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Traffic pollutants measured inside vehicles waiting in line at a major US-Mexico Port of Entry

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HIGHLIGHTS

- Crossing the US-Mexico border at Ports of Entry involves long waits.
- We measured in-vehicle exposures to traffic pollutants during border wait.
- In-vehicle levels of ultrafine particles elevated at San Ysidro, CA Port of Entry
- >60% of ultrafine particles exposure during commute was from border wait.
- Reductions in wait times through staffing or other measures will reduce exposures.

GRAPHICAL ABSTRACT

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ABSTRACT

At US-Mexico border Ports of Entry, vehicles idle for long times waiting to cross northbound into the US. Long wait times at the border have mainly been studied as an economic issue, however, exposures to emissions from idling vehicles can also present an exposure risk. Here we present the first data on in-vehicle exposures to driver and passengers crossing the US-Mexico border at the San Ysidro, California Port of Entry (SYPOE). Participants were recruited who regularly commuted across the border in either direction and told to drive a scripted route between two border universities, one in the US and one in Mexico. Instruments were placed in participants' cars prior to commute to monitor-1-minute average levels of the traffic pollutants ultrafine particles (UFP), black carbon (BC) and carbon monoxide (CO) in the breathing zone of drivers and passengers. Location was determined by a GPS monitor. Results reported here are for 68 northbound participant trips. The highest median levels of in-vehicle UFP were recorded during the wait to cross at the SYPOE (median 29,692 particles/cm^3) significantly higher than the portion of the commute in the US (median 20,508 particles/cm^3) though not that portion in Mexico (median 22, 191 particles/cm^3). In-vehicle BC levels at the border were significantly lower than in other parts of the commute. Our results indicate that waiting in line at the SYPOE contributes a median 62.5% (range 15.5%–86.0%) of a cross-border commuter's exposure to UFP and a median 44.5% (range (10.6–79.7%) of exposure to BC inside the vehicle while traveling in the northbound direction. Reducing border wait time can significantly reduce in-vehicle exposures to toxic air pollutants such as UFP and BC, and these preventable exposures can be considered an environmental justice issue.

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1. Introduction

The US-Mexico Land Ports of Entry are busy commercial and passenger vehicle crossings, important to the economy of both regions through goods movement, tourism and cross-border social, educational or shopping visits. The San Ysidro/El Chaparral Port of Entry (SYPOE) creates a conduit for traffic between the San Diego, California region and the Tijuana, Baja California region, and is described as the busiest land border crossing in the world (US General Services Administration, 2017). In 2013, 11.3 million passenger vehicles and 7.6 million pedestrians crossed the border northbound into San Diego. The nearby commercial border crossing at Otay Mesa is the second busiest along the US-Mexico border (DOT Research and Innovative Technology Administration (DOT RITA), 2017). Long waits at the SYPOE in the northbound direction with many lanes of idling vehicles are common. The San Diego Association of Governments (SANDAG) has commissioned several studies of the economic impact of the border wait times and estimated losses of over $7 billion in foregone gross output (San Diego Association of Governments, 2006).

In addition to a significant economic impact, excessive wait times can also pose exposure risks. Emissions from the lines of idling vehicles at the Port of Entry can affect workers at the border, pedestrians standing in long lines next to the border queue (Galaviz et al., 2013; Galaviz et al., 2017), and to local communities (Lwebuga-Mukasa et al., 2005; Quintana et al., 2014; Spengler et al., 2011). This source of exposure has been considered an environmental justice issue, in that the adverse effects of long processing times and resultant long lines at the POEs are most felt by local communities and local border crossers, who are often minority and low-income (Quintana et al., 2015). Levels of many pollutants associated with traffic emissions are highly elevated near roadways (Karner et al., 2010). The adverse health effects of being exposed to near road pollution are being increasingly recognized, and include asthma attacks, bronchitis, obstructive pulmonary diseases, decreased lung function, low birth weights, cellular DNA damage, coronary artery atherosclerosis, exacerbation of Type 2 diabetes, respiratory and cardiovascular morbidity and mortality, and cancer (Brugge et al., 2007; Cesaroni et al., 2013; Gauderman et al., 2005; Künzli et al., 2010; Laumbach and Kipen, 2010; McConnell et al., 2006; McConnell et al., 2010; Olvera et al., 2013a; Rosenbloom et al., 2012; Weinmayr et al., 2015).

