Eastern Research Group, Inc.

VEHICLE EMISSIONS AND FLEET CHARACTERISTICS IN BAJA CALIFORNIA, MEXICO

FINAL REPORT

Submitted to:

California Air Resources Board

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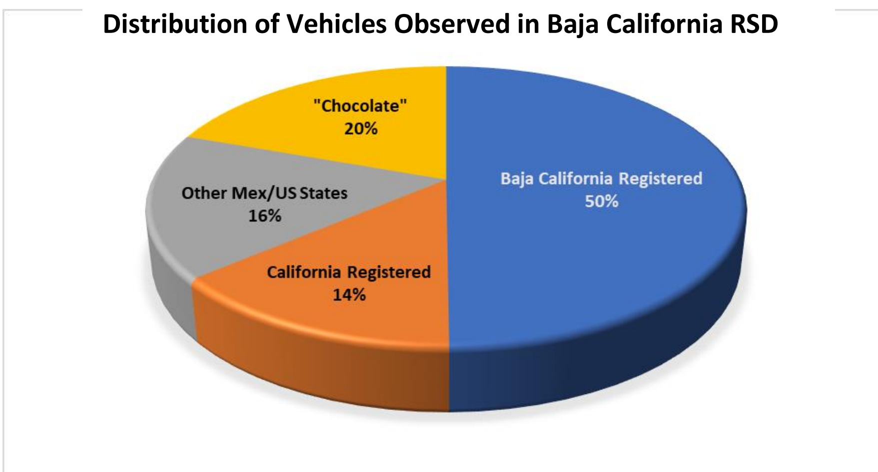
ABBREVIATIONS

ALPR	Automatic license plate recognition
BC	Baja California
CAMe	Comisión Ambiental de la Megalópolis
CO	Carbon Monoxide
DMV	Department of Motor Vehicles
HC	Hydrocarbons
HD	Heavy-duty vehicle (buses, large trucks)
IMOS	Instituto de Movilidad Sustentable Gobierno del Estado de Baja California
INECC	Instituto Nacional de Ecología y Cambio Climático
SMADS	Secretaría de Medio Ambiente y Desarrollo Sustentable Gobierno del Estado de Baja California
LD	Light-duty vehicle (cars, light trucks)
NOM-42	Norma Oficial Mexicana – 42 (vehicle emission standards)
NOx	Oxides of Nitrogen
$PM_{2.5}$	Particulate matter ≤ 2.5 microns
PPM	Parts per million
RSD	Remote Sensing Device
UV	Ultraviolet
VOC	Volatile Organic Compounds

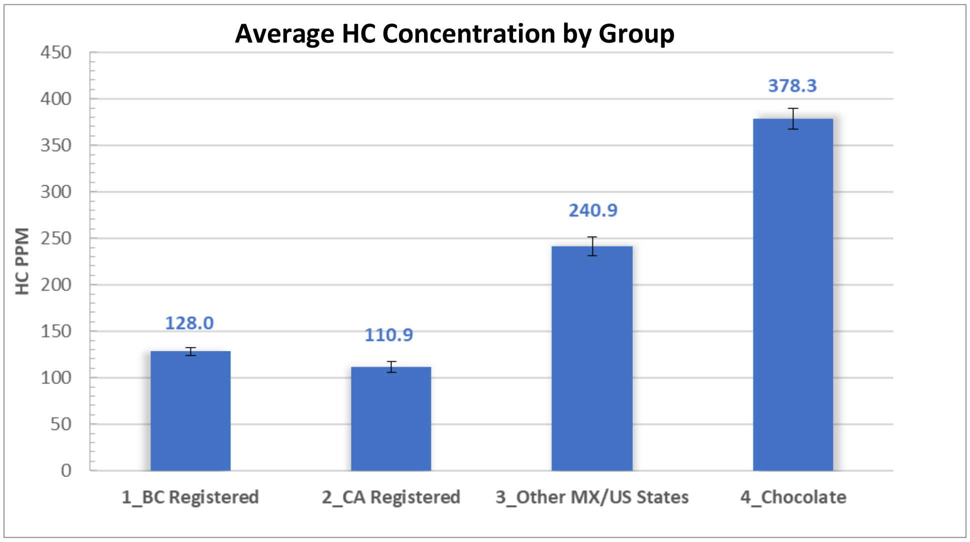
EXECUTIVE SUMMARY

The California Air Resources Board (CARB) tracks emissions inventories in neighboring Baja California for air quality planning, due to transport of these emissions and the effects of vehicles traveling between California and Mexico. ERG previously assisted CARB in compiling emissions inventories for the Northern Baja California region, including a detailed inventory of vehicle emissions at each of the six ports of entry using MOVES-Mexico. Adapted from the U.S. EPA's MOVES model in 2016, MOVES-Mexico has since been widely used to update motor vehicle emissions inventories within Mexico. For regional inventory analysis, MOVES-Mexico applies national default data on vehicle mix, age distributions and emissions, which may not reflect the unique conditions Baja California brought about by the prevalence of used vehicles from the U.S in the fleet, and commercial truck traffic serving industries that transport goods across the border. To improve model accuracy, U.S. EPA provided CARB with funding to improve the vehicle emission inventory for the northern Baja California region by gathering data on the vehicle fleet in the border region, and apply observed data to improve MOVES-Mexico specific to Baja California. For this project ERG teamed with Opus Inspections and Tejada Le Blanc (LT Consulting) to conduct roadside remote sensing device (RSD) measurements in the Spring of 2022 at seven sites across the border area, spread across Tijuana, Tecate and Mexicali. Four of these sites were selected to align with RSD collected by Mexico's federal environmental research agency (INECC) in 2010, to provide a direct comparison of emissions over one decade. Three additional sites were chosen to capture a higher rate of heavy commercial trucks. In total over 85,000 vehicles were logged, with roughly 69,000 valid emission readings.

Vehicle registration data from local and federal registration databases were used to match plates captured by RSD. This process determined that one-half of vehicles observed in the RSD sample are either unregistered "Chocolate" vehicles, visiting from the U.S., or visiting from other Mexican states.



Fleet average concentrations of exhaust hydrocarbons (HC), carbon monoxide (CO) and oxides of nitrogen (NOx) for cars and light trucks showed drops of 50-70 percent in from RSD data taken in 2010, likely influenced by the introduction of low sulfur gasoline and fleet turnover to vehicles complying with Mexico's NOM-42 emission standards.



Despite this overall drop in emissions, wide disparities were observed between legal and illegal vehicles in the 2022 RSD data. On average, emissions of HC, CO, NOx and PM for Chocolate vehicles were found to be about three times higher than either Mexican or California-plated vehicles with valid registration records. This in effect defines two fleets in Baja California: legal and illegal. One key factor behind this difference is a large disparity in vehicle age. The median age of Baja-registered vehicles in the sample was 7 years, while the median age for Chocolate vehicles was 17 years. When compared at the same age levels, Chocolate vehicle emissions remain elevated compared to registered vehicles. This could be driven by an exodus of vehicles failing California's Smog Check program, coupled with dirtier fuel and less stringent inspection and maintenance programs in Mexico.

We assessed the impact of replacing default vehicle fleet and activity data with Baja California-specific data on Baja California's emissions inventory. An auxiliary MOVES database for Baja California was created containing updates to vehicle population and age distribution to account for registered and Chocolate vehicles; and Vehicle kilometers Traveled to account for vehicles visiting (or passing through) from other states. When these updated inputs are run with MOVES-Mexico, Baja California's vehicle emissions inventory is estimated to increase 14 percent for VOC, 22 percent for CO, 28 percent for $PM_{2.5}$ and 51 percent for NOx. Chocolate vehicles account for about 20 percent of total vehicle population, but since they can be three times dirtier than the legal fleets, they contribute up to one-third of total on-road emissions in Baja California. Our analysis finds that, as a whole, emissions have dropped substantially in the border region over the past decade, and that emissions from legally registered vehicles are lower on average than those in other Mexican cities, perhaps benefitting from a large population of U.S. vehicles operated in the area that were built to more stringent emission standards. However, these gains are undermined by a large number of Chocolate vehicles operating in the area. If all light-duty vehicles in Mexico had emissions as low as the California-registered light-duty fleet, emissions may be around one-third lower relative to today's levels. This highlights an opportunity for emissions reduction in Baja California via stricter enforcement and monitoring of vehicles circulating illegally.

1. INTRODUCTION

The State of California shares its southern border with several metropolitan areas of Northern Baja California, Mexico. The similar geography and meteorology shared by both sides of the border results in a number of common airsheds, which is defined as a part of the atmosphere that behaves in a coherent way with respect to emission dispersions throughout the area. The air quality in the border region is among the worst in the State of California, which is potentially due to the mobile, stationary, and area sources from Northern Baja California, and these sources are subject to less stringent air pollution regulations than those in California.

ERG teamed with Opus Inspections and LT Consulting to undertake this project for CARB to improve the reliability of on-road motor vehicle emission inventories in the region. Reliable emission inventories will improve our understanding of sources of air pollution that impact U.S. border cities and guide future regulatory actions. In particular, this project aims to improve on-road mobile emission inventories and air quality modeling for Northern Baja California (Tijuana, Tecate, and Mexicali) with MOVES-Mexico. MOVES-Mexico is an adaptation of the U.S. EPA Motor Vehicle Emission Simulator (MOVES) model that estimates mobile source emissions at the national, state, and *municipio* (municipality) levels (U.S EPA 2020). MOVES-Mexico has been developed with a national default vehicle fleet and activity database for Mexico that can work directly with the existing U.S. MOVES2014a model, which reflects significant differences in emission standards between Mexico and the U.S (USAID 2016). Since MOVES-Mexico uses U.S. default emission rates aged to align with Mexico which are 10-20 years behind U.S. standards, the default fleet characteristics such as car/truck mix, age distribution, may not accurately reflect the real situation for the municipalities across the border from California. The primary objective of the study was to improve fleet characteristics used in MOVES-Mexico specific to Baja California, including vehicle age distribution, population and vehicle kilometers travelled (VKT).

