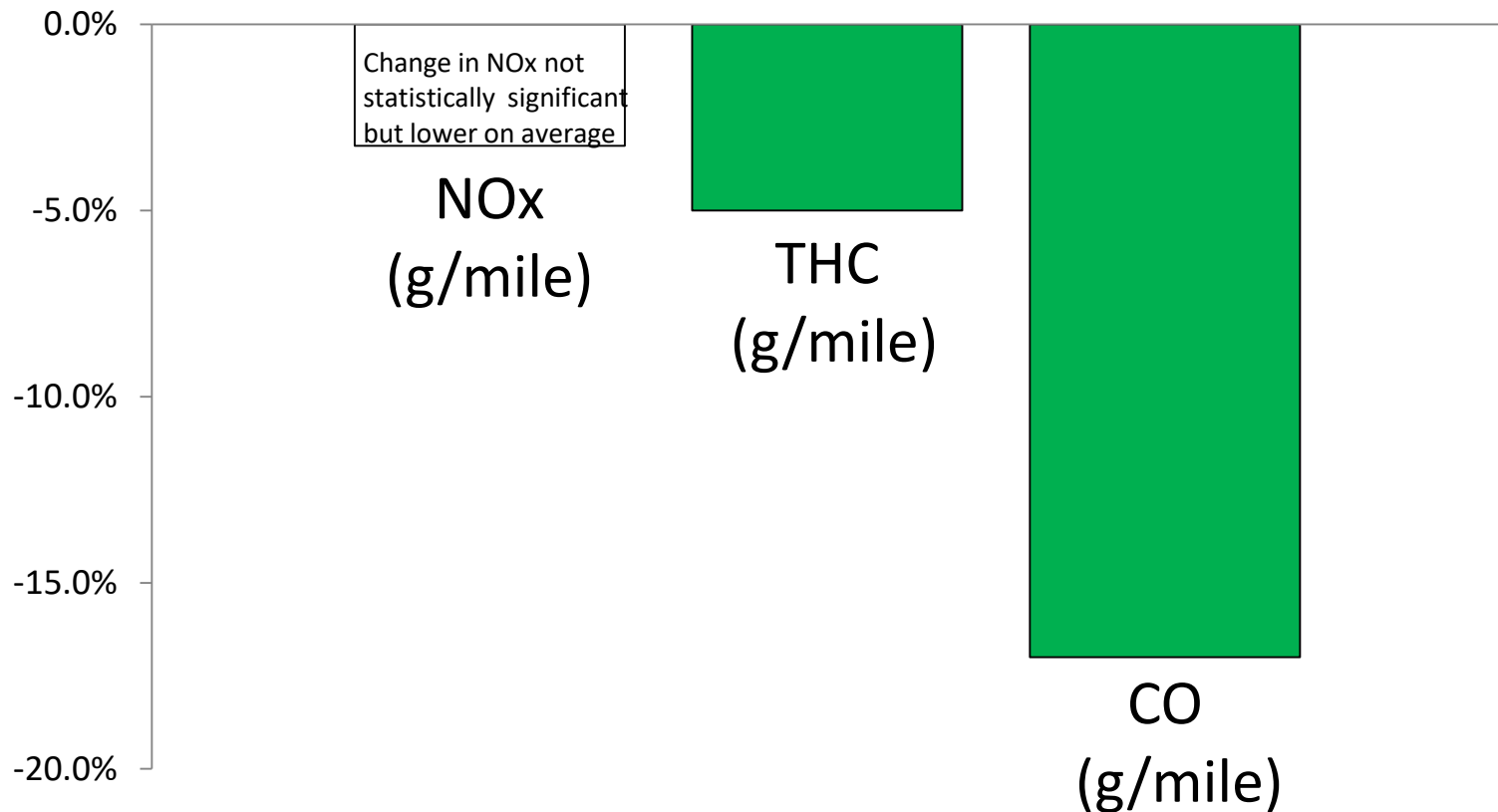
- Testing conducted in 2021
- 20 common vehicles selected by California ARB based on registration data
- E10 blended from 4 California retail sources
- E15 blended from E10 + additional ethanol

Technology Group	MY	Make	Model
SULEV 30	2019	Chevrolet	Impala
	2018	Honda	Fit
	2018	Jeep	Cherokee
	2017	Mazda	Mazda 3
	2016	Toyota	Prius
ULEV 125	2020	Hyundai	Accent
	2019	Chevrolet	Suburban
	2018	Honda	Civic 4DR
	2018	Nissan	Armada
	2017	Ford	F150 4WD
ULEV 70	2020	Ford	Fusion FWD
	2019	Dodge	Ram 1500
	2018	Kia	Optima
	2017	Chevrolet	Spark
	2016	Nissan	Rogue
ULEV 50	2020	Buick	Enclave
	2020	Jeep	Compass
	2019	Chevrolet	Colorado
	2019	Toyota	Rav4
	2018	GMC	Acadia