Drivers and passengers waiting inside vehicles to cross the Port of Entry are also at risk of exposure to emissions from adjacent idling vehicles. Exposure inside vehicles can present a significant portion of daily exposures to air pollutants (Hudda and Fruin, 2013; Zhu et al., 2007). For example in-vehicle exposure to ultrafine particles (UFPs) for an hour daily commute was estimated to contribute between 10 and 50% of the driver's total UFP daily exposure in Los Angeles, CA (Zhu et al., 2007). Fruin et al. (2008 estimated that Los Angeles residents receive between 33 and 45% of total daily exposure to (UFPs) while traveling in their vehicles. Exposures inside vehicles can potentially increase health risks as biomarkers related to adverse health outcomes were linked to in-vehicle exposures (Laumbach et al., 2010; Sarnat et al., 2014), as were cardiac events (Peters et al., 2004). Pollutants of concern measured inside vehicles include NO_2, CO, and particles, including ultrafine particles (UFP), black carbon or soot (BC), a measure of diesel exhaust, and fine particulate matter ($PM_{2.5}$) (Fruin et al., 2004; Hudda et al., 2012b; Knibbsa et al., 2011). Exposures to drivers and passengers have been shown to be affected by air circulation settings, with recirculation and air conditioning resulting in generally lower exposures (Hudda et al., 2011).

The objective of this study was to measure and characterize in-vehicle exposures to concentrations of traffic pollutants while waiting in line to cross the US-Mexico border northbound at the SYPOE, to determine the amount of driver and passenger exposures that are potentially avoidable through reducing wait times. One-minute averaged exposures and 1-minute location via GPS were measured during a round trip commute between local universities in San Diego, California, USA and Tijuana, Baja California, Mexico, and pollutant levels inside vehicles during the border wait were characterized and compared to exposures experienced during the overall commute.

2. Materials and method

2.1. Study design

Following Institutional Review Board (IRB) approval, participants were recruited who regularly commuted across the US-Mexico border at the SYPOE, in either direction. Air sampling was conducted inside passenger vehicles between January 2007 and May 2008. Air pollutant levels were measured inside passenger vehicles during one round trip commute across the US - Mexico border at SYPOE. Some subjects participated more than once. Instruments were placed in participants' cars prior to their commute either at San Diego State University(SDSU) or Universidad Autónoma de Baja California, Tijuana campus (UABC) (the two partner universities in this study) to monitor air pollutants in the breathing zone of passengers inside the vehicles. U.S. Customs provided the P·I (Quintana) with a Frequently Asked Questions (FAQ) sheet for study participants to give the inspecting officer while crossing the border at the San Ysidro Port of Entry to explain the presence of the equipment (SYPOE). A temporary importation permit was obtained and renewed from Aduana Mexico, and carried by the participants during cross border commutes to show to Mexican customs officials as needed to permit air pollution equipment to move freely. Participants were also provided with an information sheet to hand to U.S. and Mexican Customs describing the study.

All equipment was placed in two boxes and foam-in hardening insulation was used to keep instruments correctly situated. The boxes were placed in the front seat or in the back seat if two persons or more were in the vehicle. A bubble level was used to ensure that the instruments were level, and foam wedges were used as needed. Intake probes/tubing for the equipment were positioned away from vents or windows and positioned in the breathing zone of the passengers. The equipment was powered through the vehicle's 12 V plugs.

Participants were instructed to follow a set route between two Universities (Fig. 1, northbound direction) and required to cross the US-Mexico border at the San Ysidro Port of Entry. North of the border, the route followed major freeways I-805 North to I-8 East for about 35 km between San Ysidro border crossing and SDSU. Vehicle location and speed was tracked using GPS. South of the border the route followed busy urban roadways for about 8 km between the San Ysidro border crossing and UABC. During this round-trip travel, subjects stopped midway at either SDSU or UABC where the equipment was removed from the vehicles and collected data were downloaded, and they would return to have the equipment re-positioned in their vehicles. Because sampling was conducted in the vehicles of actual commuters, the timing of each drive was based on participant's schedule and availability and therefore spanned a wide range of days and times. Moreover, because this project was designed to measure true exposure to actual commuters, participants were not given instructions or restrictions on any vehicle parameters except for the driving route. Therefore, participants were able to choose their own speeds, lanes, and vehicle settings such as open or closed windows, use of air conditioning, etc. Most subjects crossed in the standard lanes, <2% used the expedited SENTRI system (Secure Electronic Network for Travelers Rapid Inspection) when driving northbound into San Diego.

Results reported here are for the northbound direction of the commute for a total of 68 participant trips. Additional subjects were recruited but did not have data for the northbound trip or did not follow the scripted route due to shopping needs, fueling vehicles, etc. (86 participant trips total). Of the 68 subjects with data for the northbound trip, data was examined for completeness. For BC data, data was excluded if there was missing data in a location due to tape advance of the aethalometer or if data was missing due to power failure. There were a total of 65 participant trips with final data results for black carbon.