2. DATA GAPS IN MOVES-MEXICO

The MOVES-Mexico model was created by replacing the underlying U.S.-centric default database of the current U.S. version at the time (MOVES2014a) with a Mexico-specific database. In keeping with the design paradigm of MOVES, the underlying Mexico-specific data are meant to represent national average vehicle fleet and activity input such as total vehicle population, VKT, temporal VKT distributions, speed distributions, age distributions, vehicle mix, and emission rates. The national default database does include some region-specific information on meteorology, inspection/maintenance (I/M) and fuels. This design paradigm encourages local areas to replace national defaults with local data if available – for example, Mexico City compiles emission inventories for their metropolitan region using MOVES-Mexico but replacing most of the input listed above with local data gleaned from traffic counts, RSD and inspection programs, and accounting for urban vehicle types such as taxis and minibuses.

The initial development of MOVES-Mexico included analysis of RSD in different spots around Mexico, including several border cities in the states of Baja California and Sonora. The analysis did indicate average vehicle emissions in border areas were different from interior cities, and that there is a difference in the emissions of three groups of vehicles identified in the border fleets: native Mexico vehicles, U.S.-plated vehicles, and Mexico vehicles imported from the U.S. Of these three groups, the third category showed highest emissions, raising the question of so-called “Chocolate” (i.e., illegal) vehicles in the border region. Identifying the prevalence and emissions profile of these vehicles was defined as an important objective of the study. Uncertainties in fuel quality and inspection status of vehicles in the border area may also contribute to an emissions profile that could differ from interior vehicles, and the national average rates that MOVES-Mexico is based on. Mexican fuel survey data shows variation in fuel properties across Mexico, and recent survey data from Baja California has not been published (Koupal and Palacios, 2019). Baja California had a vehicle emissions inspection and enforcement program that was recently suspended, meaning that current data on inspection compliance rates are not available (INECC 2022).

Key data gaps in MOVES-Mexico are the vehicle fleet information on the border. The border area has several “subfleets” of vehicles, including:

- Vehicles domiciled in Baja California, purchased in Mexico, complying with Mexico’s emission standards, and legally registered in Mexico;
- Vehicles domiciled in Baja California, purchased in the U.S., complying with U.S. emission standards, and legally registered in Mexico;
- Vehicles domiciled in other Mexican states, visiting Baja California or passing through to and from the U.S.;
- U.S. – domiciled vehicles visiting Mexico, complying with U.S. emission standards.
- Chocolate vehicles domiciled in Baja California, and not legally registered.

The mix of these subfleets in Baja California is not well known, along with their age distribution, activity, and emissions profile. Our research plan therefore centered on gathering these parameters to develop border- specific inputs for MOVES-Mexico that could improve the border inventory.

In parallel with this project, ERG and LT Consulting collaborated to update MOVES-Mexico with Comisión Ambiental de la Megalópolis (CAMe), referred to as MOVES-Mexico 2022 (ERG 2022). The end result of this project will be integrated as custom inputs for the MOVES-Mexico 2022 model to provide a state-of-the-science on-road vehicle emissions inventory for Northern Baja California.

3. DATA COLLECTION PROTOCOL

The core of our study was RSD measurements conducted by Opus used the Accuscan RSD5000 remote sensing device (Figure 1) at several locations across northern Baja California. This system incorporates several data streams: an infrared (IR)/ultraviolet (UV) emissions analyzer, comprised of a source detector module (SDM) on one side of the road and reflecting Corner Cube Mirror (CCM) on the other side; an automatic license plate recognition camera (ALPR) which captures and transcribes license plate domicile and plate number; a vehicle speed/acceleration measurement unit; and meteorology data. A schematic of these devices is shown in Figure 2. Note that Figure 1 shows ALPR positioned to capture front plates, while Figure 2 shows it positioned to capture rear plates.

Figure 1. RSD Setup at a Baja California Site

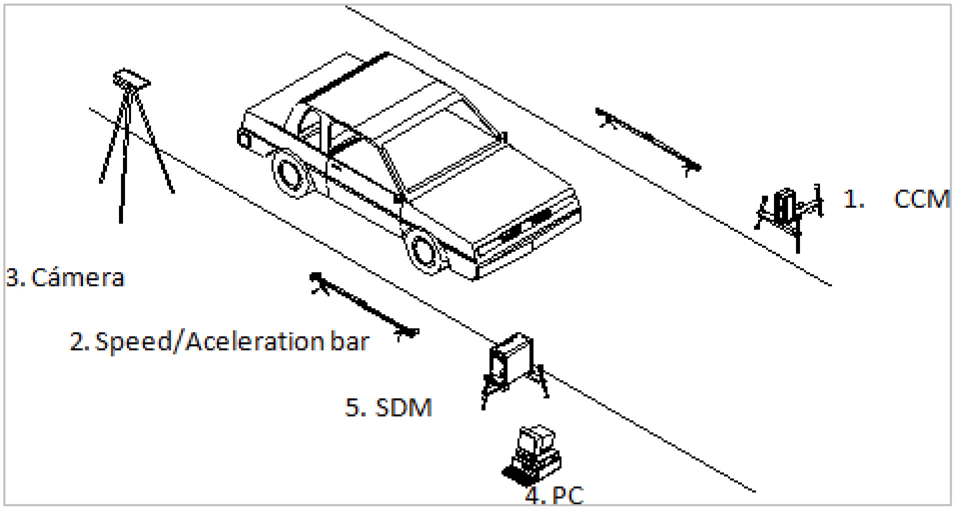


Figure 2. RSD Schematic

Plate and speed data were gathered and transcribed for all vehicles passing through the measurement zone. Due to project scope limitations, emissions data were gathered only on vehicles with low-pipe exhaust, which includes all light duty vehicles and many heavy duty vehicles. Heavy trucks with high exhaust stacks were not measured for emissions, as this would require scaffolding, adding logistical complexity, time and safety concerns. For this reason, the rate of valid emissions on heavy trucks was much lower than on light duty vehicles. A summary of data measured by the RSD5000 system is shown in Table 1.

Table 1. Data Collected by RSD5000

Item	Measurement Collected	Additional Notes
Fuel-specific Carbon Monoxide	Molar CO/CO_2 ratio	IR spectral region
Fuel-specific Total Hydrocarbons	Molar HC/CO_2 ratio	IR spectral region
Fuel-specific Opacity	Smoke Factor	UV spectral region soot particles only
Fuel-specific Nitric Oxide	Molar NO/CO_2 ratio	UV spectral region
Fuel-specific Nitrogen Dioxide	Molar NO_2/CO_2 ratio	UV spectral region
Speed	Vehicle speed (miles/hour)	70 mph > Speed > 5 mph
Acceleration	Vehicle acceleration (mph/sec)	10 mph/s > Accel > -10 mph/s
Plate Images		
Measurement location		
Measurement date/time stamp		
Meteorology data		

The individual RSD5000 components are summarized below:

- **Gas Analyzer / Source Detector Module (SDM):** The RSD has an enclosed Source Detector Module. Using Sapphire windows, the SDM is sealed against the environment to better protect the optics and electronics inside. Includes an automated gas calibration cell that eliminates the need for using gas calibration bottles and will calibrate during normal traffic movement.
- **Corner Cube Mirror (CCM):** The Corner Cube Mirror (CCM) is a simple reflector of the source light beams. It returns the beams back to the Detector side of the SDM. The CCM consists of three stationary mirrors positioned at a 90° angle with respect to one another, like the corner of a room.
- **Speed/Acceleration System (Detector/Emitter Bars):** This system records vehicle speed and acceleration and provides real-time information to the operator about the driving conditions of the vehicles at the time of the measurement. Poor test sites can be immediately identified by test results showing too many cars undergoing hard accelerations or decelerations. The Emitter and Detector Bars work in tandem to help the operator determine if a test site is favorable to capturing accurate emission readings, so quality assurance occurs in real-time.
- **Video Camera for Automatic License Plate Capture (ALPR):** This high-speed and high-resolution video camera captures a digitized picture of the rear of the vehicle. It does this at the same instant the speed/acceleration values of a vehicle are calculated as the car passes through the exit beam of the Speed/Acceleration detector bar. Camera is software- controlled from the console. The software allows for control of pan, tilt and zoom, and light control offset that automatically

compensates for the lighting conditions throughout the day.

- **System Control Unit (SCU):** The SCU utilizes Windows based XP, an Intel P4-3.0GHz or greater processor, a built-in 802.11g WiFi communication to the remote GUI Laptop and a built-in GPS module. The SCU gathers and integrates the emission readings, speed and acceleration values and video picture of the license plate. It also archives all information including the digitized vehicle license plate picture for future reference. The SCU also mediates electronic connections between the computer, monitor, CPU and other modules. The SCU provides the connection for all the peripherals to the computer and serves as a central power supply for the system.
- **Weather Station:** The Weather Station monitors external temperature and barometric pressure. The station includes an external temperature sensor. The console includes a power adapter with battery backup, backlit display for easy viewing, and a serial interface to a computer.

Synthesizing each of these equipment elements, the overall process of a single measurement is outlined below:

1. The Speed and Acceleration bar records the vehicle´s speed and acceleration.
2. The SDM/CCM module measures all exhaust pollutants.
3. The digital camera takes a picture of the license plate.
4. Data are instantaneously sent to a processor unit. Emissions concentration values and other related data are stored in the computer and can also be monitored remotely by an operator stationed in a mobile unit parked safely along the roadside.

For the measurement campaign, our team followed standard procedures to obtain prior approval from local law enforcement and traffic authorities: coning off lanes to require vehicles to slow down when entering measurement zone; using cones and signage to designate a safety zone buffer for measurement devices, instrumentation and staff; having staff on-site, in a van outfitted with computerized data collection equipment, attending to equipment and ensuring integrity of data collection; and only having equipment set up and collecting data during daylight hours.

Supplementing data collected in the field from the RSD system was registration data obtained from Tijuana, Mexicali and Tecate motor vehicle registration agencies. This effort was coordinated via Baja California’s Ministry of Environment and Sustainable Development

(SMADS).[1] California plates were matched to California DMV records with assistance from CARB. The registration data links RSD plate data to vehicle information unavailable from the field, such as vehicle model year, make, model, vehicle class, service type (e.g., taxi), and domicile (if outside the measurement area).

Personal identifiable information such as name, address etc. are not included in the data obtained for matching.

4. SITE SELECTION

Criteria for site selection were set forth by CARB, including the following:

- Sites should have high and intensive traffic counts where fleet information can be collected continuously for at least one week
- Sites should have variable traffic loads and fleet mixes.
- Sites should capture a broad representation of Baja vehicles, including heavy trucks and illegal U.S. imports referred to as "Chocolate" vehicles.
- Permission from appropriate authorities is required for each sampling site.