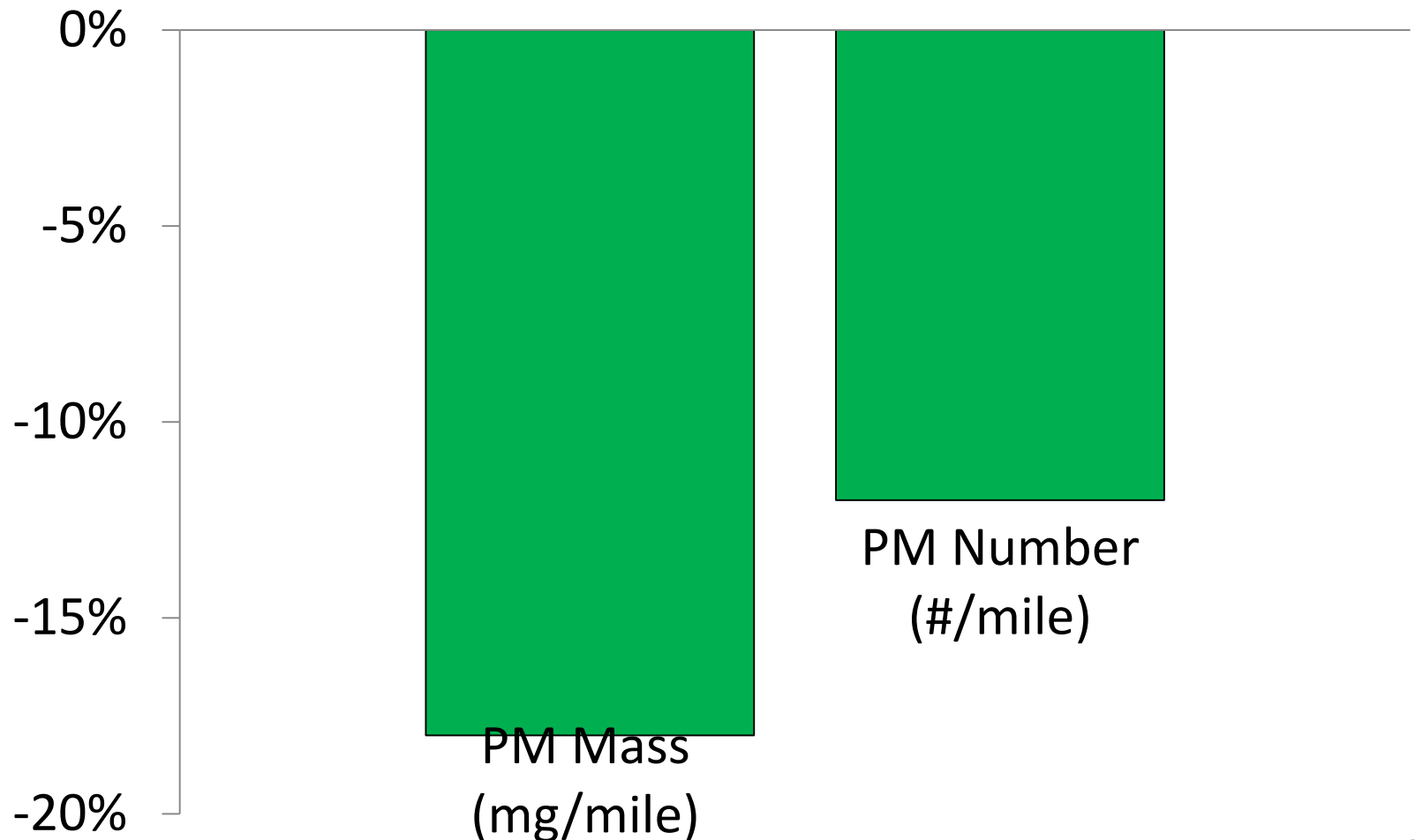
# % Change between E15 and E10

## Least Square Means

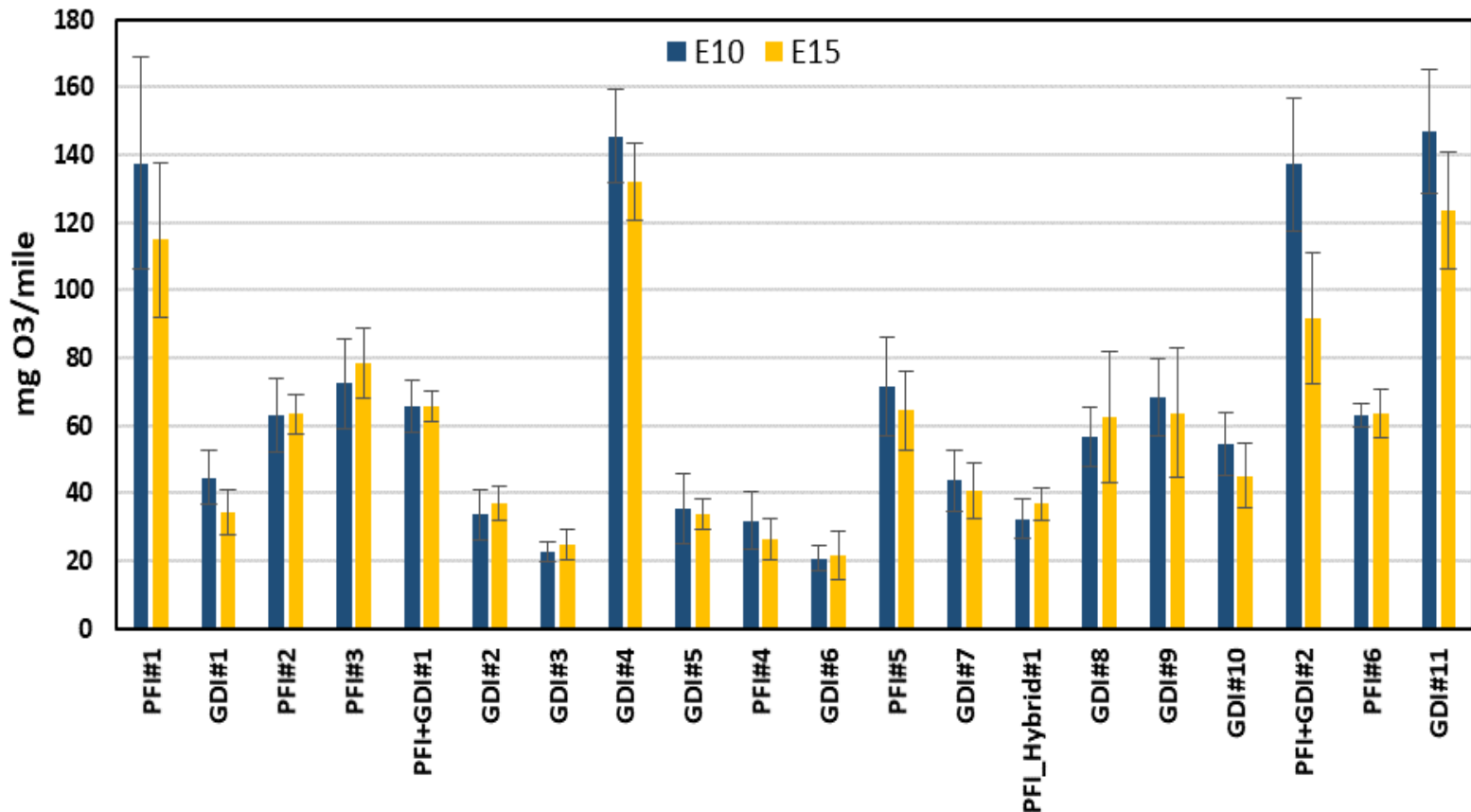


# % Change between E15 and E10

## Least Square Means

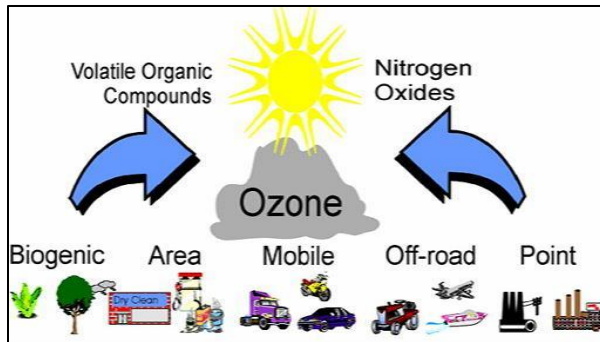
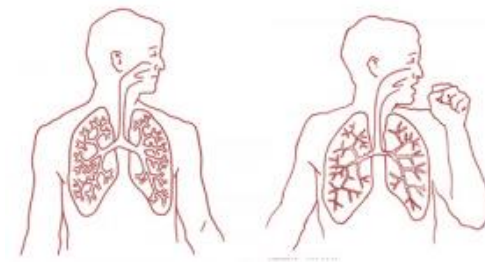


# CE-CERT found Ozone Forming Potential of Emissions “trended lower with E15”.



Karavalakis et al., Final Report ,Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15, January 2022

1. Ozone has significant human health impacts.



2. Ozone forms in the presence of VOCs, NOx and sunlight and produces visible pollution.



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CARB gasoline evap. emissions	Approx. 3

3. Not all VOCs are the same – some result in more ozone than others.

4. Recent testing shows E15 will not increase NOx or ozone forming potential in tailpipe emissions and will reduce PM and CO in comparison to fuels containing less ethanol.

