White Paper: Health Impacts of Crossings at US-Mexico Land Ports of Entry: Gaps, Needs and Recommendations for Action

Report from the Health Impacts of Border Crossings 2012 Conference May 3 and 4, 2012 San Ysidro, CA

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Executive Summary

This white paper concerns potential health effects of US-Mexico border crossings, especially regarding exposures to traffic emissions associated with the crossings. On May 3 and 4, 2012, stakeholders from both sides of the US-Mexico border gathered in San Ysidro, CA to hear presentations on traffic exposures at crossings, health effects of traffic exposures, and potential solutions as well as to jointly identify gaps and needs and to make recommendations concerning health impacts of border crossings (www.healthyborders.com).

The United States-Mexico border region is a unique area where many different people come together and cross geopolitical boundaries. This is a dynamic region, with a population that has pressing health and social needs, higher rates of uninsured, high rates of migration, inequitable health conditions and a high rate of poverty. The residents living and working along the border come from different economic and political backgrounds, yet they share a common environment and similar exposures to harmful pollutants that are generated at border crossings. U.S. border residents are predominantly Hispanic and have lower incomes than the national U.S. average, with the exception of San Diego County. However, the border area of San Diego, especially San Ysidro, is poor and Hispanic. These characteristics of U.S. border communities suggest important environmental justice issues that need to be addressed.

There are 43 points of entry (POEs) on the border between the United States and Mexico. In 2011, over 4.8 million commercial trucks, 61.2 million personal vehicles and 40.2 million pedestrians crossed northbound through the US POEs. The busiest crossings for commercial trucks were Laredo, Texas, and Otay Mesa, California. For personal vehicles, the busiest crossings were San Ysidro, CA and El Paso, TX, and these same two POEs were the busiest for pedestrian crossings as well. Long delays of idling commercial and passenger vehicles are common at many Ports of Entry. These busy border crossings present challenges for both sides of the border, including economic, social, and health issues.

Exposures to traffic emissions related to border crossing occur to people while waiting in line in vehicles or on foot to cross the border, while working at the crossing, and to communities near the border crossings or those affected by truck or other traffic moving to and from the border crossings. Traffic emission exposures have been linked to a number of adverse health outcomes in children, pregnant women and the elderly, including respiratory problems, cardiovascular effects such as an increased risk of heart attack, cancer, and adverse birth outcomes. Short-term high exposures as well as long term exposures have been linked with health effects. As an additional consideration, potential exposures from being near traffic at border crossings come in addition to background exposures to generally poor air quality along the US-Mexico border.

Workgroups at the Technical Workshop, Community Meeting and Conference included Planning and Design, Policy and Emissions Reduction, Exposure and Health, and Improving the Crossing Experience. Major gaps, needs and recommendations made by work groups, Technical Workshop attendees and Community members that were approved by the conference are summarized below.

Summary of Gaps, Needs and Recommendations from Health Impacts of Border Crossings 2012

Conference May 3 and 4, 2012

Design & Planning

Decrease border delays. There is a need to find cost-effective and safe approaches to reduce border delays in an effort to decrease exposures.

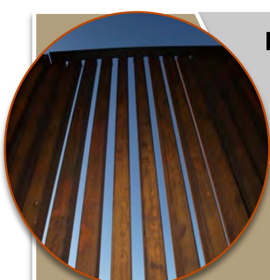
Create buffer zones. Create buffer zones between roadways and communities/pedestrians and policies to ensure planners involved in redeveloping border crossings take into account identified buffer zones.

Improve goods movement routes. Understand the impact of these routes on local communities and to re-route trucks through commercial areas in an effort to reduce exposures to pollutants of concern.

Design to reduce impact. Design or re-design border crossings to reduce the health and economic impact on the region.

Improve coordination. Local, state and federal agencies working together in an effort to improve transportation planning on both sides of the border can help to reduce the negative environmental health impacts of border crossings.

Increase financing of border crossing infrastructure. Include public-private partnerships as a potential funding source for infrastructure improvements at border crossings.



Research

Increase data collection and access to data. Measure exposures to traffic related pollution by people living in neighboring communities, people who cross frequently and those persons working at the crossings.

Understand socioeconomic and infrastructure differences. All previous border crossing health effects research has been conducted only at the US-Canadian border crossings. The US-Mexico border region has a different socio economic dynamic, climate, and considerably different infrastructure than its northern counterpart. These differences and how they impact those in the region are not very well understood.

Study infrastructure changes that reduce pollution. Researching vegetation barriers, buffer zones and re-designed crossings can increase our understanding of how these affect public health.

Research and develop indicators. Generating useful and specific indicators will aid in the evaluation of exposures and also help to measure the effectiveness of policies.

Policies & Emissions

Establish harmonized health protocols. These protocols can be used to register possible exposure related illnesses such as respiratory disease and asthma.

Reduce delays to reduce emissions: Conduct studies to quantify emissions from border crossings and calculate reductions from decreases in delay times.

Clean diesel. Implement clean diesel programs (programs increasing the use of cleaner diesel fuel and other methods to reduce diesel emissions) across US-Mexico border region, especially in commercial trucks used for US-Mexico commercial goods movement.

Extreme emitters. Investigate impact and feasibility of different programs such as removing extreme emitters from roadways.

Emission-Reduction credits. Study the potential utility of the Trading of Emission-Reduction Credits System of California's AB32 in the border region.

Air quality management. Identify (AQM) mechanisms that could be implemented in the border region addressing impacts of border crossings.

Most polluting. Identification of the types of vehicles that emit the most pollution in various regions across the border to target control efforts.

Provide amenities for pedestrians waiting in line Provision of basic comforts for elderly and disabled (e.g. seating, shade, restrooms), and make sure pedestrian crossings are compliant with the provisions of American Disabilities Act.

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US-Mexico Border Region

The US-Mexico border is approximately 1,950 miles long and is home to some 14 million people. As a result of the 1983 La Paz Agreement between US and Mexico on Cooperation for the Protection and Improvement of the Environment in the Border Area, "border region" was defined as 62.5 miles (100 kilometers) on each side of the international border [1]. The majority of the border population (90%) resides in fourteen paired, inter-dependent metropolitan areas in both countries, as well as significant tribal regions. There are 25 counties in California, Arizona, New Mexico, and Texas on the US side; and 35 municipalities in Baja California, Sonora, Chihuahua, Nuevo León, Coahuila, and Tamaulipas on the Mexico side.

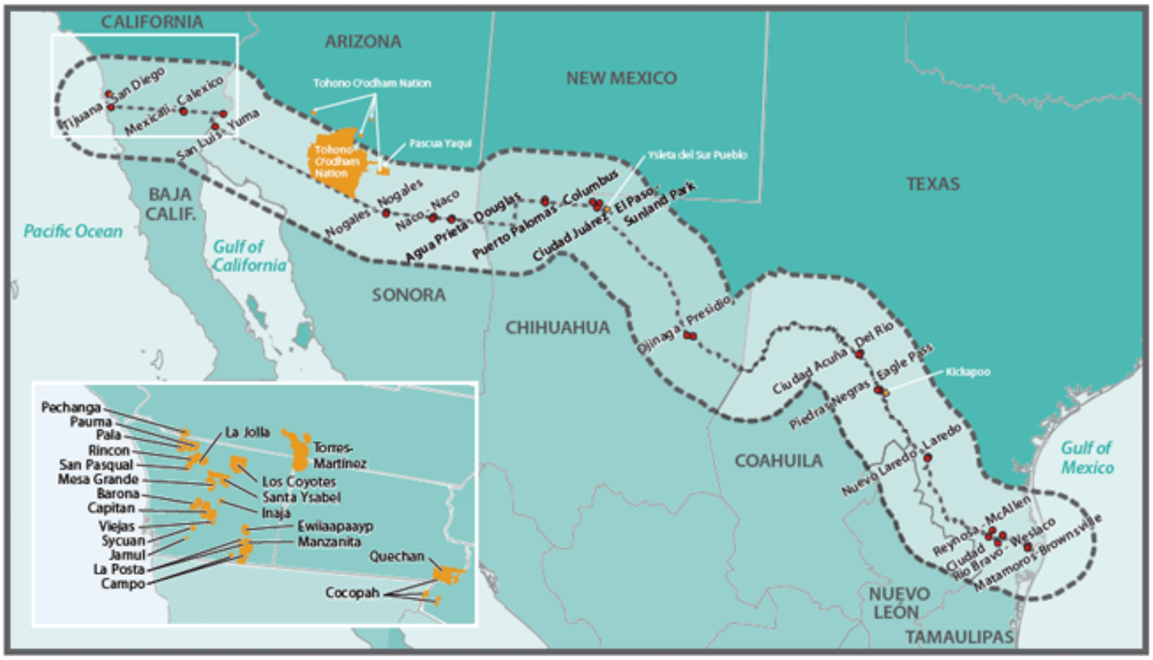

Figure 1: US-Mexico border region as defined by the La Paz agreement.
Source: EPA Border 2020 page at http://www.epa.gov/usmexicoborder/.

This region shares environmental systems such as transboundary air sheds and watersheds. There is complex series of relationships between the two countries, related to sharing natural resources, social and cultural links, and economic transactions [2].

The United States-Mexico border region is growing significantly (Figure 2) while the resources and planning to sustain such a large population growth have lagged behind [3]. This rapid population growth in the urban areas along the US-Mexico border has also created unplanned development and increased traffic congestion not only in the metropolitan regions but also at the border crossings. Projected population growth rates in the border region exceed anticipated average growth rates (in some cases by more than 40 percent) for each country. This increase, especially over the last 20 years, has been due in part to growing industrial production from the Mexican maquiladora program in Mexican border cities and increased trade flows, both associated with the implementation of North American Free Trade Agreement (NAFTA) beginning in 1994 [4]. As a result of these phenomena, many border residents may suffer disproportionately from environmental health problems, especially those related to air pollution, including respiratory diseases [2].

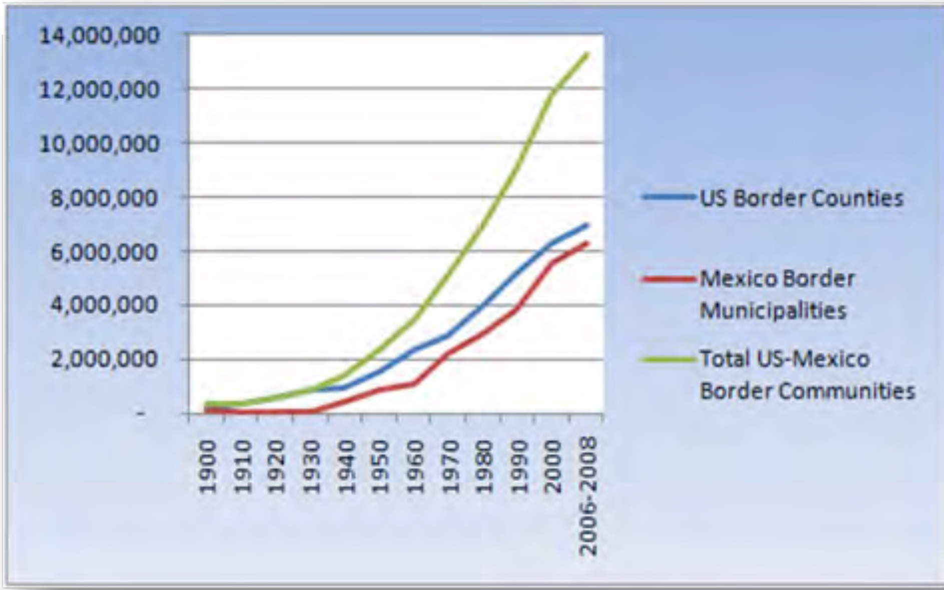

Figure 2: Population Growth in the U.S. Mexico Border Region from 1900-2008.
Source: http://www.borderpartnership.org/ourstory/border.html

Air quality in the US-Mexico border region

An airshed is a common geographical area that shares the same air. The US-Mexico border region has binational airsheds but with differing regulatory frameworks in each country that make air quality management in the border region challenging. Each state, county and city may have different regulations and air quality standards that can make it difficult to collaborate on shared pollution problems, both regionally and internationally.

There are many sources of air pollution in the US-Mexico border region. Industrial facilities, power plants, brick kilns, dust from unpaved roads, trash burning, and agricultural operations are significant, but the most important source is vehicular pollution from the many commercial and passenger vehicles in the region [5].