Relating the physical attributes of a candidate measurement site, our team identified a number of site criteria consistent with Opus' RSD siting protocol, include the following:

- Single lane uphill locations with ample room on each shoulder to safely locate the instrumentation and the support vehicle and provide a positive load for vehicle engines.
- Sites where vehicles will generally be accelerating or driving at a steady speed uphill to avoid the highly variable tailpipe emissions that can occur under deceleration.
- Sites will initially be identified by using maps and in consultation with local parties that are familiar with the area.
- Unobtrusive positioning of the remote sensing equipment to avoid motorists braking suddenly.
- Absence of cold start vehicle operating conditions that would cause atypically high emissions.
- Absence of high engine loads that could result in atypically high emissions.
- Any site with possible future construction activities will be eliminated from the list of potential sites. Those possible future construction activities might interfere with the measurement campaigns.

[1] Secretaría de Medio Ambiente y Desarrollo Sustentable Gobierno del Estado de Baja California

Site Evaluation

With these criteria set forth, our team set out to identify multiple candidate sites in and around Tijuana, Tecate and Mexicali. A source considered for candidate sites was a previous RSD campaign conducted by the Mexico federal environmental agency *Instituto Nacional de Ecología y Cambio Climático* (INECC) in Baja California in 2010, which measured emissions for thousands of vehicles at multiple locations in Tijuana, Mexicali, and Tecate, as well as other Baja California locations (INECC 2011). These sites were attractive candidates for this project because they would provide a snapshot of emission trends over the past decade, and had been previously approved by local authorities for RSD data collection. A drawback with respect to the goals of project, however, was that the 2010 INECC sites had less than 1 percent heavy trucks. In order to identify sites with higher truck counts, team members with local knowledge of Tijuana also classified three broad areas in Tijuana (Figure 3): 1) primary business, higher income residential and tourist areas of Tijuana, which in general contains more legally registered and California-plated vehicles and less heavy trucks (red circle). 4 of 5 INECC's 2010 Tijuana sites were in this area; 2) areas with lower rates of legally registered vehicles, higher prevalence of Chocolate vehicles, and moderate heavy truck travel (blue circle); and 3) industrial zone east or Tijuana with more heavy trucks (green circle).

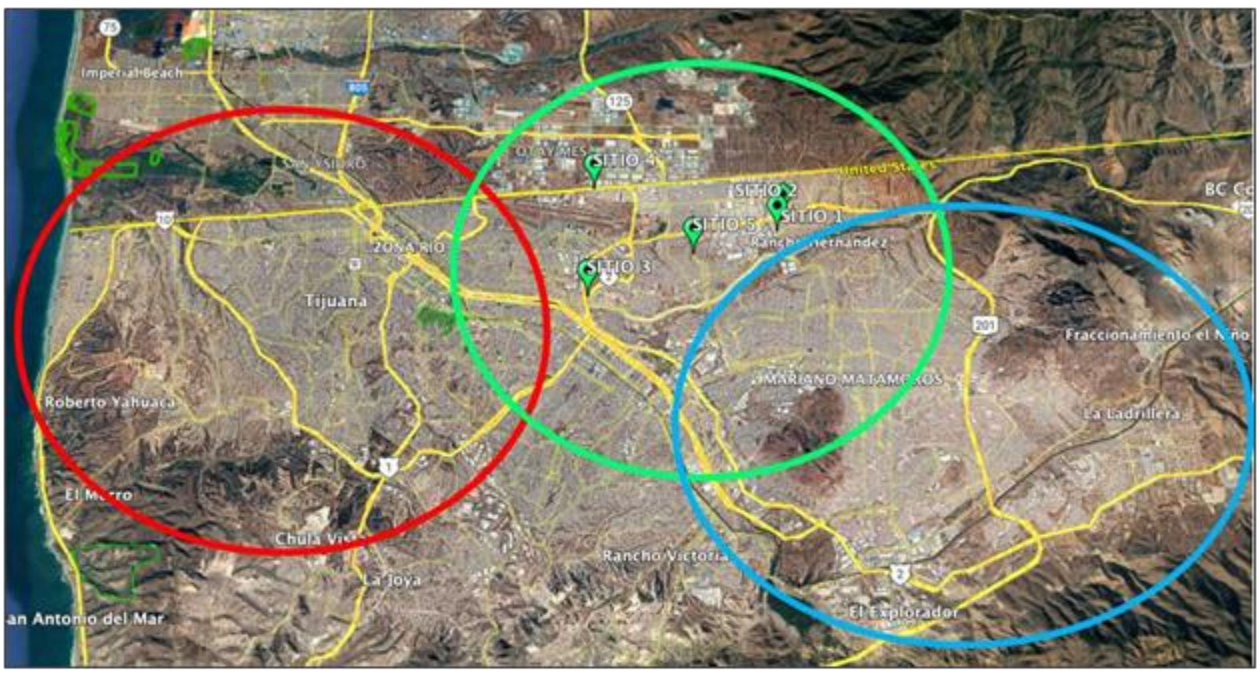


Figure 3. Site Evaluation Zones in Tijuana Area

Drawing from the Industrial zones defined above, the ERG team identified several potential sites in Tijuana that would include a higher share of trucks than observed in the 2010 measurements. A primary site was identified to meet the siting requirements listed above, and capture truck traffic: Federal Highway 2D (a toll road) between Tijuana and Tecate, which includes a highway onramp and a toll gate for westbound traffic (towards Tijuana). This site was identified as the best candidate for further evaluation.

Site Visits

LT Consulting conducted a detailed evaluation of candidate sites via site visits in Tijuana and Tecate, and remote assessment in Mexicali. The evaluations were done to determine that the sites met the physical and safety siting criteria defined by Opus. The evaluations did confirm, however, that some sites would require more traffic control than others (i.e. coning). The feasibility of controlling traffic, and the ability to gain approvals for measurement were key factors for the choice of measurement site. In-person visits were made to 3 sites in Tijuana, and 1 site in Tecate (10). At each site, a short traffic survey was conducted to provide data on the distribution of vehicle types; a short video was taken at each site as well. Sites 1 (Aeropuerto), 2 (Libramiento Sur), and 4 (Tecate) were chosen from the prior INECC study discussed previously. Site 3 (Caseta Tijuana-Tecate) was chosen as a candidate for higher truck traffic. Video observation did confirm Casete Tijuana-Tecate has the highest fraction of heavy trucks. Evaluation of Mexicali sites was conducted remotely using Google Earth, to assess the physical suitability of each site for measurement and prospect for truck traffic. The sites evaluated are shown included a "city" site comparable to INECC's 2010 Mexicali site, and three truck sites positions to capture bypass routes diverting trucks from the city center. Based on our teams evaluation a site plan was developed to include city and truck sites in Tijuana and Mexicali, plus one site in Tecate. This plan split the week of measurement in Tijuana and Mexicali between a City site and one of the sites identified as higher truck traffic (e.g., Highway 2D east of Tijuana and Highway 2 west of Mexicali). For Tecate, the INECC was used for all 7 days.

5. FIELD DATA COLLECTION

RSD was conducted between April 28 and June 3, 2022. The measurement was led by Opus with traffic support provided by Baja California's transport agency, the Institute for Sustainable Mobility (IMOS),[2] and local law enforcement. Some modification to site plan was required after visual inspection of sites, to accommodate changes requested from transport authorities, and to avoid measurement in congested conditions that would render emissions invalid. With coordination from SMADS, our team worked with IMOS and law enforcement for formal approval and traffic control. In the course of this, the locations of some of the candidate sites were modified as needed at the wish of the authorities to avoid highly congested areas, and to not conflict with other traffic projects that might be happening. The actual measurement sites are shown in Figure 4.

A total of 102,812 vehicle observations, as defined by valid plate capture, were recorded across the entire campaign. Raw observations by site are shown in Table 2. Because several sites had concurrent front and rear plate capture, ERG identified front and rear plate matches to identify duplicate vehicle hits. When this was accounted for, the total vehicle count was 85,151.

[2] Instituto de Movilidad Sustentable Gobierno del Estado de Baja California

Table 2. Raw Observations by Site

Site	Coordinates	Days/Dates	Observations
Mexicali INECC/City	32°35'08.3"N 115°26'06.8"W	(2) May 30-June 1	14,374
Mexicali Truck W	32°36'48.1"N 115°30'41.8"W	(3) May 23-25	13,019
Mexicali Truck E	32°34'30.3"N 115°20'48.5"W	(3) May 26-28	14,050
Tecate INECC	32°33'17.0"N 116°39'45.6"W	(6) May 3-6; June 2-3	20,876
Tijuana INECC City W	32°30'03.5"N 117°03'33.6"W	(6) April 28-30; May 9-11	23,327
Tijuana INECC City E	32°30'22.1"N 116°57'37.3"W	(2) May 13-14	3,975
Tijuana Truck	32°32'38.8"N 116°51'12.3"W	(6) May 16-21	13,160

