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# Riding in cars with smokers: Stanford researchers measure secondhand smoke concentrations in automobiles

BY DAVID ORENSTEIN

It's Labor Day weekend and you have packed the family into the car for the two-hour drive to grandma's house. Because of the heat, you crank the AC and keep the windows closed. The problem is you are a smoker and after just two cigarettes you will have exposed your spouse and kids to particulates at a level well above government safety standards. That's the bottom-line finding of measurements recently published by engineering researchers at Stanford University.

"This is the most comprehensive set of measurements ever made of vehicle air change rates and smoke particulate levels in real driving conditions," says Neil Klepeis, a consulting professor of civil and environmental engineering (CEE) at Stanford. Klepeis co-authored the study published online July 18 in the *Journal of Exposure Science and Environmental Epidemiology*. "Conditions in a car with a smoker can vary widely, but in some situations we can confirm that passengers will receive an exposure to secondhand smoke that is considered unhealthy."

Co-author Wayne Ott, also a CEE consulting professor who worked for decades as a scientist at the U.S. Environmental Protection Agency (EPA), noted that legislation banning smoking in cars with children present passed in Arkansas last year and has been considered in seven other states.

"Our hope is that this research can lend rigorously acquired and analyzed, objective scientific information to this debate," Ott says.

Klepeis and Ott collaborated with Stanford statistics and earth sciences Professor Paul Switzer on the paper, which followed an article the team published in June on secondhand smoke exposure in outdoor café settings. That paper, the first of its kind, almost immediately began to be cited in policy debates about regulating outdoor smoking, Ott says.

## Measuring particles

In both the café and the car studies, the team sought to measure smoke particles of less than 0.0001 inch (2.5 millionths of a meter) in diameter. These particles are deemed a health risk by the EPA because they can penetrate deep into lung tissue when inhaled. The level the EPA considers unhealthy is 35 millionths of a gram per cubic meter (35  $\mu\text{g}/\text{m}^3$ ), averaged over 24 hours.

To make air exchange and secondhand smoke measurements in four different cars, the team released a tracer gas or engaged volunteer smokers to puff as they drove. While taking the measurements, the engineers kept track of a number of independent variables including whether the fan or air conditioning was off or on, the car's speed and whether the windows were open or closed.

Accounting for all of these parameters allowed the engineers to calculate the air change rate, or the number of times per hour that the air in the car cabin flows out and is replaced by fresh air. It is the air changes per hour (ACH) that determines the concentration of particulates in the vehicle's air, Ott says, but it has never before been systematically studied on such a large scale. More than 100 air change rate measurements were made at different speeds, vent settings, air conditioner settings and window positions.

To understand how conditions affect the exposure of passengers to secondhand smoke particles, consider three measurements made in a 2005 Ford Taurus under different conditions while driving at 60 miles an hour. With the front passenger window cracked open 3 inches and no air conditioning on, the particulate concentration reached a maximum of only 608  $\mu\text{g}/\text{m}^3$  while a cigarette was smoking. With the windows shut and regular (non-recirculating) air conditioning on, the maximum concentration rose to 1,394  $\mu\text{g}/\text{m}^3$ . With the windows closed and the air conditioner on maximum (recirculating air), the peak concentration hit 3,808  $\mu\text{g}/\text{m}^3$ .

From their data, Ott and Klepeis have calculated that in a car with the windows up and the air conditioning on maximum, a passenger would be exposed to such a high particle concentration that his or her exposure averaged over 24 hours would be 21  $\mu\text{g}/\text{m}^3$  per cigarette. After just two cigarettes, the exposure of a passenger would exceed the 35  $\mu\text{g}/\text{m}^3$  EPA cutoff by 20 percent.

"In other words, being in the car with a smoker under these conditions gives such a huge amount of particulates that you'll exceed what would be considered a safe level of exposure," Klepeis says. "If more people become aware that smoking in their car could lead to harmful toxic exposures for their family and friends, they may decide to ban smoking in their cars—at least while others are present."

Ott adds that even with a car's windows open, smoke particle concentrations were higher than the levels he measured in California bars during studies in the mid-1990s before the state banned smoking in taverns.

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## Related Information

- Journal of Exposure Science and Environmental Epidemiology
- Exposure to secondhand tobacco smoke in outdoor settings a risk, study shows