The United States and Mexico have each adopted their own set of air quality standards; in the US it is referred to as the National Ambient Air Quality Standards (NAAQS) and in Mexico, the *Normas Oficiales Mexicanas* (NOM) [6].The pollutants regulated by concentration in air are particulate matter (PM_{10} in Mexico and $PM_{2.5}$ in USA), sulfur dioxide, lead, nitrogen oxides, ozone and carbon monoxide. In addition, the US border state of California has set additional, more stringent standards [7]. Table A-1 in the Appendix gives US and Mexico national air standards for regulated criteria pollutants.

Although significant improvements have been made, air pollution remains a concern across the US-Mexico border region. Meteorological conditions such as inversion layers, which trap pollutants near the ground, and abundant sunshine, which contributes to ozone formation, make controlling air pollution in the US-Mexico border region more difficult than along the U.S.-Canadian border. In addition, there is the challenge of increased population growth and differing regulatory frameworks on the U.S.-Mexico border.

Historical air quality data in the US-Mexico border region is provided by the U.S.-Mexico Border Information Center on Air Pollution (CICA) Technology Transfer Network, [8]. Using a query about values above US EPA federal standards for 2007, the most recent year for which data is available, areas along the US-Mexico border reporting values above the US EPA levels for at least some of the monitoring stations were El Paso ($PM_{2.5}$ and ozone), Ciudad Juárez (ozone and PM_{10}), Imperial Valley (ozone), Mexicali (PM_{10}, ozone and carbon monoxide), San Diego ($PM_{2.5}$ and ozone), Tijuana (PM_{10}), and Nogales (PM_{10}). Figure 3 shows some of the airsheds providing data to this network. Of course, some areas do not measure $PM_{2.5}$ and whether exceedances occur is unknown.

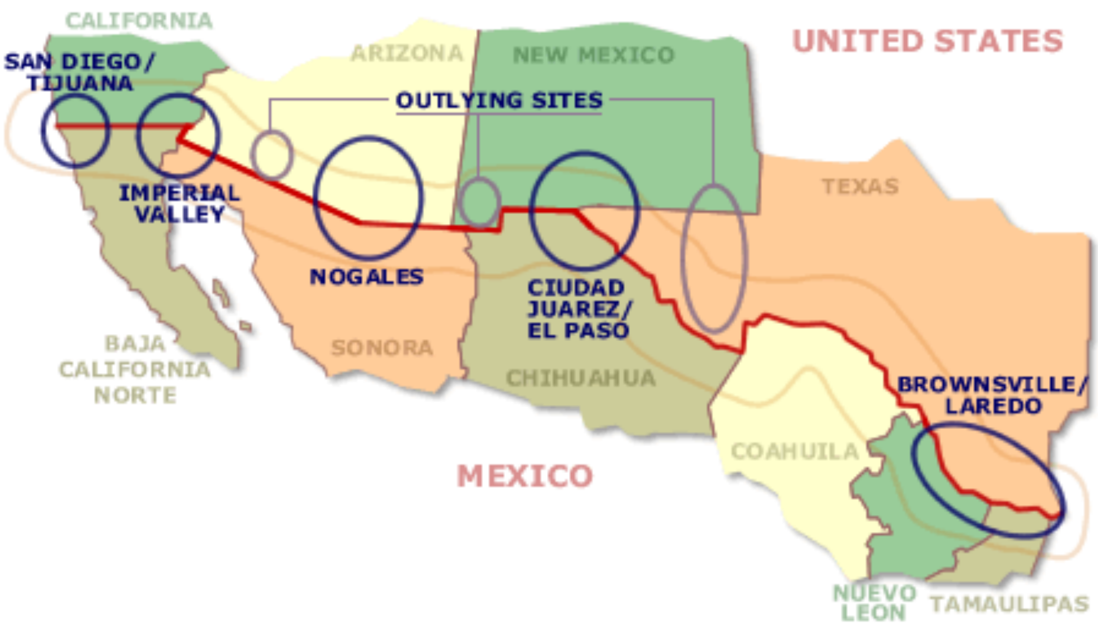

Figure 3: Air sheds and areas providing monitoring data along the US-Mexico border.
Source: http://www.epa.gov/ttn/catc/cica/geosel_e.html

There are excellent examples of binational cooperation to address air quality. For the Ciudad Juárez/El Paso area, a strong binational effort to control air quality has been in place since the mid-1990s. The Joint Advisory Committee (JAC) for the Improvement of Air Quality in the Paso del Norte is a binational organization composed of local, state and federal representatives, as well as other local representatives, and is a model for the kind of binational cooperation needed to tackle such complex issues. [9]. The EPA environmental program implemented under the 1983 La Paz Agreement, Border XXI, Border 2012, and Border 2020, have all made addressing air pollution a priority goal for the US-Mexico border region [10]. Table 1 gives a timeline of binational environmental accords relating to air quality in the US-Mexico border region. Noteworthy is Goal 1 of objective 1 of Border 2020 that explicitly mentions vehicle emissions at Ports of Entry (see Table 1).

Table 1: Timeline of Binational Environmental Accords Relating to Air Quality in the US-Mexico Border Region

Accord or Program	*General description*
La Paz Agreement (1983)	Binational environmental agreement. It defines the U.S.-Mexico border region as the area situated 100 kilometers on either side of the border. This agreement considers air quality in its annex IV, in particular the impact of copper smelters located at the border region. This consideration allowed experts groups to be convened as well as the installation of air monitoring systems in the border cities.
Environmental Integrated Border Plan (PIAF) (1992)	This plan was created by presidential decree between the U.S. and Mexico. It authorizes the USEPA and SEDUE (Secretariat of Urban Development, Mexico) and Energy to program joint activities in the Tijuana-Rosarito-San Diego region, among them air quality characterization.
Joint Advisory Committee for the Improvement of Air Quality in the Paso del Norte, (JAC, 1996).	Appendix I of Annex V of the La Paz Agreement created the formal authority for the JAC as a binational, air basin-wide advisory group
Border XXI (1996)	USEPA and Mexican environmental secretariat program implemented under La Paz agreement, Its goal was to promote sustainable development. It is recognized as the first binational attempt to derive environmental indicators of development. In this program, air quality is recognized as a public health problem for the border residents exposed to air pollution.
Border 2012 (2002)	Followed on Border XXI. The main objective is the reduction of water, air and soil pollution. The USEPA and Mexican environmental secretariat created national strategies to improve the air quality, establishing harmonize air quality standards for ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), total suspended particulates (TSP), particulates less than 10 microns or smaller (PM_{10}), $PM_{2.5}$, and lead (Pb).
Border 2020 (2010)	Expands Border 2012 with increased emphasis on communication. Includes 2 year action plans. Improvement of border air quality is Goal 1, and Objective 1 explicitly states "By 2020, in accordance with the NAFTA, promote the reduction of the number of vehicles operating in the border region that do not comply with the respective vehicle emissions standards, and reduce vehicle emissions at ports-of-entry through anti-idling and other feasible reduction measures."
Memorandum of Cooperation on air quality monitoring between the USEPA, SEMARNAT, CAL/EPA, the Government of Baja California	This memorandum has the objective to establish procedures to transfer responsibilities of air quality monitoring to Mexican governmental agency within two years for the municipalities of Tijuana, Playas de Rosarito, Mexicali, Ensenada, and Tecate. During the next two years the Secretary of Environmental Protection of Baja California was to train these municipalities to operate, maintain monitoring stations, validate collected data from monitoring stations and send information to the USEPA databases.

Air pollutant concentrations near traffic sources

Ambient or regional-scale air pollution is monitored by a few stations per region that are purposely located away from local sources. As such, these reflect regional scale pollution data and do not reflect the true spatial variability in air pollutants in communities. Pollution measurements near areas of idling traffic and near major roadways can be much higher than areas in the same city away from traffic. In recognition of the importance of controlling spatial variability due to traffic, the EPA has recently set forth a new 100 ppb 1 hour nitrogen dioxide standard for the U.S. that includes a requirement for monitoring near roadways [11]. Table 2. lists some major pollutants that are found in high levels near roadways. Some of these are criteria air pollutants, e.g. carbon monoxide and nitrogen dioxide, but many are not routinely measured. These include benzene, a known carcinogen, black carbon (BC), a marker for diesel exhaust, and ultrafine particles, very small nanoparticles that are implicated in health effects ranging from cardiovascular to neurological, and others. This is an abbreviated list; other pollutants of potential health significance such as latex particles from tire debris, metals and others are also found near roadways [12].

Table 2: Some of the traffic-related pollutants found in higher concentrations near roadways and traffic sources.

Pollutant	*Abbreviation*	*Type of traffic*	*Criteria pollutant?*
Gases and Vapors			
Carbon monoxide	CO	Trucks, older or poorly maintained cars, cold start	Yes
Nitrogen dioxide	NO_2	Trucks and cars	Yes
Benzene	Benzene	Cars (gasoline)	
Particles			
Particulate matter less than 2.5 micrometers in aerodynamic diameter	$PM_{2.5}$	Trucks (diesel)	Yes
Ultrafine particles	UFP	Trucks and cars, esp. during acceleration or stop and go	No
Black carbon	BC	Trucks (diesel)	No
Particle-bound toxics			
Polyaromatic hydrocarbons (also exist as vapors)	PAHs	Trucks (diesel) and also cars	No
Noise			No

Distances from roadways associated with elevated pollutant levels.

The distance from roadways where traffic-related pollutants are found to be higher than levels found in region-wide air pollution varies with the pollutant, weather conditions, and time of day. The following table (Table 3) presents information on distances from roadways associated with elevated pollutant levels, adapted from a paper by Karner at al., [13]. The authors analyzed many studies near roadways and grouped pollutants into the following categories: pollutants with rapid decline with increasing distance from roads (>50% decay by 150 meters), pollutants which displayed a less rapid drop, and those not displaying a clear difference near roadways (Table 3). It should be noted that these distances were derived from studies performed in the daytime, and do not represent distances that pollutants may spread at night [14]. For example, Hu et al., [15] have found that ultrafine particles associated with freeways are elevated up to more than a kilometer away when measured before sunrise.

Table 3: Drop or decay in pollutant concentrations near roads (adapted and condensed from Karner et al., 2010, who reviewed 41 papers)

Pollutant	*Approximate multiplier at edge of road above regional background*	*Approximate distance to reach background concentration, in meters*
Rapid decay (>50% decay by 150 meters)		
Carbon monoxide	21 x	(>285 meters)
Ultrafine particle number (> 3 nm)	4.0 x	189
Metal deposition	2.9 x	161
Less rapid decay or change		
Benzene	2.1 x	280
Elemental carbon(similar to black carbon)	1.7 x	420
NO2	2.9 x	380
Ultrafine particle number (> 15 nm)	4.8 x	910
PM10 (Particulate matter less than 10 micrometers in aerodynamic diameter)	1.3	176
No trend around roadways		
PM2.5	-	-

US-Mexico Border crossings.

There are 43 points of entry (POEs) on the border between the United States and Mexico. In 2011, over 4.8 million commercial trucks, 61.2 million personal vehicles and 40.2 million pedestrians crossed northbound through the US POEs [16]. Table 4, below, gives the top ten busiest POEs for commercial trucks, personal vehicles, and pedestrian crossers (northbound data only, for the year 2011). The busiest crossings for commercial trucks were Laredo, Texas, (1.7 million truck crossings) and Otay Mesa, California (0.7 million). For personal vehicles, the busiest crossings were San Ysidro, CA (12.4 million) and El Paso, TX (9.1 million), and these same two POEs were the busiest for pedestrian crossings as well, at 8.5 million for San Ysidro and 6.2 million for El Paso in 2011 (see Table 4).

Table 4: Top 10 Ports of Entry as ranked by trucks, personal vehicles and pedestrians for US-Mexico border ports of entry for the year 2011, as estimated by the DOT (does not include southbound crossings).