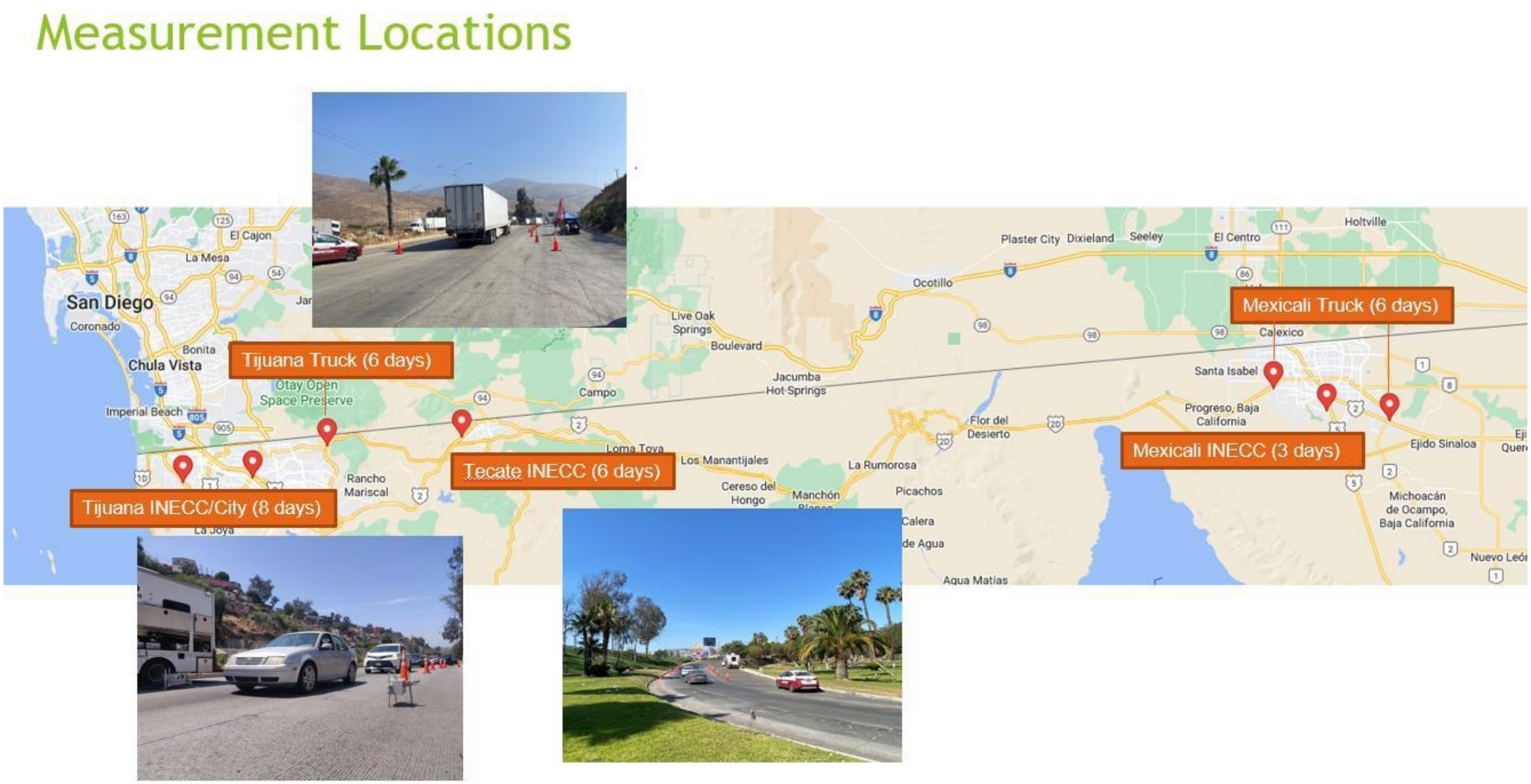


Figure 4. RSD Measurement Sites

6. DATA ANALYSIS

Fleet characteristics

RSD observations were categorized using vehicle classification scheme developed by INECC for prior RSD campaigns (a visual key of INECC categories is shown in Appendix A). Table 3 shows the number of vehicle observations for each INECC vehicle class, along with the associated MOVES-Mexico source type. Note that because the INECC categories are determined through visual observation without the benefit of complete vehicle information, the mapping of these categories to truck weight class and MOVES source types is approximate. For this analysis we defined the categories Auto, Pickup, and SUV to private light-duty vehicles , which accounted for 92 percent of all observations.

Table 3. INECC Vehicle Classification & RSD Observations

INECC Category	MOVES Source Type Mapping	Count of plate	Percent of Total
Auto	Passenger Car (21)	47,661	55.97%
Bus Foraneo (Foreign Bus)	Intercity Bus (41)	170	0.20%
Bus Urbano (Urban Bus)	Transit Bus (42)	110	0.13%
Camion Ligero (Light Heavy Truck)	Single Unit Truck (53)	1,069	1.26%
Camion Mediano (Med. Truck)	Single Unit Truck (53)	397	0.47%
Motorcycle	Motorcycle (11)	115	0.14%
OffRoad	-	48	0.06%
Pick Up	Light Commercial Truck (32)	8,501	9.98%
SUV	Passenger Truck (31)	22,400	26.31%
Taxi	Taxi (22, special to MOVES-Mexico)	1,552	1.82%
Tracto Camion (Tractor Truck)	Combination Truck (61-62)	1,068	1.25%
Van Carga (Cargo Van)	Single Unit Truck (53)	1,505	1.77%
Van Publica (Public Van)	Microbus (44, special to MOVES-Mexico)	546	0.64%
Other	-	9	0.01%
Total		85,151	

For this analysis the INECC categories *Camion Ligero*, *Camion Mediano*, *Tracto Camion, Bus Fornaeo, Bus Urbano, Van Cargo,* and *Van Publica* were defined as heavy-duty trucks/buses/vans. The campaign captured about 2,800 heavy trucks and buses and 2,000 vans. The count of heavy vehicle class by measurement site is shown in Figure 5. Large and medium single unit (box) trucks (Camion Ligero/Mediano) were distributed across most of the sites. Passenger vans (Van Publica) were concentrated in Tijuana City Site 1, and combination trucks (Tracto Camion) were concentrated at the Tijuana Truck site, which was chosen for this purpose.

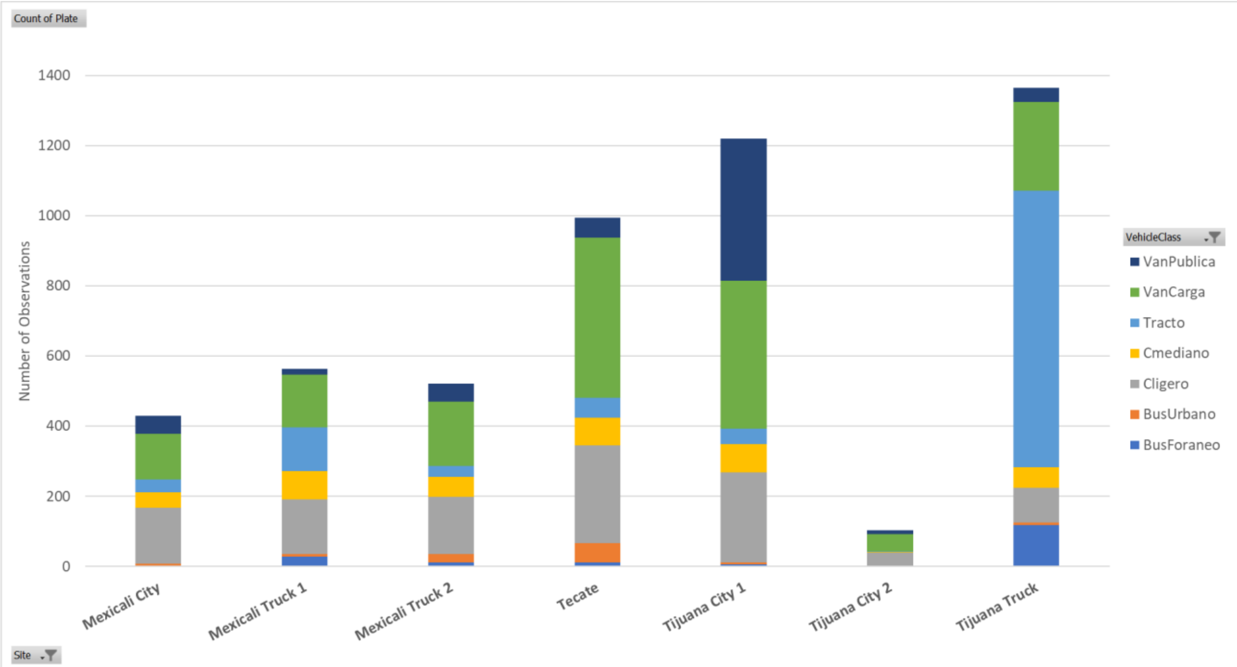


Figure 5. Heavy vehicle counts by measurement site

Emission characteristics

Valid emission readings by vehicle class are shown in Figure 6 (V=valid, X=invalid). Emissions measurement attempts are deemed invalid when the exhaust plume is of insufficient, strength, shape and duration to produce an accurate reading - for example, when a vehicle is coasting by. For light vehicles the valid rate was about 80 percent, which is consistent with Opus' U.S. studies. For tractor trucks it was closer to 30 percent, reflecting the prevalence of high exhaust systems on these trucks whose emissions were not captured.

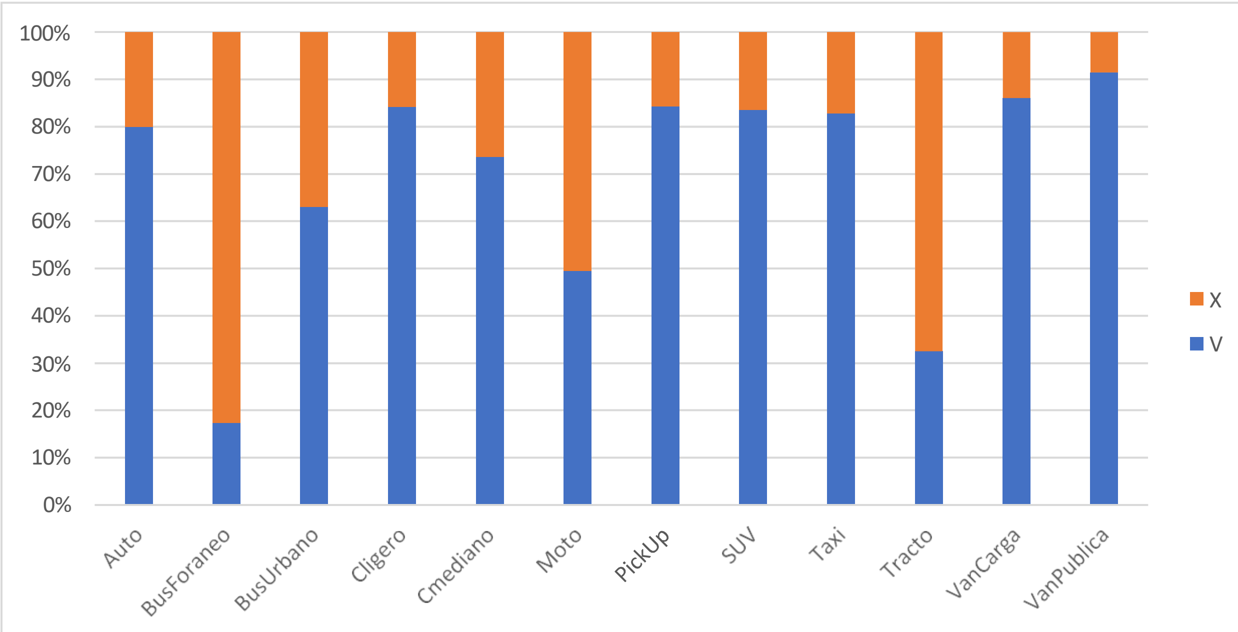


Figure 6. Valid emissions (V) readings by vehicle class

The mean concentrations for HC, CO, NO and Opacity (proxy for PM emissions) are shown in Figure 7 through Figure 10. Superimposed on the HC, CO and NO charts is the average concentration for LD vehicle categories from the 2010 measurements in the three Baja cities taken by INECC (opacity measurements between the two campaigns are not directly comparable). LD emissions in general dropped 50- 70 percent for all three pollutants relative to 2010; HD emissions are not shown for 2010 due to inadequate sample size. This drop may reflect the reduction in gasoline sulfur mandated during this period, as well as fleet turnover to Mexico’s NOM-42 vehicle emission standards.

