Title

On-Road Motor Vehicles No Longer Dominate Ozone Formation

Author

Kleeman, Michael, PhD

Publication Date

2024-08-01

DOI

10.7922/G2222S4P

On-Road Motor Vehicles No Longer Dominate Ozone Formation

Michael Kleeman, Ph.D.
Department of Civil and Environmental Engineering, University of California, Davis

August 2024

Issue

The amount of traffic on California's roadways decreased by approximately fifty percent during the COVID-19 pandemic lockdown in March and April of 2020. Conventional wisdom led to the expectation that reduced traffic would result in reduced ozone (O3) concentrations—ozone being a main component of smog—yet ozone concentrations increased during this period. Internal combustion vehicles emit oxides of nitrogen (NOx) and volatile organic compounds (VOCs). These emissions are precursors for ozone formation, but the relationship between these precursor emissions and the final ozone concentration is complex. The ratio of NOx/VOCs determines if the ozone formation will be "NOx-limited" or "NOx-rich". Major NOx reductions are required to reduce ozone concentrations when the atmosphere is NOx-rich. Small NOx reductions in a NOx-rich atmosphere can actually increase ozone concentrations.

To inform ongoing efforts to reduce ambient O3 concentrations, our team collected and analyzed air pollution measurements in urban locations adjacent to major freeways in the City of Sacramento and the City of Redlands—both during and after COVID-19 stay-at-home orders. The results provide an updated estimate for how many more years of NOx control will be required before O3 benefits are realized.

Key Research Findings

The traffic reductions during COVID-19 had a limited effect on ozone concentrations. Ambient NOx concentrations decreased by approximately 30% during COVID-19 shutdown periods due to reduced traffic, with lesser reductions in evaporative VOC emissions. This emissions change happened in the spring when ozone chemistry is NOx-rich and so ozone concentrations did not respond favorably to reduced traffic. A similar emissions change in summer months when ozone chemistry is more NOx-limited would have reduced ozone concentrations in small and medium-sized cities. Traffic reductions alone cannot reduce ozone concentrations in the center of major urban cities.

Policy Implications

Short term vehicle emissions reductions must be coordinated with changes in other sectors. Ambient NOx concentrations will need to decrease by approximately 40% in small and medium cities and by approximately 80% in larger cities before ozone concentrations reliably decrease during summer months. Reductions in traffic emissions alone cannot achieve this level of control in the near term. Traffic control programs should be coordinated with emissions reductions in other sectors such as volatile chemical products to continue reducing ambient ozone concentrations.

Long term greenhouse gas (GHG) reductions will play an important role in ozone control. Given the natural VOC emissions from vegetation, deep NOx reductions are the only viable long-term pathway to controlling ozone concentrations. California's plan to reduce GHG emissions from the transportation sector will largely accomplish the goal of ozone control. However, achieving healthy air quality across California is a broader goal that will require coordinated emissions reductions beyond the transportation sector.

What you Should know About Ozone Formation

Ozone chemistry goes through a seasonal cycle. Warmer temperatures in the summer months increase emissions of VOCs from vegetation and evaporative emissions from transportation sources, leading to changes in the ambient NOx/VOC ratio. Reductions in NOx emissions during summer months will be more effective at reducing ozone concentrations than similar NOx reductions in other months.

Ozone chemistry changes with population density. Normal human activity generates emissions of NOx and VOCs, with higher emissions in areas with higher population density. Ozone chemistry is solidly NOx-rich in urban cores and transitions towards NOx-limited in downwind regions. Small reductions in NOx concentrations in a NOx-rich environment increases ozone concentrations.

Some VOC sources cannot be controlled. VOCs are emitted by a variety of human and natural sources. Emissions from traffic sources have strongly decreased in past decades, but emissions from vegetation have remained largely unchanged, making this natural VOC source a major contributor to ozone formation in present-day California.

Ground-based measurements, satellite measurements, and models all agree. Direct measurements of ozone response to NOx/VOC changes are consistent with weekday/weekend ozone trends driven by changing traffic patterns. Both ground-based observations are consistent with satellite measurements of NOx/VOC concentration patterns. Models of atmospheric chemistry that are used to design control programs agree with measurements. All evidence supports the seasonal and spatial trends summarized.

More Information

This policy brief is drawn from the report "Measuring Changes in Air Quality from Reduced Travel in Response to COVID-19" available at: www.ucits.org/research-project/2021-07. For more information about findings presented in this brief, please contact Michael Kleeman at mjkleeman@ucdavis.edu.

Research presented in this policy brief was made possible through funding received by the University of California Institute of Transportation Studies (UC ITS) from the State of California through the Public Transportation Account and the Road Repair and Accountability Act of 2017 (Senate Bill 1). The UC ITS is a network of faculty, research and administrative staff, and students dedicated to advancing the state of the art in transportation engineering, planning, and policy for the people of California. Established by the Legislature in 1947, the UC ITS has branches at UC Berkeley, UC Davis, UC Irvine, and UCLA.

Project ID UC-ITS-2021-07 | DOI: 10.7922/G2222S4P