RANK	*Port Name*	*Trucks*	*Port Name*	*Personal Vehicles*	*Port Name*	*Pedestrians*
1	TX: Laredo	1,695,916	CA: San Ysidro	12,373,011	CA: San Ysidro	8,454,391
2	CA: Otay Mesa	744,929	TX: El Paso	9,148,377	TX: El Paso	6,172,346
3	TX: El Paso	714,699	TX: Hidalgo	4,878,003	CA: Calexico	4,451,119
4	TX: Hidalgo	453,235	TX: Laredo	4,746,355	AZ: Nogales	3,525,540
5	CA: Calexico East	312,973	CA: Otay Mesa	4,213,804	TX: Laredo	3,089,561
6	AZ: Nogales	287,091	TX: Brownsville	4,122,648	AZ: San Luis	2,762,696
7	TX: Brownsville	208,021	CA: Calexico	4,095,450	CA: Otay Mesa	2,478,409
8	TX: Eagle Pass	106,046	CA: Calexico East	2,784,769	TX: Brownsville	2,113,425
9	NM: Santa Teresa	71,362	AZ: Nogales	2,641,068	TX: Hidalgo	1,998,203
10	TX: Del Rio	62,723	TX: Eagle Pass	2,271,836	AZ: Douglas	1,030,357

Source: Queries on Border Crossing/Entry Data, provided by Research and Innovative Technology Administration (RITA), U.S. Department of Transportation (DOT) website
http://transborder.bts.gov/programs/international/transborder/TBDR_BC/TBDR_BC_QuickSearch.html

Figure 4 displays the approximate volume of crossings at all US-Mexico border POEs and also displays the percent of crossing volume that consists of commercial trucks at each crossing. It can be seen that some POEs mainly serve personal vehicles, such as San Ysidro, which is separated from the truck crossing at Otay Mesa, CA, and some are mainly used as truck crossings, such as Nogales, AZ.

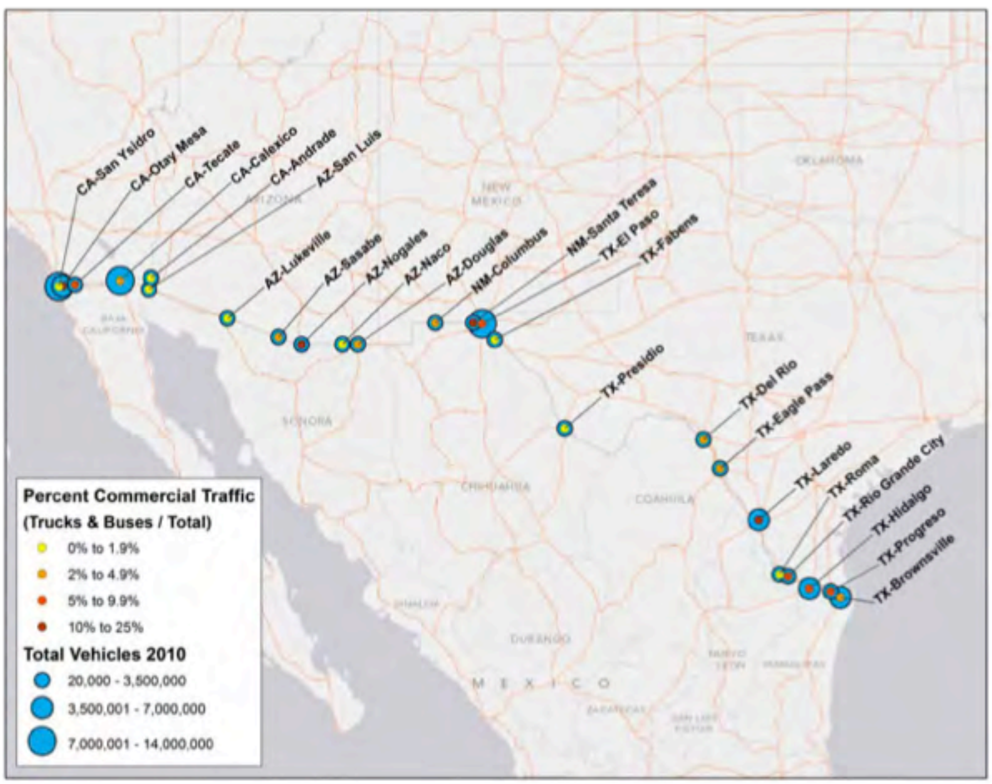

Figure 4: Map of Total Vehicle Crossings, with Percent Commercial Traffic, Trucks and Buses
Source: Kear, Thomas, Cambridge Systematics, under contract DTFH61-11-D-00030-T11-002 (EN 1002): Emissions and Border Wait-Time Analysis Support, from US DOT, used by permission.

Border delays/ border wait times

Waiting in line on foot or in a passenger or commercial vehicle is an often frustrating and potentially avoidable part of the border crossing experience. The delay times at each crossing, with associated volumes of idling vehicles, vary by season, type of use (commercial or passenger) and direction, with northbound crossings usually, but not always, having the longest delay times. The delay time is also called the border wait time, and as such has been formally identified by the US and Canadian working group as "the time it takes, in minutes, for a vehicle to reach the CBP's primary inspection booth after arriving at the end of the queue." [17]. Delay times, as well as lanes open for each Port of Entry, are reported by Customs and Border Protection on their website and on mobile apps in real time [18]. In 2010, the US Government Accountability Office (GAO) conducted an analysis of commercial truck border wait times at the US-Canadian Border as a part of an assessment of the improvements from the Free and Secure Trade (FAST) system launched in 2002. They stated that "CBP officials and the 13 border stakeholders, importers, and trade organizations GAO interviewed about wait times questioned the accuracy and reliability of CBP's wait times data"[19]. They recommended that data be collected to better evaluate border wait times and effects of interventions. In April, 2012, Senator Kay Bailey Hutchinson of Texas requested that a similar study be performed on commercial crossings at the US-Mexican border, and the US GAO is currently performing this evaluation[20].

Both radio and TV stations on both sides of the border report delays times along with traffic reports. Calit2, at UCSD, has developed a mobile app that provides data on delay times at each port by day of the week, and also has a feature that allows users to self-report delay times to compare with official CBP data ([21].

Assessment of delay times:

How delay is assessed varies. For example, at San Ysidro POE, delays are reportedly assessed by CBP through a combination of visual estimates of queue length, questions to drivers and crossers as to how long they have been waiting, and judgment. At Tijuana news stations, delays are often reported as number of vehicles in the queue, sometimes gauged through aerial means.

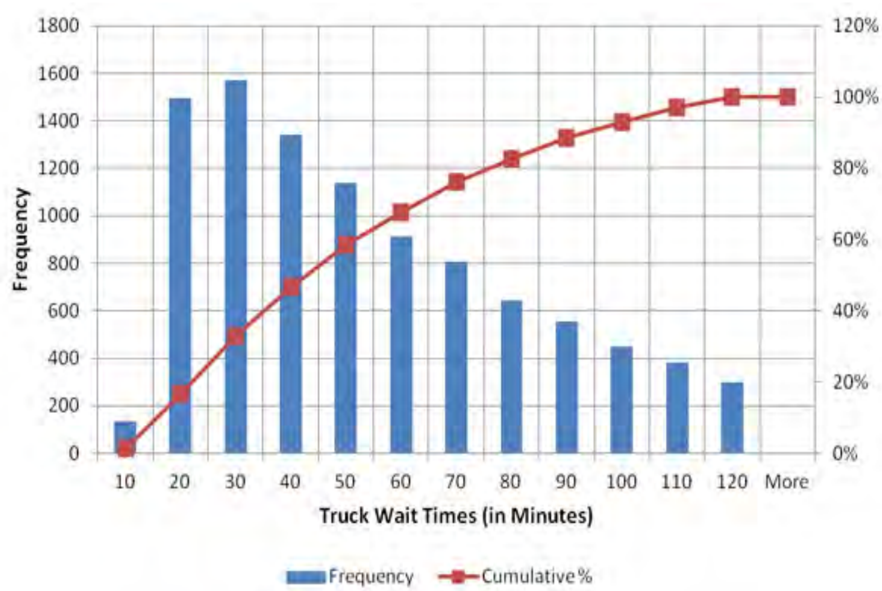

Figure 5: Pharr-Reynosa commercial POE wait time data assessed using RFID technology February 2012. Source: [http://www.ops.fhwa.dot.gov/publications/fhwahop12049/ch7.htm#ss3_2)

Apparently, CPB data reflect average wait times at San Ysidro and fail to capture the waits for 2-3 hours for pedestrians and for passenger that frequently occur during peak crossing hours. For commercial crossings, delays can be assessed by length of the queue, questions to drivers, and also more sophisticated means such as GPS tracking in vehicles, vehicle license plate recognition, and automated vehicle identification. The US FHA/ DOT has sponsored pilot projects related to technologies for assessment and study of delay time, summarized and available at[22]. Although GPS effectiveness was assessed previously at the Otay Mesa commercial crossing [23], a passive RFID system was recently investigated and identified as potentially the most promising technology [24].

Social and economic impact of delays: The economic aspect of border delays was the subject of a recent op-ed piece in the New York Times (Escobar, 2013), and called efficient cross-border movement to be part of any immigration reform discussion. Several studies have examined the social and economic costs of delays at US-Mexico border crossings. In California, the San Diego Association of Governments (SANDAG) has conducted an analysis of the economic effect of border delays on cross-border personal travel (2005) and freight travel in a study titled 'Economic Impacts of Border Wait Times at the San Diego-Baja California Border Region [25]. They estimated that freight delays alone cost in total 6 billion a year and the equivalent of over 50,000 jobs in the binational economy, significantly hurting competitiveness. In 1998, the US DOT sponsored a study called Binational Planning and Programming Study, and Phase II Products, Task 10 detailed economic impacts of delays [26]. Fuentes and del Castillo [27] calculated the annual direct costs of 745, 975 vehicles waiting for three hours as 139,870,200 dollars annually, or 466,236 dollars per day For social effects, surveys have been conducted among border crossers at POEs and found border delays were reported by survey responders to increase stress, form a barrier to visiting relatives and friends, provoke feelings of concern regarding physical safety, cause physical distress during the long waiting periods, and lead to a perception of discriminatory behavior at times by agents, as well as other issues [28].

Relation of delay time to number of idling vehicles in the queue*:* Delay time is not a direct measure of emissions, as emissions are related to number of vehicles idling in line and the type of vehicles, as well as the vehicle speed and load. The number of lanes open also affects delay times, as a border POE with few lanes open might report a long vehicle delay time but have fewer emissions than the same POE with a shorter border wait time but with all lanes open. Vehicle type also affects emissions, as commercial trucks emit more pollutants per vehicle than do passenger vehicles. Therefore the number of lanes open and the delay time, together with the type of vehicles at each crossing, form a crude estimate of the potential emissions. For a more sophisticated estimate, exact vehicle mix, vehicle ages, vehicle registrations, average speed, creep idling vs. pure idling, grade, fuel and other considerations influence the accuracy and need to be estimated from models or direct measurements [29, 30].

Estimates of emissions at border crossings

A comprehensive estimate of emissions for all US-Mexico Ports of Entry, including the emissions during idling and creep idling in a queue, has not yet been made, although such as effort is currently underway under the direction of the US DOT (see preliminary findings, [29], below). Some initial estimates of the contribution from delay times have been performed. Estimates of criteria pollutant and greenhouse gas emissions just from the northbound delay period were made for all San Diego County border crossings, (the passenger and bus crossing at San Ysidro POE, the commercial crossing at Otay Mesa POE, and the much smaller crossing at Tecate, which handles both [31], [32]. Official CBP delay times were used for the estimates for the year 2009. The crossing type which contributes the most emissions in these 2009 estimates is very different for greenhouse gases as compared to criteria pollutants $PM_{2.5}$, CO, etc. For greenhouse gases, San Ysidro Port of Entry delays contributed the majority (76%) of the estimated GHG emissions due to the very large volume of vehicles and long delays ([31], Appendix Figure 1). However, when $PM_{2.5}$ emissions were calculated, due to the fact that commercial trucks emit much more particulate pollution on a per vehicle basis, delays at the commercial truck crossing at Otay Mesa were the majority contributor, at 63% of emissions for the San Diego County northbound delays ([32], Appendix Figure 2A). The distribution also changes for each pollutant. For example, for carbon monoxide, motorcycles at San Ysidro contributed only 0.4% of $PM_{2.5}$ but 15.4 % of CO from delays at northbound crossings in San Diego, since motorcycles lack emissions exhaust controls ([32] Appendix Figure 2B).