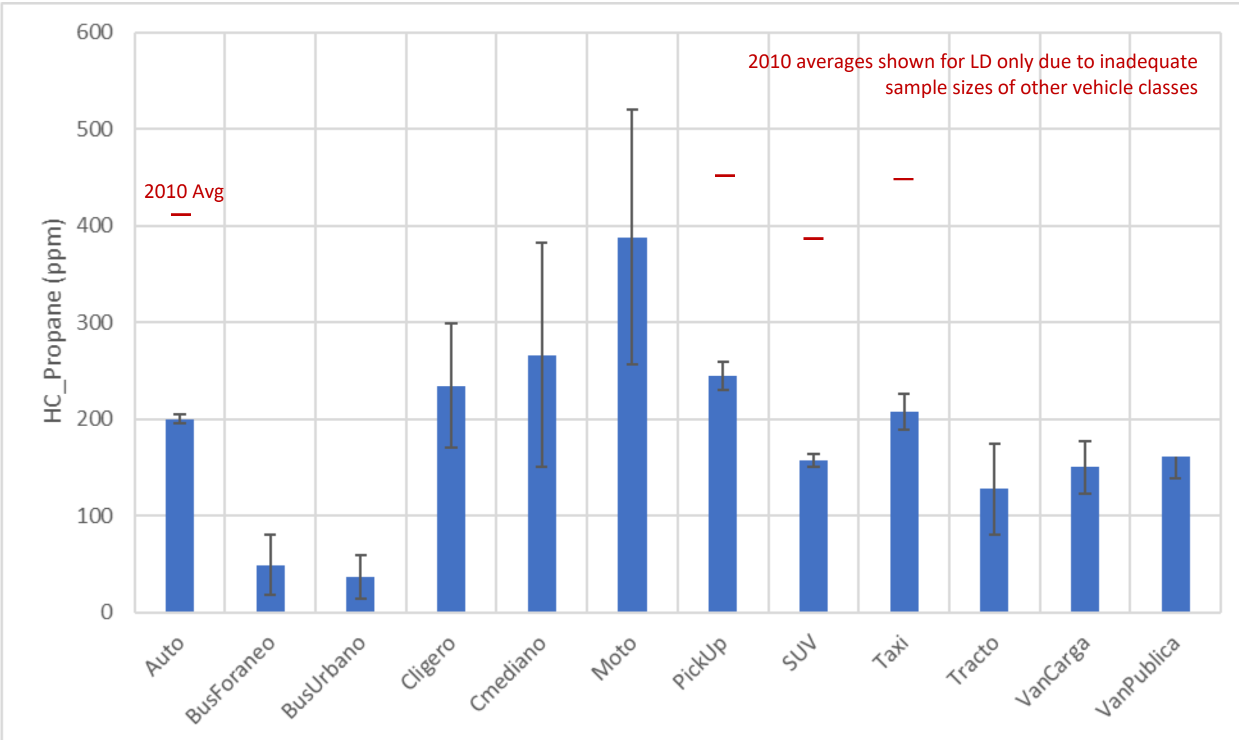


Figure 7. Average HC concentration by vehicle class

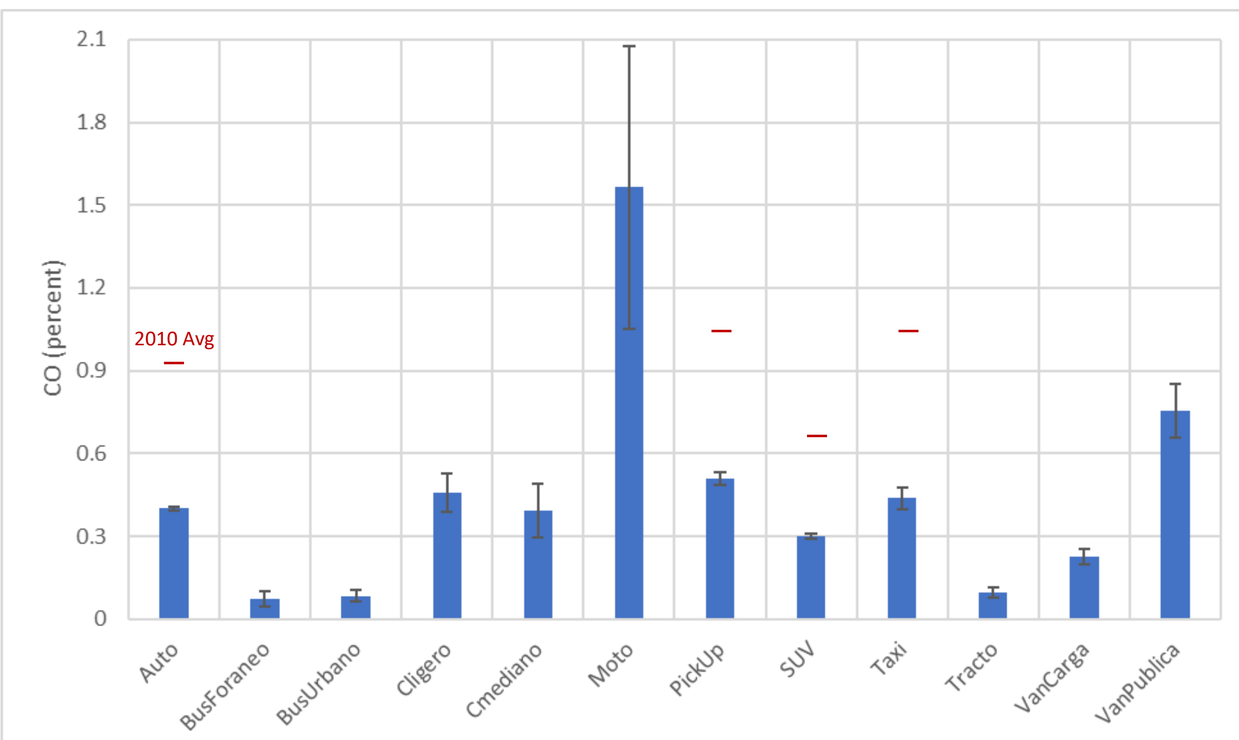


Figure 8. Average CO concentration by vehicle class

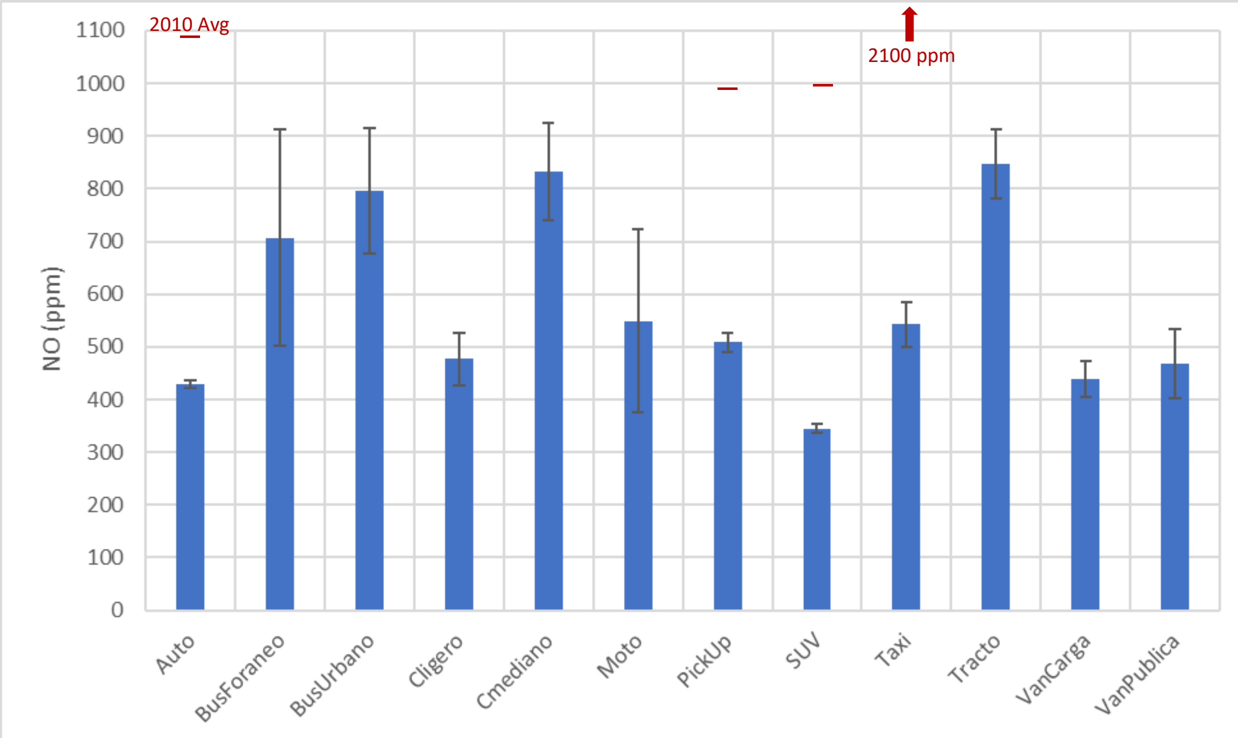


Figure 9. Average NO concentration by vehicle class

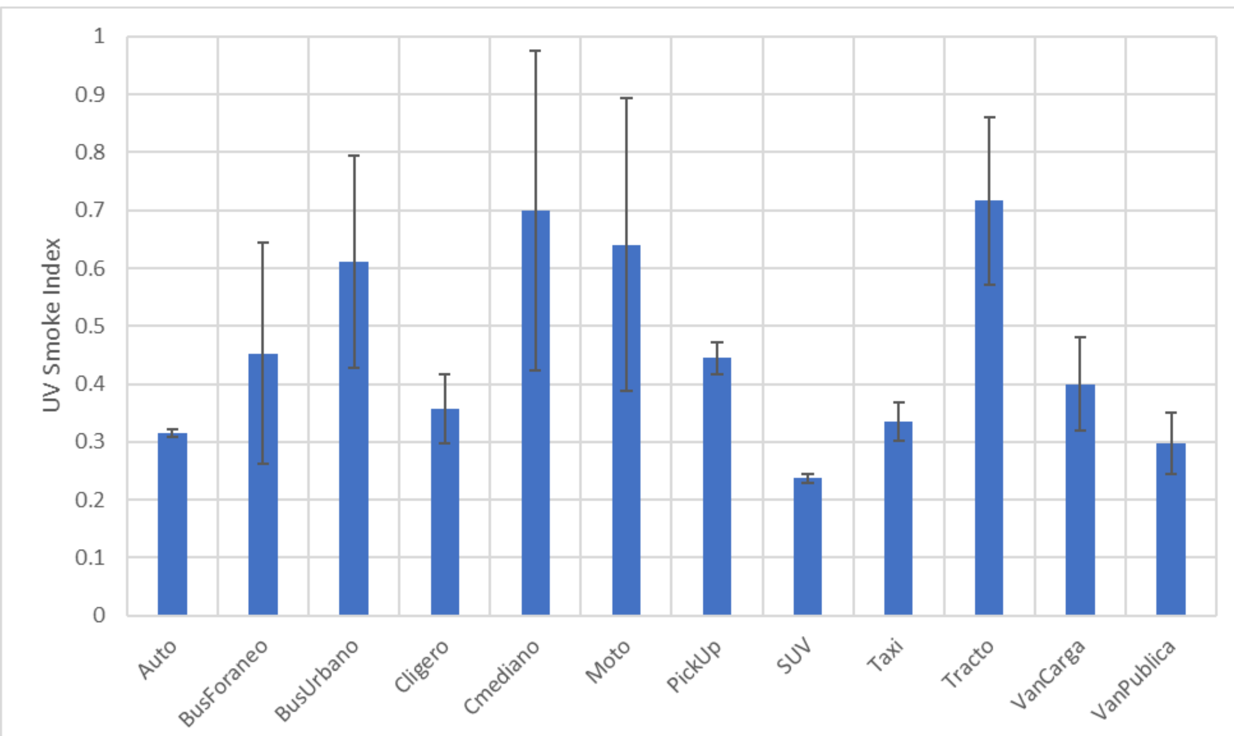


Figure 10. Average Opacity (UV Smoke Index) by vehicle class

Registration data matching

Baja California vehicle registration data was obtained from SMADS. These data provided vehicle information to the RSD observations where plate numbers matched registration records. Registration data also were used as a source for analyzing MOVES vehicle fleet inputs such as vehicle population and age distributions. California plate numbers observed in the RSD were shared with CARB for matching through the California DMV registration database as well. The percent of RSD vehicles that had a match with registration data is shown in Figure 11. Light vehicles had a match rate over 70 percent (except taxis), while buses and heavy trucks had lower match rates. This may be attributable in part to unsuccessful plate reads on these vehicles.

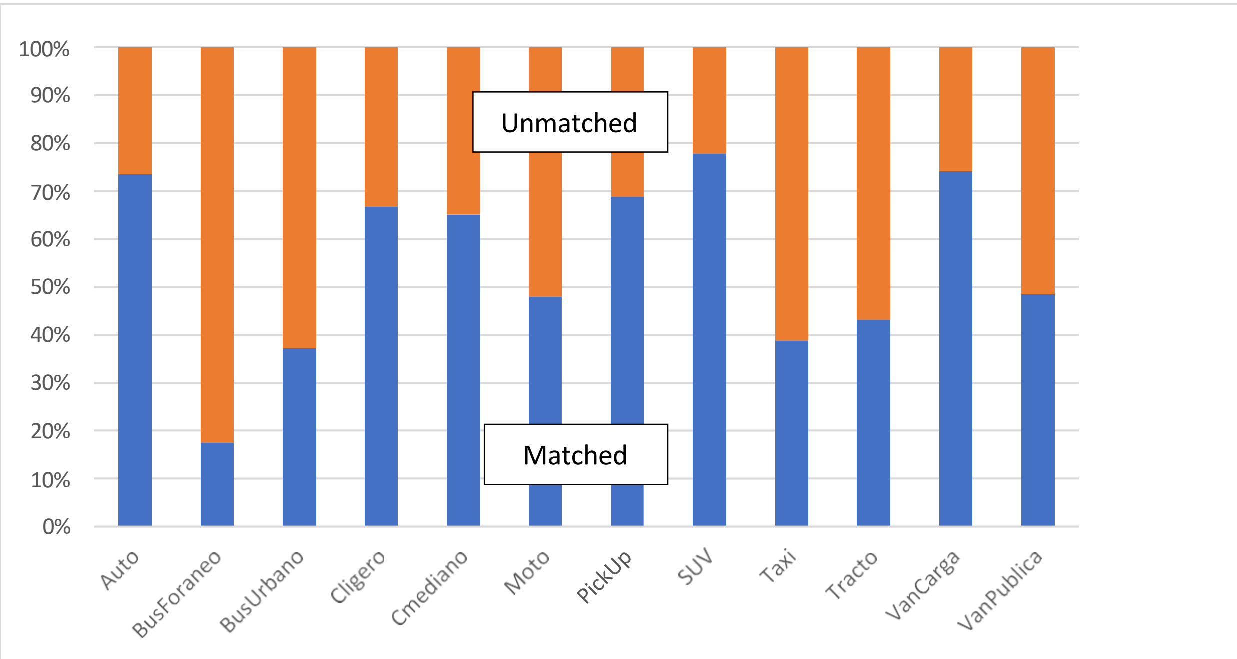


Figure 11. Percent of Baja or California registration database matches by vehicle class

Matched and unmatched groupings were further disaggregated, with a focus on the identification of illegally circulating "Chocolate" vehicles. Any vehicle without a plate match to a current registration on record in either the Baja or California database is a candidate Chocolate vehicle – however, there are also many valid reasons for lacking a match: e.g., being registered in another state, incorrect plate reading, or unreadable plate. For this analysis we made a conservative estimate of Chocolate vehicles based on three criteria:

- California-plated vehicles without a match in the California registration database (~4,600 vehicles). According to the California DMV, vehicle records are dropped from the master DMV database after 4 years, so unmatched California plates were assumed to fall in this category (California DMV, 2022).

- California-plated vehicles with a match in the California registration database, but with a registration code other than "current" and whose last registration was before July 1, 2020 (~8,500 vehicles). These were assumed to be vehicles yet to be dropped from the California DMV database.

- Manual identification of illegal plates distributed by "driver protection" organizations (~ 3,000 vehicles).[3] Examples of vehicle with these plates are shown in Figure 12 (partially obscured for privacy). The plates follow a similar numbering and lettering format different from valid Baja plates, so are generally easy to identify in the database.

Figure 12. Example "Organization" plated vehicles

Vehicles identified as "Chocolate" were predominantly cars and light-trucks (99 percent). For emissions analysis, other vehicles were grouped into three registration categories:

- **Baja California (BC) matches**; legally registered vehicles domiciled in Baja California.
- **California (CA) matches with current registration**; these are legally registered California vehicles considered visiting California vehicles.
- **Other MX/US States**; unmatched vehicle primarily from other Mexico or U.S. states; plates that could not be read by the ALPR system; or vehicles without plates. Visual inspection of these vehicles found that that majority of Mexico-plated vehicles were from Sonora, and the majority of U.S.-plated vehicles from southwestern states (led by Arizona).

The distribution of registration group for the entire sample is shown in Figure 13. Only one-half of the sample was registered in Baja California. 20 percent were identified as Chocolate, 14 percent California registered, and the rest were other unmatched plates. As indicated, nearly 80 percent of the latter category were from other Mexico or U.S. states.

[3] More detail on the driver organizations and plates are found in this article: https://www.sandiegored.com/en/news/138556/ONE-MILLION-ILLEGAL-CARS-CIRCULATE-ON-THE-STREETS-OF-BAJA-CALIFORNIA

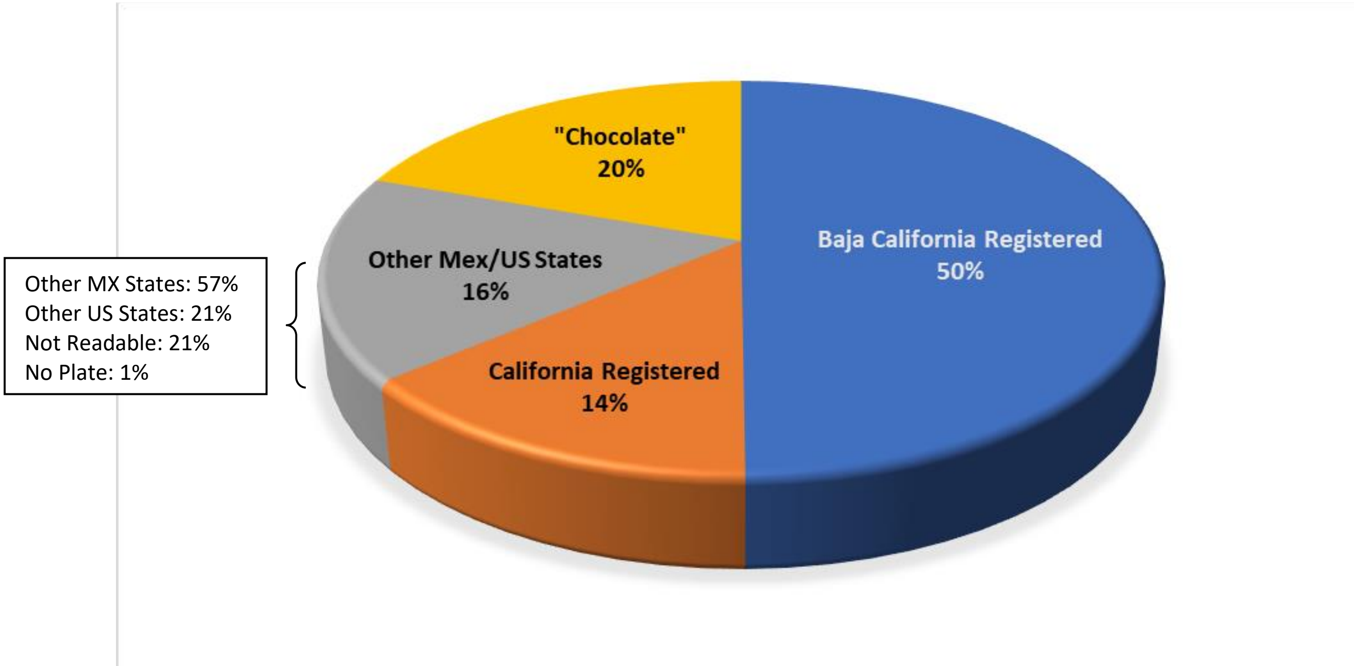


Figure 13. Distribution of RSD sample by registration group

The breakdown of registration group by vehicle class is shown in Figure 14. The highest prevalence of Chocolate and California-registered vehicles are for cars and light trucks (auto, SUV, pickups). Intercity buses (bus forneao) and combination trucks (Tracto), which include long-haul semi trucks, have a high prevalence of vehicles registered in other states.