The US DOT in conjunction with Cambridge Systematics began conducting a study in 2012 to estimate emissions at all the US-Mexico border crossings, as well as consider options for reduction [29]. The Ysleta-Zaragoza port near El Paso was used as a case study (2010 data) to demonstrate the approach to be used at all US-Mexico border crossings (Figure 6, below). The US EPA criteria pollutants PM2.5 and NOx emissions were calculated for four scenarios: 1. "No delay" scenario where vehicles pass through the POE as if it did not exist, 2. "No-action" scenario, 3. "Privately Owned Vehicle (POV) Strategy" that shifts vehicles to the faster SENTRI lanes, 4. "Commercial Vehicle (COM) Strategy" that assumes U.S. and Mexican cargo inspections are combined to eliminate duplicative inspections. Initial estimates indicate that using this approach, the delay accounts for the majority of emissions and reduction in delay time is an effective control measure.

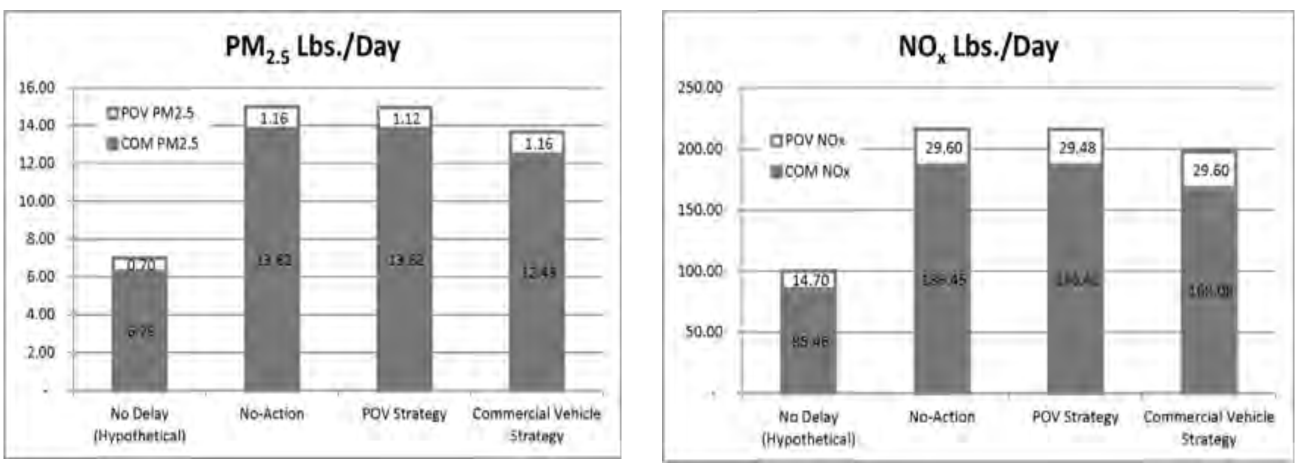

Figure 6: Case Study: Estimated daily emissions of PM2.5 and NOx for 2010 at the Ysleta-Zaragoza port near El Paso under various scenarios for emission reduction. Source: Kear et al., (2012)
http://www.fhwa.dot.gov/planning/border_planning/us_mexico/publications/emissions_and_border/sec01.cfm#fig12

Health effects of traffic emissions

Before considering potential health effects of border crossings, a brief review of health effects of traffic pollution is provided. Near traffic exposures have recently been documented to cause an array of health effects. Respiratory illness, asthma, cardiovascular disease, increased mortality, and adverse birth outcomes are only some of the health effects associated with living and working near high-traffic areas [12, 33-35]. Exposure to even short-term high levels of traffic-related pollution can be of immediate health concern and have been shown to be associated with cardiac events [36]. Table 5 lists some recent studies that review scientific literature that link traffic exposures to adverse health effects.

Table 5: Some recent publications that review health effects of near-roadway or heavy traffic exposure

Year	*Title*	*Reference*
2007	Near-highway pollutants in motor vehicle exhaust: A review of epidemiologic evidence of cardiac and pulmonary health risks.	Brugge, (2007)[37].
2010	Traffic-related air pollution: a critical review of the literature on emissions, exposure, and health effects	HEI (2010)[12].
2011	Black carbon as an additional indicator of the adverse health effects of airborne particles compared with PM10 and PM2.5.	Janssen, (2011)[38].
2012	Respiratory health effects of air pollution: update on biomass smoke and traffic pollution	Laumbach (2012)[39].

Populations susceptible to heavy traffic or near-road exposures

Figure 7 gives the framework for understanding the link between traffic exposures, for example from idling traffic at border crossings, and health effects such as asthma. Using this framework, it can be seen that children are potentially at increased risk due to their susceptibility due to stage of life and also from their activity level, as on a playground, which increases absorbed dose [40]. In addition, for children living in many border communities, the increases from the border crossings may be in addition to a background of poor regional air quality.

Table 6 lists some of the populations susceptible to traffic pollutants and some of the adverse health effects, such as asthma. A major risk factor for the development and exacerbation of asthma is proximity to traffic-related air pollution. In Southern California, the Children's Health Study at USC has linked close proximity to a freeway or a busy street and increased traffic pollution estimated or measured at residences and schools with incidence and exacerbation of asthma and lung deficits in children [41-45].Traffic exposures have been suggested to act synergistically with other exposures that are risk factors for wheeze and asthma, and with parental stress [46, 47]. Pregnant women are another susceptible population. Adverse birth outcomes including low birth weight and pre-term birth, a leading cause of neonatal morbidity, have been linked with maternal exposure to traffic in studies in Southern California and elsewhere [48-53]. Traffic pollution has also been linked with cardiovascular effects. Peters et al. in 2004 [36] reported an increased risk of a cardiac event immediately after exposure to heavy traffic. Recently, a study reported that persons discharged after a heart attack that lived near heavy traffic were more likely to experience a second event [54]. Adult asthma is also affected by traffic exposure [12]. Recently, traffic exposure has been linked with Type II diabetes, possibly due to inflammatory mechanisms [55]. The US Occupational Safety and Health Administration (OSHA) has also declared occupational exposure to diesel exhaust a known cause of lung cancer [56]. An increased risk of lung cancer in non-smokers who live near heavy traffic has been recorded [57]. However, the weight of evidence at this point for non-occupational exposures is strongest for respiratory, cardiovascular and mortality effects.

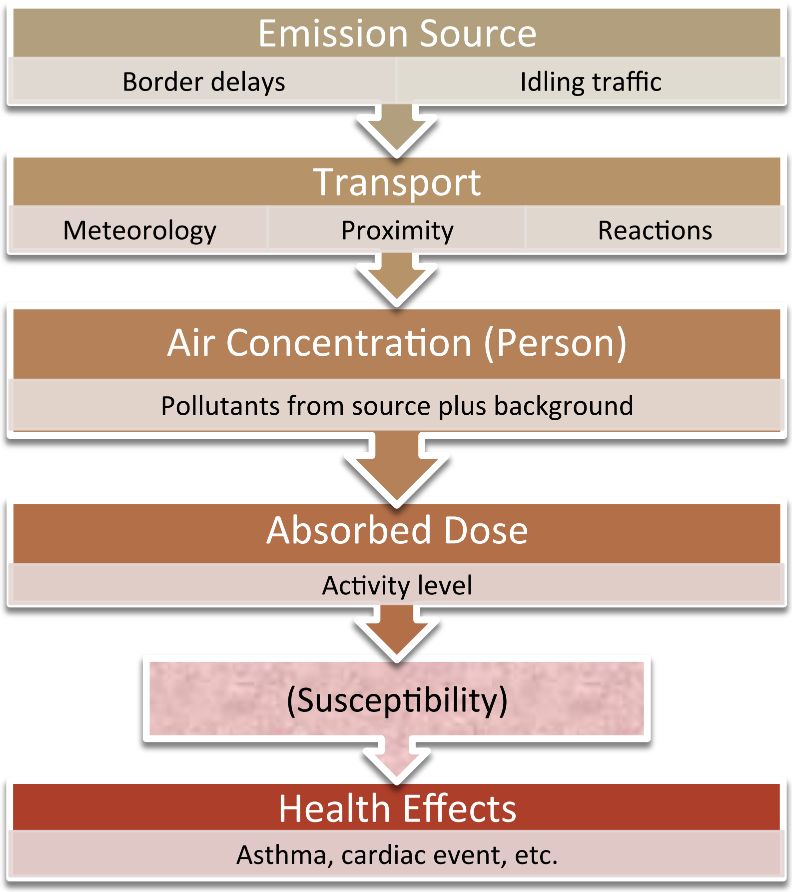

Figure 7: Framework for understanding pathway from sources of traffic pollution to disease.

Table 6: Selected susceptible populations to pollutants in near-traffic exposures. Adapted from Sacks et al., 2011

Selected susceptible populations for traffic exposures	***Types of outcomes***	***Example of study***
Children	Asthma, poor lung development, possible risk for leukemia	Children's Health Study, USC [42, 45] [58]
Pregnant women	Pre-term birth, Lowered birth weight	[49] [50]
Persons with pre-existing disease		
Cardiovascular	Increase in heart attacks Increased mortality after first heart attack	[36] Rosenbloom et al., 2012
Pulmonary (asthma, COPD)	Increased symptoms	
Diabetes	Possible increased incidence of Type II diabetes	Kramer et al., 2010
Workers with occupational exposure to diesel exhaust	Lung cancer	IARC, 2012, Benbrahim-Tallaa et al., 2012

Assessment of traffic levels in health effect studies

Two main ways of measuring traffic exposures have been used in studies of adverse health effects. One is directly measuring traffic and factors such as distance to roadways, vehicle count and mix, or, more complicated models that include traffic counts and distance with measures of prevailing meteorology and land use. For example, in a study measuring lung function in children exposed to traffic, distance of residence less than 1500 meters was associated with a reduction in lung function by age 18 [42]. The other method is to measure pollutants in air as a surrogate for traffic exposures. The most commonly measured are PM2.5, CO, black or elemental carbon, and NO_2 [12]. The individual components of traffic emissions associated with the various health outcomes is a question still under investigation. It is likely that effects vary by pollutants, for example, benzene is a known cause of leukemia but unlikely to cause asthma [59].

Environmental justice and traffic exposures

It has been shown that neighborhoods with high poverty rates tend to experience higher traffic densities, and that these inequalities exacerbate the problem of environmental justice and health disparities in these underserved communities [60]. Disparities in exposure to traffic have been documented and are considered an environmental justice issue in Southern California [61]. Environmental justice concerns the inequitable exposure of poor and minority communities to environmental hazards [62]. In California, Hispanic children have been shown to be more likely to live in areas with higher traffic density than non-Hispanic whites [63]. In addition, despite health risks posed by traffic exposure, some schools in California are located close to traffic sources, and these schools are more likely to be poor and serve Latino students [64]. Studies have found that parental stress can also heighten the adverse effects of traffic exposures on asthma in children [46]. Environmental justice is required to be considered in federal planning as described in executive order 12898 [65].

Traffic exposures and health effects at border crossing POEs.

Studies of health effects of traffic exposures at border crossings

Only three studies have been identified to date that directly addressed health effects of traffic at US-Canada or US-Mexico border crossings. (Appendix, Table A-2), and these are all on the Canadian border. The studies were all by the same research group and investigated asthma in adults and children near at the Buffalo NY Peace Bridge crossing. One study linked increased traffic volume related to NAFTA with an increase in adult asthma cases[66], another did a spatial analysis of adult asthma cases and found a significant clustering near the Peace Bridge crossing [67]. A third study found a clustering of child asthma cases near the Peace Bridge crossing but this was not statistically significant[68]. No studies have been identified that examine health effects in relation to traffic at any US-Mexico border crossing. A related set of studies, although not specifically at border crossings found an increase in subclinical inflammation associated with traffic pollutant exposure in a panel of asthmatic children in the El Paso/Ciudad Juárez border region, (Table A-3, [69] [70]).

Studies of traffic-related emissions and pollutant concentrations at and near border crossings

Studies of traffic pollutants at border crossing and in nearby communities can be made at various points along the continuum from emissions to exposure to disease. The first step in the pathway is characterizing emissions (Figure 7). A large effort is currently underway to characterize emissions and changes under varying scenarios for emissions reduction at US-Mexico Ports of Entry [29], as mentioned above. A step closer on the continuum for understanding possible adverse health effects is to estimate personal exposures through measurement of air concentrations where people come in contact with border pollutants (Figure 7). Studies carried out at crossings at the Canadian border are given in Table A-4 in Appendix.

Only a few measurements have been made at US-Mexico POEs (Table A-5 in Appendix). Olvera et al. [71] characterized ultrafine particles at a fixed monitoring site at the Ciudad-El Paso crossing (Bridge of the Americas, BOTA) over the course of a year. They reported ultrafine particle levels to average 35,000 particles per cubic centimeter (pt/cc) at the BOTA, with highest concentrations in the winter and at low wind speeds. Traffic pollution fixed site measurements were also made in the border community of San Ysidro, CA during the year 2010. The highest mean daytime BC and UFP concentrations recorded at the near-border site were associated with calm wind conditions. Positive correlations were found between CBP reported northbound wait times at the POE and daytime median BC concentration during calm winds or when winds were blowing from the border[72]. As part of another study measuring exposures to pedestrians waiting in line to cross northbound at San Ysidro (see below,[73]), fixed site measurements were made at the border gate where pedestrians are in US territory but still waiting in line, adjacent to the line of diesel buses and passenger vehicles in the SENTRI lanes. During 31 days of measurements in 2011, ultrafine particle concentrations at the border gate averaged 39,800 particles/cc and BC averaged 8 $\mu g/m^3$[74]. In a pilot sampling period carried out in November 2010 in San Ysidro with a nanoparticle surface area monitor (TSI, Inc) which mimics lung deposition, border vehicle delay times were shown to have a significant association with elevated concentrations of ultrafine particles characterized by surface area deposition in lungs [75].

Exposures to persons crossing the border

A few studies have measured pollution in the breathing zone of the person crossing the border. At the San Ysidro crossing, passenger vehicles were tracked with monitors measuring air inside the car during a commute northbound from Universidad Autónoma de Baja California (UABC), Tijuana, to San Diego State University (SDSU) [76, 77]. Figure 8 gives an example of the profile of ultrafine particle concentrations inside the car of one person driving northbound from Tijuana to San Diego. A noticeable spike in ultrafine particles can be seen when the border queue was reached and that persists until the border was crossed. Overall, in-car levels of ultrafine particles and carbon monoxide were significantly higher at the border than at other locations in the commute, with ultrafine particles averaging 30,000 pt/cc inside passenger vehicles waiting in the border queue[77]. Another study has measured personal breathing zone air concentration and absorbed dose of traffic pollutants to pedestrians waiting in line to cross northbound at San Ysidro These pedestrians can wait for an hour or sometimes up to three hours or more near the passenger vehicles and diesel buses that are queued next to the pedestrian line before arriving at the gate. Subjects who crossed the San Ysidro POE northbound regularly in the pedestrian line had urinary 1 NP metabolite levels 10 fold higher level that those in control subjects who also worked or went to school in San Ysidro/South Bay and did not cross the border[73].

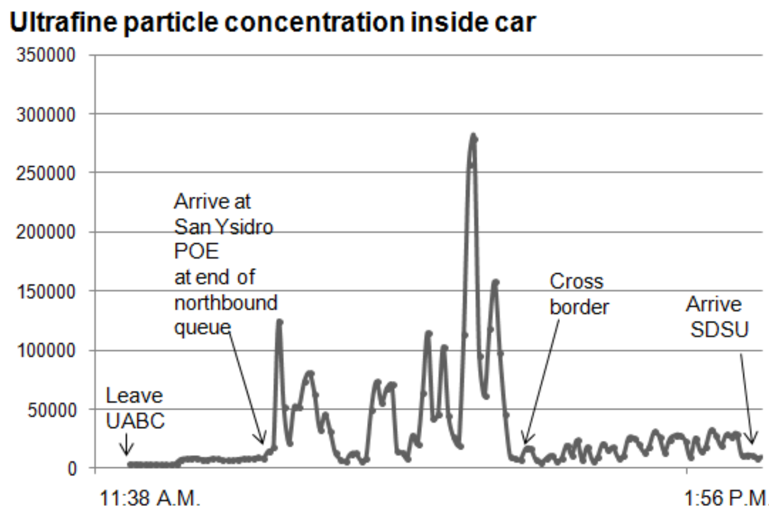

Figure 8: Ultrafine particle concentrations (particles per cubic centimeter of air) measured inside a passenger vehicle commuting from Tijuana to San Diego at the San Ysidro Port of Entry and waiting in border queue over 1 hour (adapted from data in [77]. UABC, Universidad Autónoma de Baja California, Tijuana, SDSU, San Diego State University.POE Port of Entry.

Reduction of delay times: evidence for improved health

No studies have been conducted on the health effects of reducing delay times and other border improvements, though one such study is in process by SANDAG [78]. One ecological study examined the health effects before and after 'EZ Pass' installations at toll booths in two US eastern states (NJ, PA), which reduced delays and idling and creep idling traffic. The authors examined adverse birth outcomes in nearby communities. They reported in a preliminary working paper that they found a reduction in both pre-term births and low birth weight infants in mothers living near toll plazas after the installation of EZ Pass [79].

Mitigation strategies to reduce exposure

Several options are available to reduce exposure of workers, communities and commuters to border traffic pollution. Selected options are summarized in Table 7, below. These are, broadly, reduction in border delays/wait times through methods such as increased staffing, improved technology, and increased capacity; reductions in emissions per vehicle; anti idling measures; and reductions in personal exposures through such measures as separation of pedestrians from traffic, the use of vegetation, rerouting traffic away from schools, and planning and design improvements.

Table 7: Selected mitigation strategies to reduce exposure to US-Mexico Border traffic

Approach and Actions	*Example*
Reductions in delays ….Increased staffing/ hours ….Technology ….Prescreen and enroll crossers ….Increase capacity ….Delay time as performance indicator	 SENTRI http://www.cbp.gov/xp/cgov/travel/trusted_traveler/sentri/
Reductions in emissions per vehicle ….Truck emissions ……..Clean diesel ……..Retrofit/ new technologies e.g. particle filters ….Program of operation ….Passenger car emissions controls ….Remove extreme emitters	 State of CA http://www.arb.ca.gov/fuels/diesel/diesel.htm West Coast Collaborative's San Diego-Tijuana Diesel Emissions Reduction Project http://www.epa.gov/international/air/transport.htm#idrp SmartWay http://www.epa.gov/smartway/ Smog Certification State of CA http://www.dmv.ca.gov/pubs/reg_hdbk/ch10/ch10_7.htm Voluntary Accelerated Vehicle Retirement (VAVR) Program State of CA http://arb.ca.gov/msprog/avrp/avrpeo.htm
Anti-idling measures ….Truck Stop Electrification ….Passenger anti-idling	 Truck stop electrification and anti-idling as a diesel emissions reduction strategy at US-Mexico Ports of Entry http://www.epa.gov/region9/climatechange/pdfs/TSE_Otay_report.pdf Peace Arch (US-Canada) anti-idling programme http://www.thetbwg.org/meetings%5C201102%5C16bcarlson.pdf
Reduce personal exposures to border traffic Barriers between vehicles and communities/ pedestrians *Physical barriers (e.g. sound walls)* *Vegetative barriers* *Catalytic paints that reduce pollution* Rerouting traffic away from communities	 EPA Near-Roadway Research http://www.epa.gov/airscience/air-highwayresearch.htm EPA Workshop The Role of Vegetation in Mitigating Air Quality Impacts from Traffic Emissions http://www.epa.gov/nrmrl/appcd/nearroadway/workshop.html Restriction of maquila truck traffic on route to border from Colonia Chilpancingo in Tijuana, BC http://www.environmentalhealth.org/index.php/en/what-we-do/border-environmental-justice/air-pollution
Planning and design to reduce exposures ….Incorporate local exposure reduction and health improvement into design and planning	

As mentioned earlier, the US DOT has begun a study of modeling emissions at US-Mexico border crossings. A major advantage of creating models of emissions is the ability to predict emissions reductions using various mitigation strategies. According to the authors, Kear et al. [29] the approach of modeling emissions allows evaluation of the following mitigation categories: staffing and management, technology (new technology applications to improve the efficiency of cross-border movements, inspections, or information) and traffic engineering and infrastructure. One pilot product for modeling emission reduction was given in Figure 5, above, which suggested reducing congestion and delay was an efficient strategy to reduce emissions [29].

Reduction in delay/border wait times

Reductions in border delays/wait times could be achieved through increased staffing and hours of operation at commercial and passenger crossings. Harmonization of US and Mexican customs would also speed processing. Increased use of technology such as RFID chips could be employed to speed throughput. Enrollment into prescreening programs such as SENTRI could shorten wait times; however, if all persons were enrolled, SENTRI wait times would increase. Capacity increases would also help speed crossings, and new border crossings are being planned or are under construction[80].

Reduction of personal exposures to border traffic pollutants

An obvious target to reduce people's exposures when waiting to cross at POEs is to reduce the time vehicles and pedestrians wait in line exposed to emissions. This would directly benefit drivers and pedestrians crossing the border and also improve air quality near the crossing**.** If possible, separation of pedestrians from the vehicles waiting in line is desirable. Barriers between roadways and exposed persons have also been shown to be effective [81]. In addition, new technologies could be explored such as the application of new paints and coatings that catalyze pollutant gases and change them into CO_2 and water, and reduce pollution levels near the treated area [82, 83]. Anti-idling measures could also be employed. At the Canadian border at the Peace Arch Crossing, there is a program of traffic lights that encourages passenger vehicles to turn off their cars while waiting at red lights (see Table 7). At commercial crossings, Truck Stop Electrification has been investigated as an anti idling measure to reduce emissions [84]. Long-term solutions also include state-mandated reductions in vehicle emissions, and increased provision of clean public transportation.

Reduction of exposures to children and other sensitive groups in communities disproportionately affected by border traffic can be achieved in several ways. Long-term solutions include zoning and planning so that schools, homes and parks are not located near truck routes or heavy or idling traffic. Shorter-term solutions that have been applied in a community setting include improving indoor air quality through high-efficiency filtration of schools [85]. One interesting mitigation solution that merits investigation is the potential utility of vegetation in reducing exposure to traffic pollution. New research suggests that a promising solution may be vegetative barriers, which have been shown to reduce traffic-related ultrafine particulate matter concentrations [86, 87]. The US Environmental Protection Agency sponsored a workshop on this issue in 2010 on "The Role of Vegetation in Mitigating Air Quality Impacts from Traffic Emissions"[88]. Community groups such as Breathe California and Sacramento-Emigrant Trails have also been active in investigating potential benefits of vegetation on air pollution in improving air quality near traffic and sponsored a workshop in June 2012 [89].Since much of the research on the effects of vegetation on air quality has been done in climates that are not like that of the US-Mexico border, research on the effectiveness of vegetation appropriate to the border region is needed. Recent work [90]using a wind tunnel to investigate reductions in particulate matter achieved by various species has indicated that needle trees are especially effective, and potentially the California Pepper tree, which grows well on the border would be a suitable species. California Pepper trees are being planted near the rail yard in San Bernardino, CA, in an effort to reduce community exposures to rail yard emissions [91]. Considerations such as deciduous nature of the trees, litter, water needs, space available, pollen production, and other factors are important considerations for selection of plant species as well [92].

Policy Actions

Table 8 lists recent policy actions in the state of Baja California that relate directly or indirectly to air quality at the border. A recent opening of the Air Quality Laboratory for Baja California will help strengthen monitoring efforts in this region. The vehicle verification or smog check program recently instituted in Tijuana will help reduce emissions per vehicle crossing the border (Table 8).

Table 8: Recent state and local actions related to control of Air Pollution in Baja California

Action:	***Current status:***
Strengthening state air monitoring network	Infrastructure. New air quality laboratory (Control center and analytical laboratory) for Baja California opened in 2012 in Tijuana
State Reforestation Program Implementation	Program started in schools in 2011 in 2012 extended to the industrial sector
State Program of Vehicle Verification (Smog Check)	Program started in 2012 in two centers in Tijuana on a voluntary basis; obligatory from 2013 onwards
Programs to improve air quality	“Proaire” program is currently almost completed for Tijuana, Playas de Rosarito, and Tecate
Inventories of air pollutants emissions	In 2010, the last inventory for Mexicali and Tijuana-Tecate-Rosarito was presented
Integrated Program of Pavement and Air Quality (PIPCA)	Main goal is to pave streets in Baja California in order to reduce the dust and particle air contaminants.. As of 2010, 80 areas in Tijuana have benefitted

Binational actions have also been successfully undertaken to improve border air quality and to address commercial truck emissions that will affect air quality at border crossings (Table 9). These include a pilot project retrofitting diesel trucks in Baja California, programs to reduce emissions such as SmartWay , and efforts to increase community reporting of health effects (Table 9).