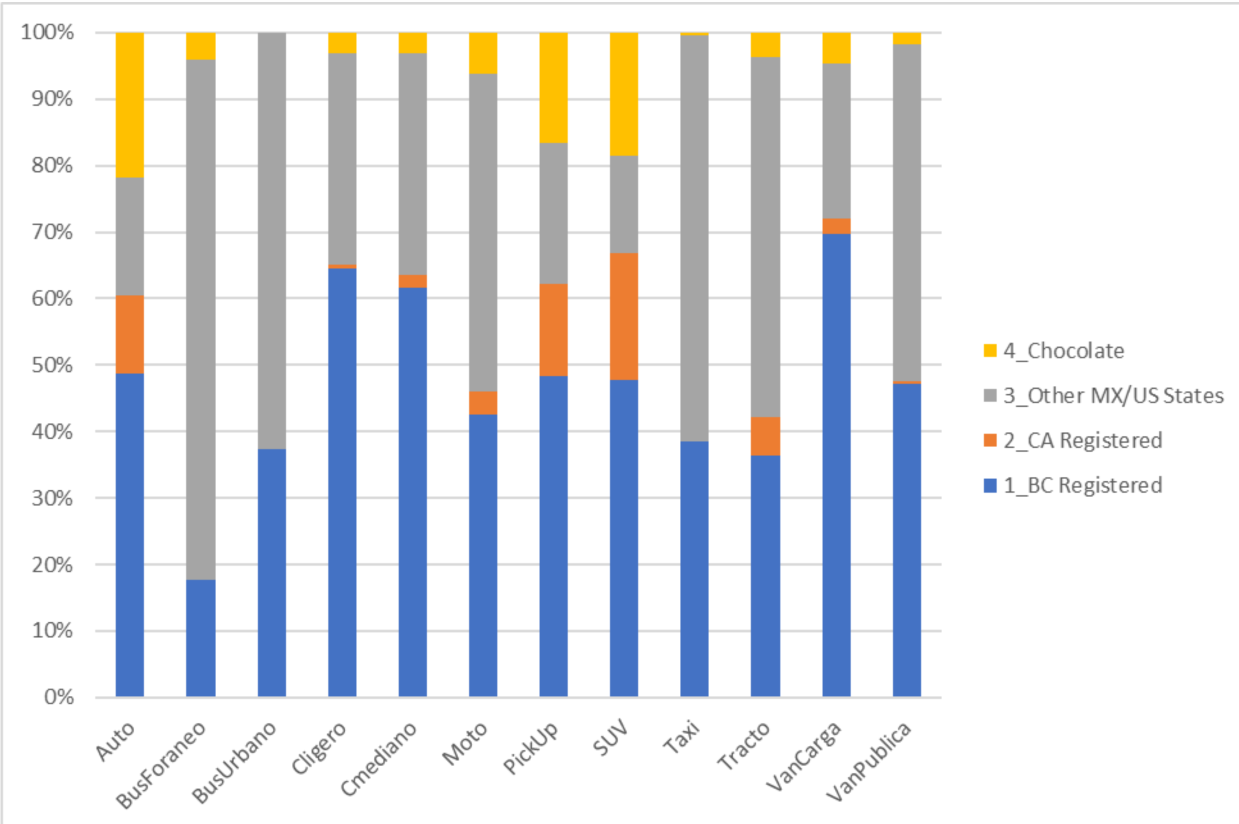


Figure 14. Distribution of registration groups by vehicle class

The distribution of each category for the three cities (Figure 15) shows that Tijuana has the highest rate of valid California registrations, while Mexicali has the highest prevalence of Chocolate vehicles. In particular, over 90 percent of the “organization” plates were observed in Mexicali.

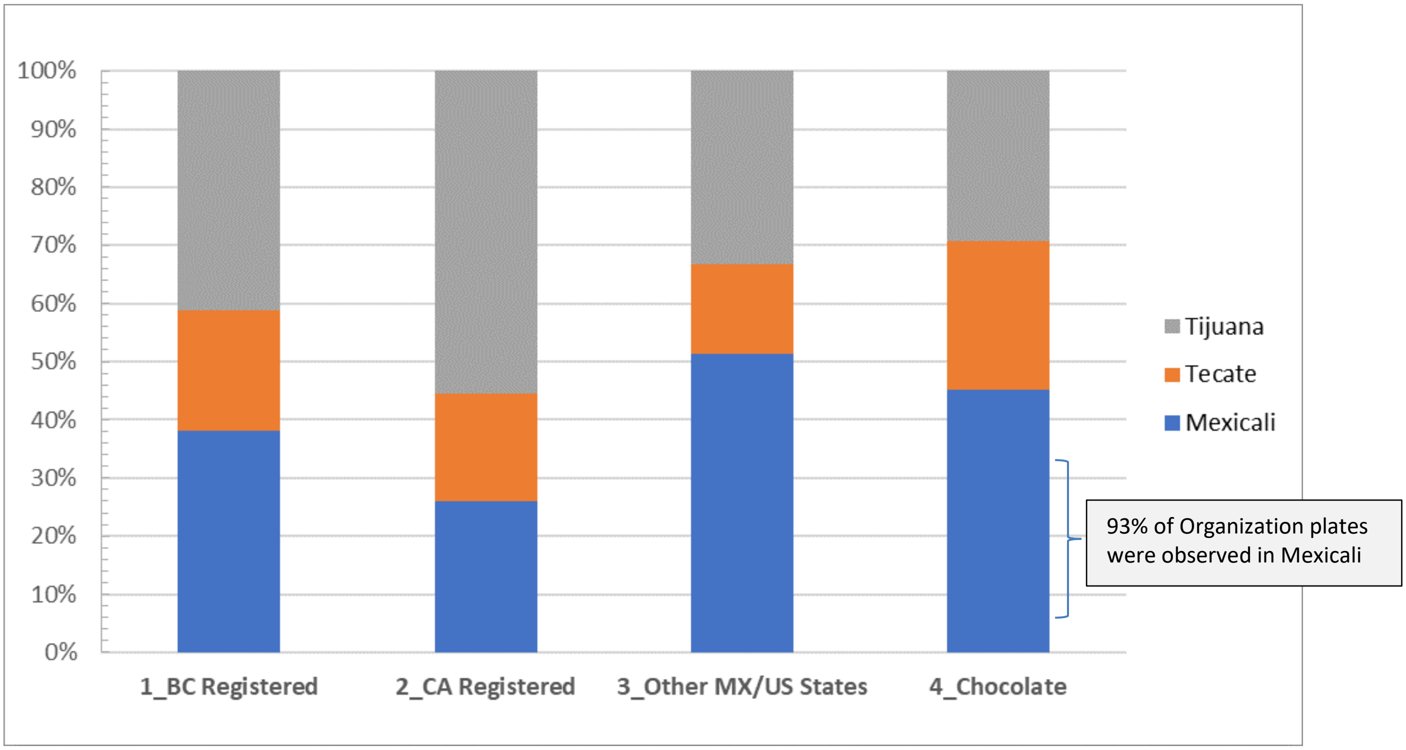


Figure 15. Registration group distribution by city

Emissions by Registration Group

Emissions by registration group were assessed for LD vehicles (cars, SUVs, pickups) as their sample size was large enough to determine significant differences. Average LD emissions for Baja-registered, California-registered, Other MX/US states, and Chocolate vehicles are shown in Figure 16 through Figure 19. The general trend across all pollutants is that California-registered vehicles are 5-15 percent lower than Baja-registered vehicles, with the difference statistically significant for HC and CO. Relative to Baja-registered vehicles, the Other MX/US state group had 1.7-2.1x higher emissions, and Chocolate vehicles were 2.5-3.2x higher.