Table 9: Recent Binational and National actions related to air pollution and health

Program	***Description***
Clean Diesel Demonstration Project Tijuana/San Diego	This project was to demonstrate the feasibility of refitting diesel trucks in the region, and to thus speed up the introduction and use of ultra-low sulfur diesel at the border region, build business alliances, improve the air quality and establish precedents in Mexico to implement clean diesel projects. Funded by USEPA and managed by SDAPCD (San Diego Air Pollution Control District). For this project, 50 heavy duty Mexican trucks—all post-1988—were provided with both Diesel Oxidation Catalyzers (DOC) and Spiracles by Ironman Parts and Services and Donaldson; respectively. The emission reduction of the whole fleet was equivalent to 25% of particulates, CO, and precursors of O3.
SmartWay, USEPA http://www.epa.gov/smartway/	Explore ways to reduce fuel consumption, reduce emissions and increase productivity in commercial trucking. International initiative. Addressed application to US-Mexico POE emissions in study [30],http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/TTI-2009-5.pdf)
Implementation of Clean Transportation Tijuana, BC and Nogales, Sonora	This project was preceded by "SmartWay" in the U.S. It is funded by US EPA through the Border Environment Cooperation Commission (BECC). In this project, 15 semis were provided with low rolling resistance tires and ecological cabins. The participating companies were Cemex Transport, Express Milac, Praxair, and Pepsico.
FAST (Free and Secure Trade)	Opening and operation of FAST (Free and Secure Trade) lines in Tijuana started on October 15, 2004. Companies allowed to use FAST lines must be previously certified to U.S. standards. One of the objectives of this actions was to reduce traffic jams and vehicle idling and hence reduce fuel combustion and emissions.
REPORTA Civic monitoring system of respiratory diseases	The objective of this network is to have a global and updated panorama of respiratory diseases in Mexico through the collection of data and consolidation of a database that identifies incidence, type and location of respiratory diseases of populations in Mexico. This online survey was developed by UNAM. http://reporta.c3.org.mx/Cuestionario.php

Conference photos courtesy of Ángel Granados.

Gaps, Needs and Recommendations from the Conference

The Health Impacts of Border Crossings Conference in May 2012 brought together researchers, community leaders, planners, government agencies, and concerned citizens to discuss issues of critical importance in recognizing health issues related to border crossings along the US-Mexico border. The 2-day conference asked participants to deliberate on the gaps in understanding about health related concerns at border crossings and to determine possible solutions to address the issues. This conference took place in San Ysidro, CA, over two days, May 3 and 4. The first day consisted of a Technical Workshop that featured presentations by leading researchers on the topics of traffic exposures and health, as well as a poster session for all participants. This was followed by a community meeting organized by Casa Familiar, a local community organization concerned about the effect of the San Ysidro POE on the health, social welfare, and economic wellbeing of their community. Participants from both the Technical Workshop and the community meeting provided consensus recommendations to the main conference, which was held the next day. At the main meeting, participants heard presentations and recommendations from the previous day, then were asked to break up into workgroups. There were four major workgroup areas that were discussed: (1) planning and design, (2) exposure and health, (3) policy and emissions reductions, and (4) border crossing experience. Recommendations on these areas from these workgroups are presented below.

Planning and Design

As the border region grows and as security measures change the dynamics of border crossings, planning and design are critical for ensuring safe and efficient border crossings. Currently there are several areas in which improved planning and design could impact the health of residents living and working in the region.

Decrease border delays. Due to increased security post 9-11, border delays have increased significantly. These increased border wait times consequently produce increased exposure time to pollutants for those people living and working near border crossings. There is a need to find cost-effective approaches to reduce border delays in an effort to decrease the level of pollutants in the region.

Create **buffer zones between roadways and communities/pedestrians**. By separating residents and border crossers from the roadways and heavily congested traffic areas, there would be a reduction in exposure to harmful pollutants. It is important to study optimal distances and recommend design policies be in place to ensure that planners involved in designing and /or redeveloping border crossings comply with guidelines.

Study and make accessible **goods movement routes to reduce impacts on local communities**. Heavy traffic of trucks carrying goods across the border often passes through the middle of communities and near schools and other sensitive zones. It is important to understand the impact of these routes (both north and southbound) on local communities and consider re-routing trucks through commercial areas in an effort to reduce exposure to pollutants of concern.

Investigate the feasibility of implementation as well as the likely impacts of **short-term mitigation measures as well as long-term designs** on local communities and workers. Gaining a better understanding of potential mitigation measures such as vegetation barriers, buffer zones, re-routing of traffic and reducing delay times is important for determining best practices for designing and redevelopment of border crossings. Increased funding for research and implementation in these areas is critical.

Incorporate community and border crossers exposure information into design of crossings. Knowledge of exposures experienced and determinants of these exposures could better inform design.

Improve coordination among local, state, and federal agencies. Identify better ways of coordination between agencies such as NADBank, the Mexico and Baja Secretariat of Communications and Transportation (Secretaría de Comunicaciones y Transportes), and California Transportation Commission (CTC) in an effort to improve and fund better transportation planning on both sides of the border.

Understand the **economic impacts** of delayed border crossings. Improvements and additions to infrastructure of ports of entry are merited not only for the reduction of emissions from idling vehicles but also for economic reasons; congestion causes additional costs to trade.

Improve financing of border crossing infrastructure. Include public-private partnerships as a potential funding source for infrastructure improvements at border crossings.

Exposure and Health

Study the **health impacts of border crossings**. Research on the health effects of border crossings on those people who live, work and play nearby is extremely limited. More resources need to be allocated to the study of these effects to better understand the best practices for preventing harm and illness.

Establish **harmonized health protocols** that register possible exposure related illnesses such as respiratory disease and asthma using the same criteria on both sides of the border.

Improve and increase **access to existing data**. Currently there are very little data on exposures to traffic related pollution at the US-Mexico border crossings. There are limited data from the US-Canada border crossings, however it is not enough to draw any conclusions regarding the actual risk of exposure to people living, working and crossing at the border. Although recent years have seen an increasing number of traffic-related pollution exposure studies, exposure assessment data on this topic are still limited. Differences among measuring methods and a lack of strict quality control in carrying out exposure assessment make it difficult to generalize and compare findings between studies.

Support **community based projects that focus on exposure measurements and mitigation effectiveness**. There are a few border community based projects that are looking at exposure levels to traffic related pollution in their communities. For example, in the Tijuana community of Chilpancingo, community members are working with the non-profit Collectivo Chipancingo to monitor and measure air pollution levels near local schools. Trucks carrying goods to and from the commercial port of entry at Otay Mesa travel through their community and often idle next to schools. By supporting local projects, we can learn more about exposures and ways to prevent them by re-routing the trucks and determining best practices for the transportation for goods across the border. A similar project is being conducted in San Ysidro, CA, at local schools and a school flag program for air quality has been proposed that will indicate the levels of air pollution. Allocating more resources and support to these types of projects would greatly enhance not only knowledge of exposures but also strengthen community partnerships.

Measure exposures at all US- Mexico border crossings and document exposure levels and differences. Increased monitoring of exposures and exposure levels at the border crossings will assist in better understanding the differences in types, timing and places of exposures. Since every crossing is unique, documenting the different levels of exposures can help identify problem areas and compare crossings for similar concerns.

Determine **effective indicators of exposure to and toxicity of border traffic-related pollutants**. Exposure assessment is usually focused on ambient air pollution levels. However, due to spatial variations of the pollutant levels, exposure monitoring data obtained from these limited number of fixed-sites usually are not accurate enough for epidemiological studies. An alternative for this is the adoption of appropriate indicators and the use of technologies such as geographic information systems (GIS), especially when traffic-related exposure assessment is the main focus. For example, by collecting traffic indicator information, personal exposure can be estimated. This is an effective method when the main goal is to estimate the exposure profiles of a certain area, and it is better in addressing spatial variations of air pollution levels in a certain area than fixed-site monitoring.

Investigate **distances from border crossings** that elevated levels of pollutant are found and factors that influence that distance.

Fund projects exploring the **effectiveness of vegetation as a barrier** between border traffic and exposed persons.

Policy and Emissions Reduction

Support projects to model emissions and exposures and model effects of policy measures. This is a cost effective approach to moving forward efficiently.

Investigate **implementation of clean diesel programs** in the US-Mexico border region. Several clean diesel programs have been implemented in the US-Mexico border region and it is important to monitor the impacts of these programs on the reduction of emissions and to determine their efficacy. Retrofitted vehicles and trucks should be monitored continuously and interviews conducted with the business owners to determine how well the programs are functioning for them and to learn of suggested changes or improvements.

Investigate impact and feasibility of other programs such as programs to **remove extreme emitters** from roadways.

Develop an **additional annex to the La Paz Agreement** that adds one or more “study areas” and encourages even greater collaboration on air quality across the border.

Analyze the potential impact of the **Trading of Emission-Reduction Credits System** of the AB32 in the region.

Identify **air quality management mechanisms** that could be implemented in the border region.

Identify the **types of vehicles that emit the most pollution** at various border crossings and determe vehicle characteristics that predict emissions.

Better understand appropriate **performance indicators for improving air quality**.

Community Voices

The children who breathe the fumes from idling trucks waiting to cross the border and the parents of those children who struggle to pay the medical bills to deal with their child’s asthma...they are the ones who are dealing with this problem. Some communities are standing up and asking the local authorities to take notice. They are asking that trucks not be allowed to be routed through their communities on the way to and from the border. They are asking for more monitoring and notification of bad air quality days so their kids can stay indoors that day. The communities are asking for more understanding that they are living and breathing the pollution at the border and that there must be a way to move traffic through a little faster so that they are not exposed to so much contamination. It is important that decision makers understand the true problems faced by the people living, working, commuting, and playing along the border in order to develop effective policies to protect their public health.

Study **contribution of border traffic and crossing delays to pollutant, greenhouse gas, and black carbon emissions**. Black carbon is a short-term climate forcer that also has public health co-benefits and is an appropriate target for reduction efforts.

Improving Border Crossing Experience

Reduce delay/ wait times to reduce the amount of time pedestrians and vehicles passengers are exposed to vehicle emissions.

Separate pedestrians from cars, buses, and trucks.

Provide seating and shade for elderly and disabled.

Make available **adequate restroom facilities.**

Create a **number waiting system** for the crossers who physically cannot wait in long lines.

Improve working conditions and protection from pollutants for workers.

We would like to thank all of the participants, presenters and volunteers in the Health Impacts of Border Crossings 2012 Conference. We would also like to give a special thanks to Casa Familiar for their partnership and work in our border communities.

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Appendix

Table: A- 1 Comparison of Ambient Air Quality Standards in the United States and Mexico

Pollutant	*Averaging Time*	*U.S. NAAQS*	*Mexico NOM*
Carbon monoxide (CO)	8-hour	9 ppm (10 mg/m^3)	11 ppm (12.6 mg/m^3)
	1-hour	35 ppm (40 mg/m^3)	
Lead	Rolling 3-Month Average	0.15 µg/m^3	1.5 µg/m^3
Nitrogen dioxide (NO_2)	Annual (Arithmetic Mean)	0.053 ppm (100 µg/m^3)	
	1-hour	0.100 ppm	0.21 ppm (395 µg/m3)
Particulate Matter (PM_{10})	24-hour	150 µg/m^3	120 µg/m^3
	Annual (Arithmetic Mean)		50 µg/m^3
Particulate Matter ($PM_{2.5}$)	Annual (Arithmetic Mean)	12.0 µg/m^3	15.0 µg/m^3
	24-hour	35 µg/m^3	65 µg/m^3
Total suspended particulates (TSP)	24-hour		210 µg/m^3
Ozone (O_3)	8-hour	0.075 ppm (2008 std)	0.08 ppm (1993 std)
	1-hour		0.11 ppm
	Annual (Arithmetic Mean)		0.03 ppm (79 µg/m^3)
Sulfur dioxide (SO_2)	24-hour		0.13 ppm (341 µg/m^3)
	1 hour	0.75 ppm	

Sources: U.S. Environmental Protection Agency http://www.epa.gov/air/criteria.html. Shown are primary standards and not additional secondary standards. , *MexicoSecretaría de Protección de Medio Ambiente y Recursos Naturales and Secretaría de Salud.* Units of measure for the standards are parts per million (ppm) by volume, milligrams per cubic meter of air (mg/m^3), and micrograms per cubic meter of air (µg/m^3). NAAQS -National Ambient Air Quality Standards, USA, NOM -Normas Oficiales Mexicanas.

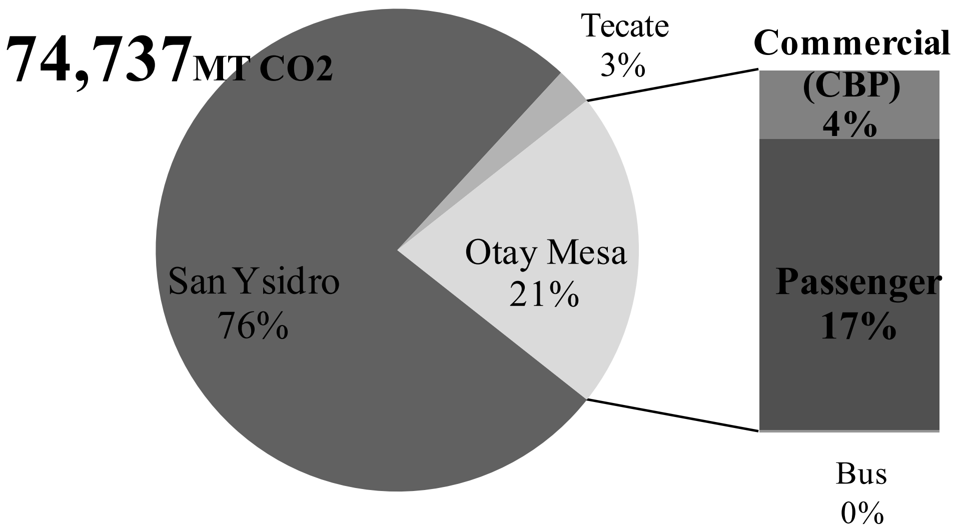

Figure: A- 1 Relative greenhouse gas emission contributions from each San Diego border crossing (2009) using CBP's delay data. Emissions from the final post inspection acceleration are included. Units are megatons of CO2 equivalents. Source, Barzee, 2010, http://sdsu-dspace.calstate.edu/handle/10211.10/262

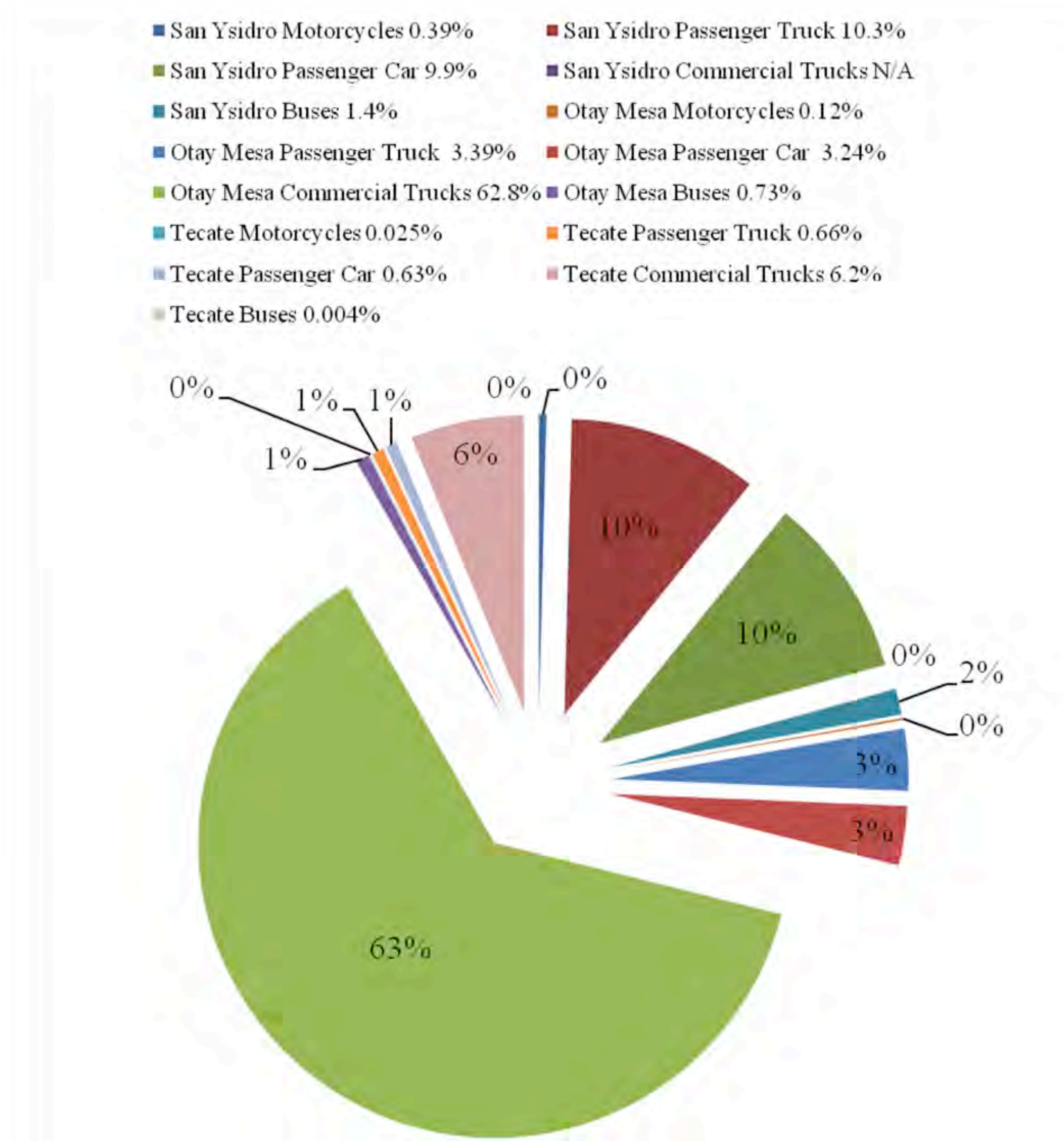

Figure: A- 2 Percent Contribution of Particulate Matter 2.5 per Vehicle Source Type at the California-Baja Border Crossings for FY2009 Source: Shwayhat, 2011, http://sdsu-dspace.calstate.edu/handle/10211.10/1301

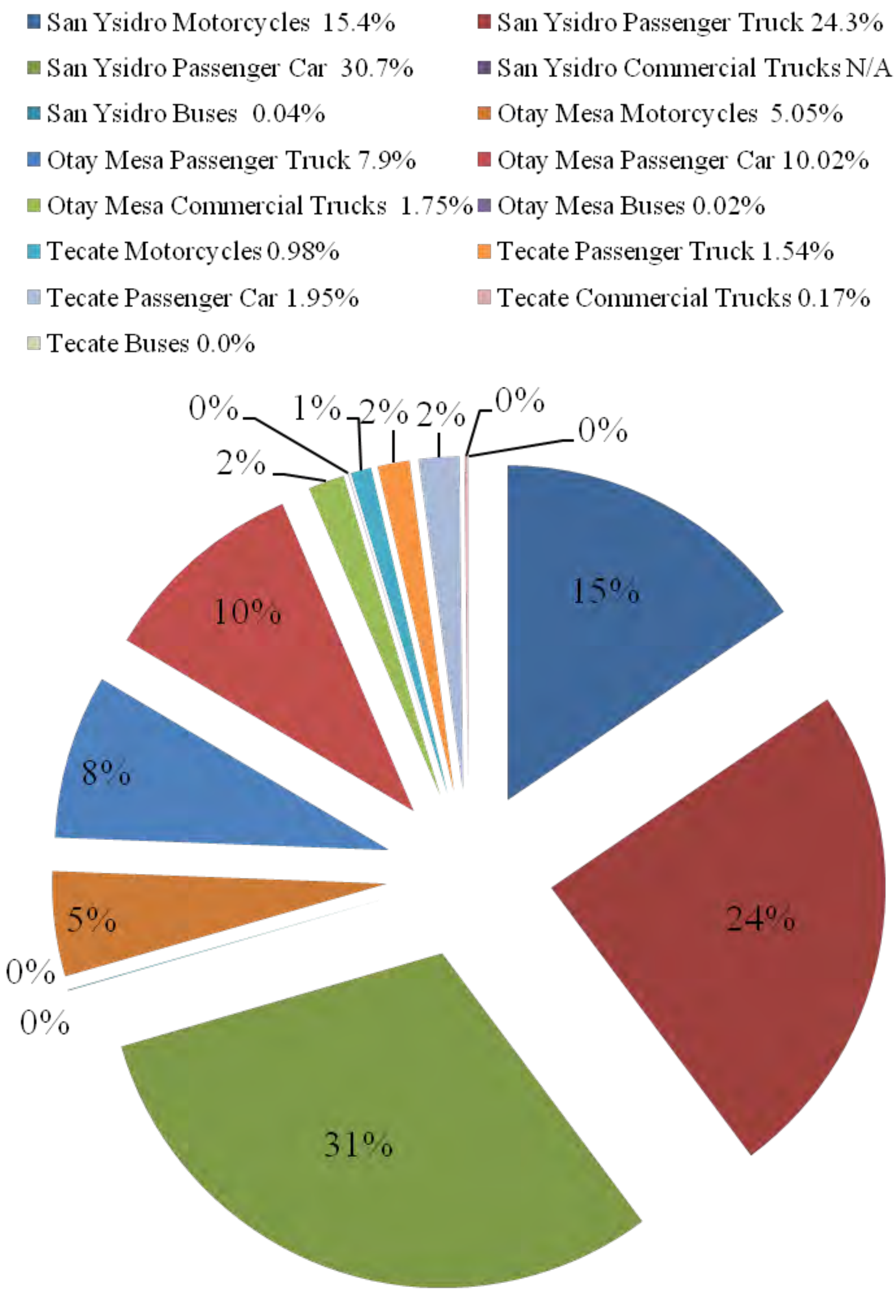

Figure: A- 3 Percent Contribution of Carbon Monoxide per Vehicle Source Type at the California-Baja Border Crossings for FY2009. Source: Shwayhat, 2011, http://sdsu-dspace.calstate.edu/handle/10211.10/1301

Table: A- 1 Health effect studies directly associated with traffic pollution at border crossings

Study	***Which border***	***Which crossing***	***Traffic pollutants***	***Study design***	***Description of study***	***Findings in relation to border crossing***
Lwebuga Mukasa et al., 2004	US-CANADA	Buffalo, NY Peace Bridge	(none specific)	Retrospective study	Adult asthmatics and traffic volume	Increased traffic volume related to NAFTA has been associated with increases in adult asthma cases
Oyana et al., 2004	US-CANADA	Buffalo, NY Peace Bridge	(none specific)	Case-control	Adult asthma near crossing	Clustering of adult asthma cases in close proximity to bridge and freeways is statistically significant.
Oyana et al., 2005	US-CANADA	Buffalo, NY Peace Bridge	(none specific)	Case-control	Childhood asthma near sources including crossing	Spatial clustering of cases near Peace Arch Bridge but not statistically significant in case control analysis

Table: A- 2 Health effects in US-Mexico border communities potentially affected by border traffic

Study	*Which border*	*Which crossing*	*Traffic pollutants*	*Study design*	*Description of study*	*Findings in relation to border crossing*
Sarnat et al., 2012	US-MEXICO	El Paso / Cuidad Juárez	Traffic, PM, EC, NO2	Panel	Respiratory responses and biomarkers of lung function	School-based monitors on both sides of border were more associated with lung function than regional monitors. Evidence of traffic-associated health effects.
Holguin et al., 2007	US-MEXICO	El Paso / Cuidad Juárez	Traffic, PM, EC, NO2	Panel	Lung function measured in asthmatic kids in Ciudad Juárez	Children closest to high traffic areas had worst measures of lung function

Table: A- 3 Traffic-pollutant exposure studies near border crossings: US-CANADA

Study	*Which border*	*Which crossing*	*Traffic pollutants*	*Study design*	*Description of study*	*Findings in relation to border crossing*
Baxter et al., 2008	US-CANADA	Detroit, MIAmbassador Bridge	EC	Environmental survey in community near crossing	16 homes in close proximity to Ambassador Bridge.	Indoor air quality was affected by outdoor air quality and the amount of time home; was downwind from border crossing, calm winds increased indoor concentrations
McAuley et al., 2010	US-CANADA	Buffalo, NY Peace Bridge	Ultrafine particles (UFP)	Environmental survey in community near crossing	Penetration of trafffic particles inside 5 homes near crossing	Ultrafine articles inside homes lower than outside but some homes had a high level of ultrafine particles penetrate indoors
McAuley et al., 2010	US-CANADA	Buffalo, NY Peace Bridge	Ultrafine particles (UFP)	Environmental survey near crossing	Continuous measurements of UFPs	300 meters downwind of bridge concentrations 60,000 - 70,000 p/cc, upwind in traffic 8,000 -10,000 p/cc
Oguiel et al., 2007	US-CANADA	Buffalo,NY	Ultrafine particles (UFP)	Environmental survey in community near crossing	Analysis of submicron particle size distributions near border crossing.	Highest concentrations of particles were located closest to the border crossing.
Spengler et al., 2011	US-CANADA	Buffalo, NY Peace Bridge	Air toxics (various)	Environmental survey in community near crossing	Measured traffic pollutants and wind direction at varying distances	Levels of elemental carbon, benzene, formaldehyde (among other air toxics) higher near crossing
Wheeler et al., 2007	US-CANADA	Ontario, Canada Ambassador Bridge	$NO2$, $SO2$, VOCs	Environmental survey Winsor, Ontario	Modeled levels of pollutants related to sources and traffic	Distance to border crossing significant variable among others

Table: A- 4 Traffic-pollutant exposure studies near border crossings: US-MEXICO

Study	*Which border*	*Which crossing*	*Traffic pollutants*	*Study design*	*Description of study*	*Findings in relation to border crossing*
Dumbauld et al., 2011	US-MEXICO	San Ysidro - Tjuana	BC, $PM_{2.5}$, UFPs	Environmental survey in community near crossing	Air pollution measurements compared to border delay time and wind condition	Black carbon in community significantly higher when wind direction from border area, significantly correlated to border delay time in calm wind condition
Galaviz et al., 2013a,b	US-MEXICO	San Ysidro - Tjuana	Nitropyrenes, CO, UFPs, BC	Environmental survey at crossing and personal exposure to pedestrians waiting in line	Monitored at border gate and by monitors carried by pedestrians, biomarkers of diesel exposure (1 NP) in urine	Border gate where pedestrians cross approx 40,000 ultrafine particles/cc, air levels 1-NP higher in border crossers than non-crossers, urine biomarker 10-fold higher in pedestrian crossers
Olvera et al., 2013	US-MEXICO	El Paso-Ciudad Juárez	Ultrafine particles (UFP)	Environmental survey at crossing	Measurements at crossing in relation to weather and vehicle volume	Average ultrafine particles 34,000 p/cc with very high excursions up to 700,000 p/cc, and levels related to traffic and truck volume at crossing
Mota-Raigoza, 2012	US-MEXICO	San Ysidro - Tjuana	Nanoparticle surface area monitor	Environmental survey in community near crossing	Air pollution measurements compared to border delay time and meteorology	Border vehicle delay times significantly associated with elevated concentrations of ultrafine particles characterized by surface area deposition in lungs
Quintana et al., 2010, Bryden, 2009	US-MEXICO	San Ysidro - Tjuana	BC, UFPs, PM2.5, CO	Air measured inside passenger vehicles waiting in line	Air quality inside vehicles measured during northbound commute	Ultrafine particles (UFP) and CO highest inside vehicles during border wait (UFP 30,000 p/cc)
Smith et al., 2006	US-MEXICO	El Paso / Cuidad Juárez	VOCs, NO2	Environmental survey El Paso	Modeled levels of pollutants related to sources and traffic	Distance to border crossing significant variable among others

Table: A- 5 Emissions from border crossings: US-MEXICO

Study	*Which border*	*Which crossing*	*Traffic pollutants*	*Study design*	*Description of study*	*Findings in relation to border crossing*
Barzee et al., 2010	US-MEXICO	San Diego - Baja California border crossings	Greenhouse gases	Emissions associated with delays - model of emissions using EPA MOVES	Modeled emissions using delay times at crossings and vehicle and truck volumes	FY 2009 emissions 80,000 metric tons (MT) of CO2Eq. The San Ysidro Port of Entry contributed the most GHG emissions (68% of total). Heavy-duty diesel trucks contributed the most on a per vehicle basis.
Ghosh et al., 2000	US-MEXICO	Otay Mesa, San Ysidro	CO, HC	Cross-sectional	Assessment of emissions and drivers' attitude toward vehicle maintenance, testing	More vehicles emitted CO over limit (12%) than HC, lower than in El Paso / Ciudad Juárez (37 %). Drivers in Tijuana less willing to pay for maintenance, testing. Suggest outreach and education, removing dirty cars.
Kear et al., 2012	US-MEXICO	Ysleta-Zaragoza	NOx, PM2.5			
Schwayat, 2011	US-MEXICO	San Diego - Baja California border crossings	Criteria pollutants NOx, PM2.5, CO etc.	Emissions associated with delays - model of emissions using EPA MOVES	Modeled emissions using delay times at crossings and vehicle and truck volumes	Passenger vehicles emitted the most NOx and CO (San Ysidro crossing), while commercial trucks emitted the majority of the particulate air pollution (Otay crossing)
Zietsman et al., 2005	US-MEXICO	El Paso/Juárez		Mexican truck idling emissions		

Table: A- 6 Other emission studies relevant to US-Mexico border crossings

Study	*Which border*	*Which crossing*	*Traffic pollutants*	*Study design*	*Description of study*	*Findings in relation to border crossing*
Hesterberg et al., 2011	US		Particulate matter (PM)	Compared new technology diesel exhaust (NTDE) to traditional diesel exhaust TDE	Reviewed composition and toxicity (preliminary)	NTDE very different and likely less toxic than TDE (based on limited human, animal, and cell data), although it may increase ultrafine particle number
Kelly et al., 2006	US-MEXICO	Vehicle emissions in Calexico/Mexicali and El Paso/Juárez	Black Carbon and PAHs	Roadside probe of emissions	Recorded emissions and type of vehicle	Mexican buses and all medium duty trucks more frequently identified as high emitters than heavy duty trucks or passenger vehicles

Table: A- 7 Occupational exposure and health studies at border crossings: US-MEXICO

Study	***Which border***	***Which crossing***	***Traffic pollutants***	***Study design***	***Description of study***	***Findings in relation to border crossing***
Cohen et al., 1971	US-MEX	San Ysidro - Tjuana	CO and carboxyHb	Worker absorption of carbon monoxide	Measured carboxy hemoglobin, a biomarker of absorption and exhaled CO	Very high levels carboxy hemoglobin levels in smokers and non-smoking workers alike, and related to high CO exposures from vehicles (estimated over 50 ppm, much higher than current levels)
Dunn et al., 1999	US-MEX	Calexico		Walk through survey	Options to control worker exposure to vehicle emissions	*pending receipt of report*
Lynch and Humpherys, 1975	US-MEX				Assess heat stress and carbon monoxide exposure at US-Mexico border crossings (NIOSH investigation)	*pending receipt of report*

Table: A- 8 Policy impacts on traffic-related air pollution near border crossings: US-MEXICO

Study	*Which border*	*Which crossing*	*Traffic pollutants*	*Study design*	*Description of study*	*Findings in relation to border crossing*
Fernandez et al., 2008	CAN US MEX		O3, CO, PM2.5, PM10, NOx, SOx	Retrospective	Examined the impact of trade and environmental policies on air quality along US Mex border.	Air quality improved after 2004 implementation of diesel engine policy. Trade policy results are mixed due to implementation time variation.
Fernandez et al., 2010	CAN US MEX		O3, CO, PM2.5, PM10, NOx	Retrospective	Assessed impact of policies on reducing air emissions	Policies effective through changes in vehicle characteristics and vehicle movement through the border. Type of engine impacted the amount of NOX emissions. FAST program reduced wait times. Reducing congestion and improving infrastructure decreased pollution levels.
Applegate 1984	US-MEX			Theoretical	Reviewed the success and failure of policies and institutions along the border that deal with transfrontier air pollution	Provides theoretical framework and suggests bi-national air shed 'bubbles' that follow natural, not political boundaries.
Fernandez et al., 2011	US-MEX	San Ysidro, Otay Mesa, Calexico, El Paso, Laredo, Brownsville, Santa Teresa, Nogales		Retrospective	Measured impacts of trade policies and environmental policies on border air quality.	Air quality improved after 2004 diesel engine policy was implemented. The impact of other policies was difficult to measure due to different implementation times along the border.

Table: A- 9 Studies reviewing health effects of traffic-related air pollution or traffic-related exposure in the US-MEXICO border region

Study	*Which border*	*Which crossing*	*Traffic pollutants*	*Study design*	*Description of study*	*Findings in relation to border crossing*
English at al., 1998	US-MEX	San Diego and Imperial Counties	Ozone and PM	hospital records	Childhood asthma hospitalizations	Imperial Valley higher rate of hospitalizations and high pollution relative to San Diego
Gonzales et al., 2005	US-MEX	El Paso	NO2	Cross-sectional	NO2 measurements were taken at 20 elementary schools and 4 air monitoring stations.	The distance from vehicle emissions affects exposure to NO2 levels.
Mukerjee, 2001	US-MEX	US Mexico border cities	Ozone	Cross-sectional	Review of factors influencing cross-border pollution and air quality along the US Mex border	Air quality is affected by the volume of traffic, the types of vehicles, policies that promote cross border traffic.
Raysoni et al., 2011	US-MEX	El Paso / Cuidad Juárez	PM10, PM2.5, BC, NO2	Case-control	Indoor and outdoor concentrations of pollutants were taken from elementary schools in high and low traffic areas.	Schools in high traffic areas have higher levels of pollutants indoors and outdoors. Schools within high traffic zones in Cuidad Juárez had highest concentrations of NO2 and BC

Table: A- 10 Key to White Paper Tables – Traffic-related pollutants

Acronym in table	*Name*		*Notes*
Particulates		**X**	**= EPA criteria pollutant (regulated in air basins)**
PM_{10}	Particulate matter less than 10 micrometers in aerodynamic diameter	x	Units in weight/volume, micrograms/cubic meter (μg/m^3)
$PM_{2.5}$	Particulate matter less than 2.5 micrometers in aerodynamic diameter	x	Units micrograms/cubic meter (μg/m^3). Can reach the deep lung.
UFP	Ultrafine particles, particles less than 0.1 micrometers in diameter		Not regulated by EPA except as it makes up mass of PM2.5 particles. Units in particle number per cubic centimeter (particles/cc). Particle number and surface area thought to be related to toxicity.
BC	Black carbon (soot)		Not regulated by EPA except as it makes up mass of PM2.5 particles. Units in micrograms/cubic meter (μg/m^3) or nanograms/m^3, ng/m^3. Of concern as a marker of combustion, especially diesel vehicles, and also contributes to climate change.
EC	Elemental carbon (soot)		See above -analyzed with different methods
Gases and vapors			
CO	Carbon monoxide	x	Associated with traffic, poorly tuned vehicles or no catalytic converter
NO_x	Oxides of nitrogen	x	NO_2 especially associated with near traffic
SO_2	Sulfur Dioxide	x	Associated with traditional diesel combustion
O3	Ozone	x	Units parts per billion or hundred million (ppb or pphm) . Unlike other traffic-related pollutants it is not directly emitted, but is prodced by interaction of NOx and VOCs, plus sunlight (uv).
	Benzene		An air toxic and not regulated by air concentration. Human carcinogen
	Formaldehyde		An air toxic and not regulated by air concentration. Human carcinogen and irritant.
VOCs	Volatile organic compounds		Gasoline is made up of many VOCs
PAHs	Poly-aromatic hydrocarbons		A class of compounds often created by combustion, many of which are suspected human carcinogens, such as benzo-a-pyrene.