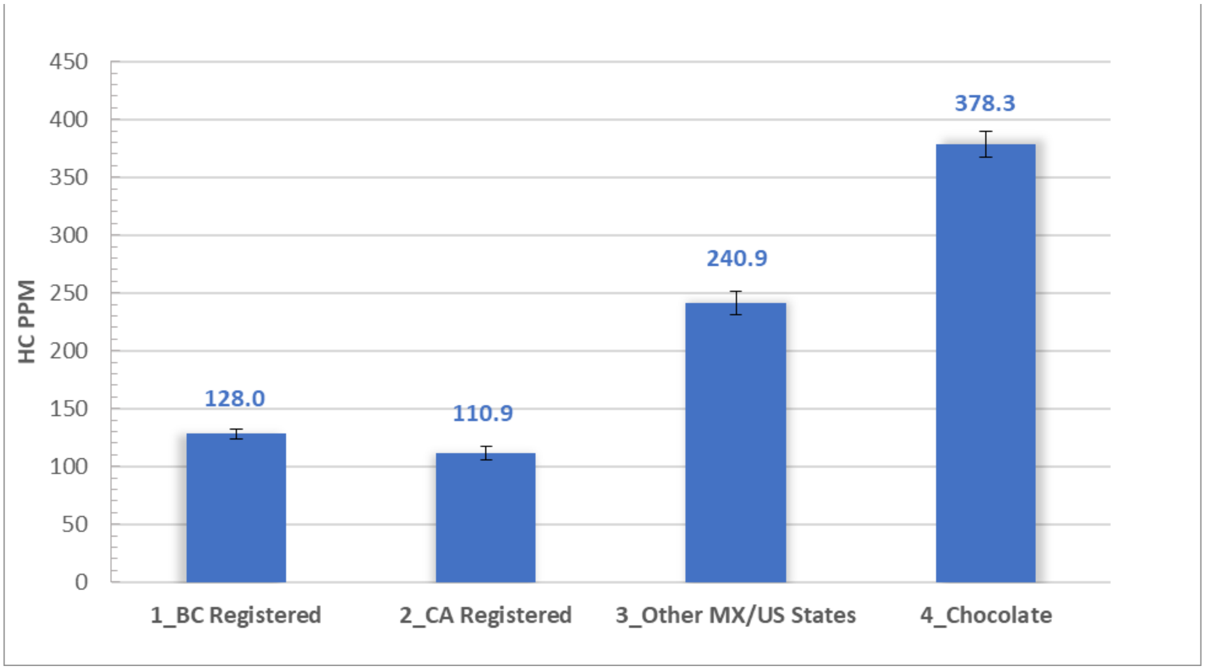


Figure 16. Average HC concentration for LD vehicles by registration group

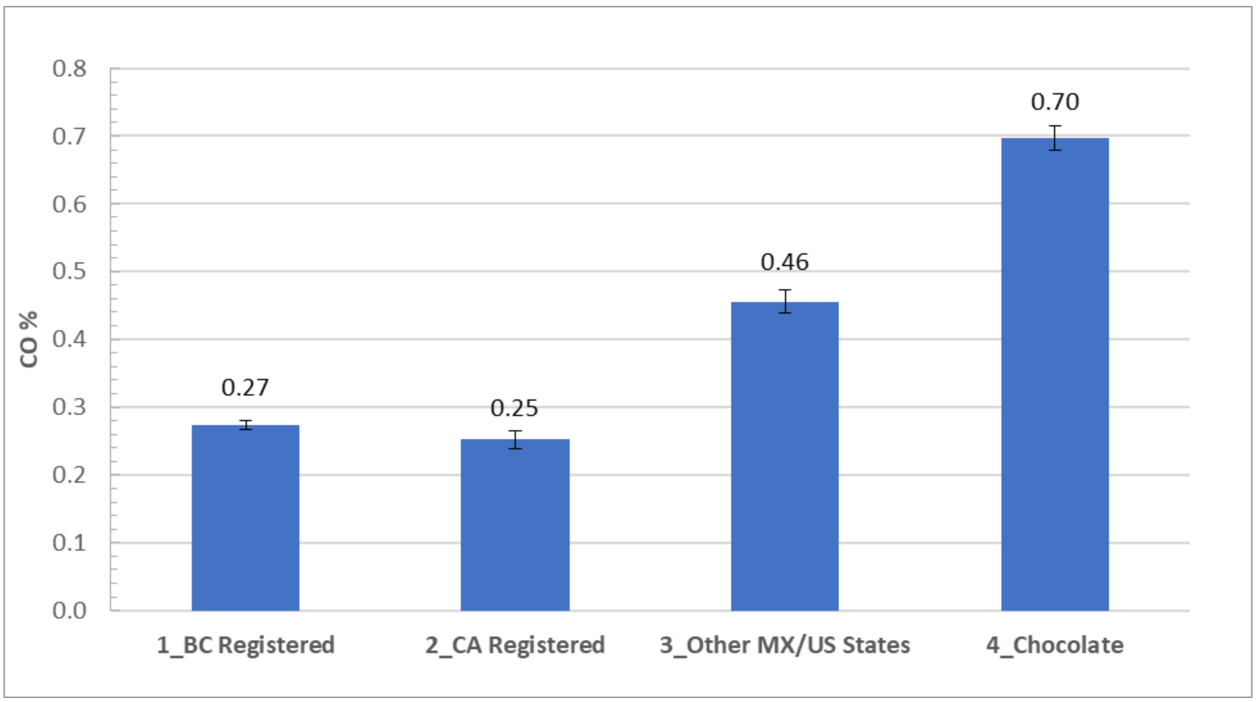


Figure 17. Average CO concentration for LD vehicles by registration group

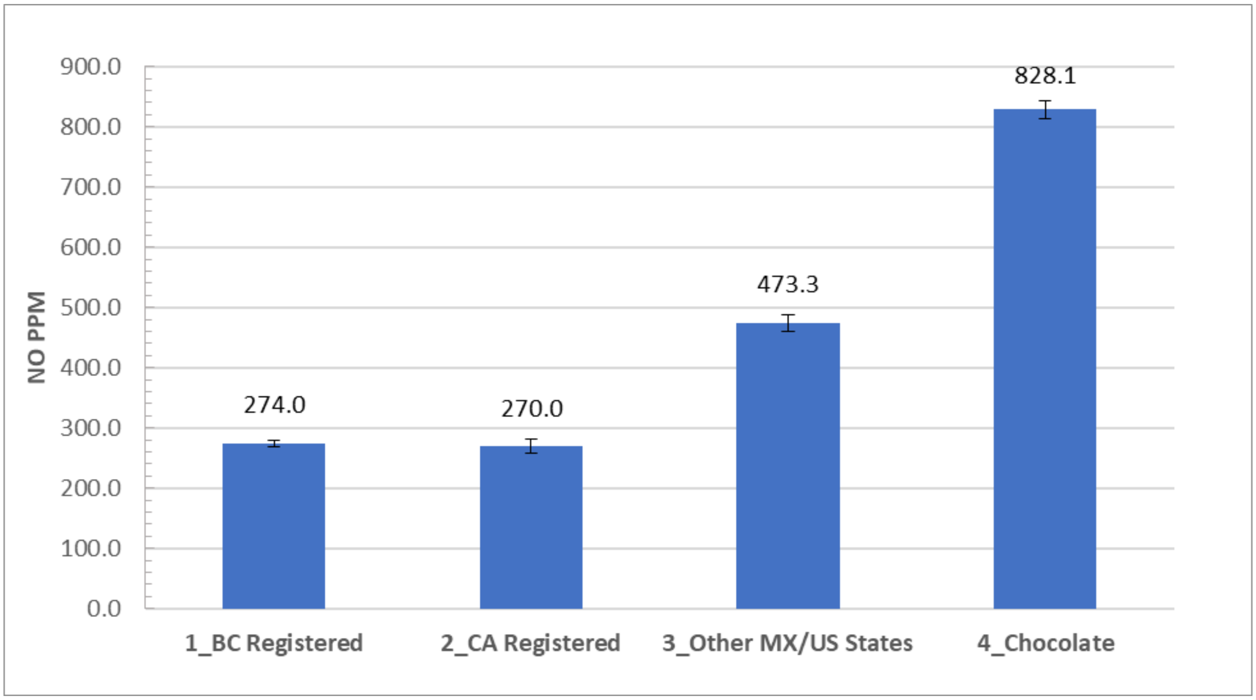


Figure 18. Average NO concentration for LD vehicles by registration group

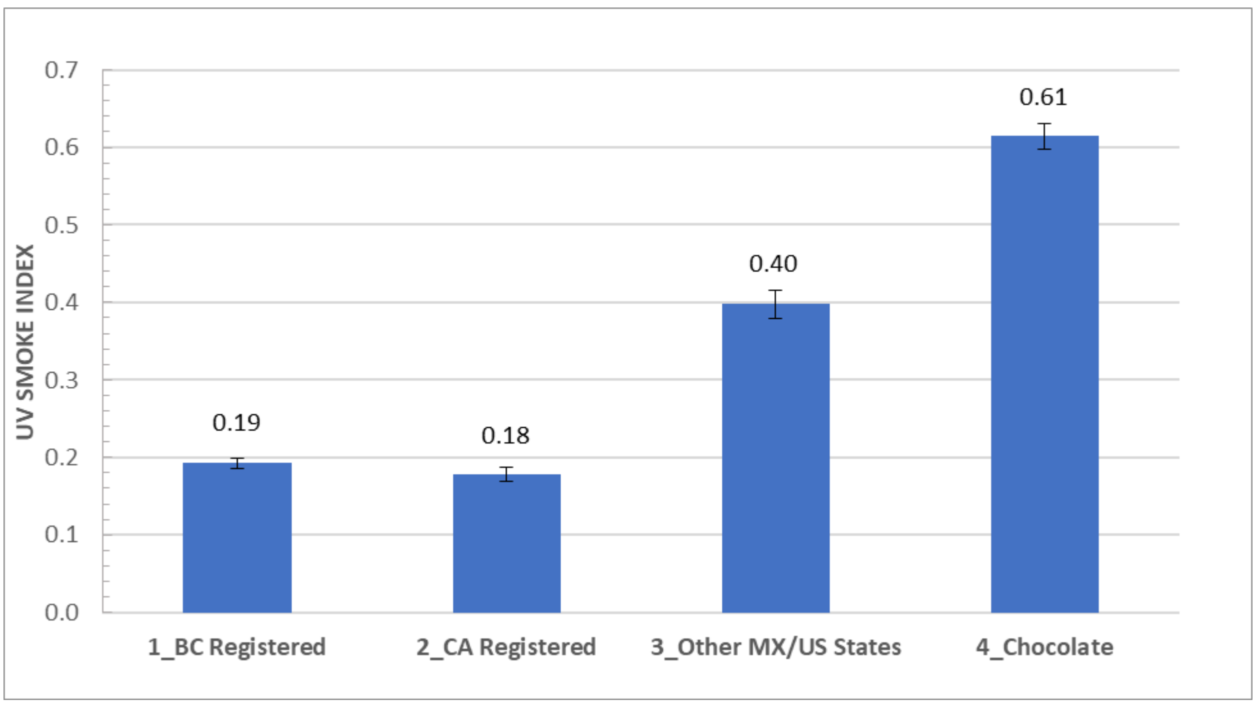


Figure 19. Average Opacity for LD vehicles by registration group

One key reason for the emissions difference between registration groups appears to be the age of the respective fleets. The model year / age distribution could be assessed for vehicles with matched plates, which would include all of the Baja-registered and California-registered vehicles, and the subset of Chocolate vehicles with expired plates still in the California DMV database (Figure 20). The Baja-registered fleet is the youngest, with a median model year of 2015 (age 7). The California-registered fleet has a median model year of 2011 (age 11), while the Chocolate vehicles show a much older distribution, with median model year of 2005 (age 17).

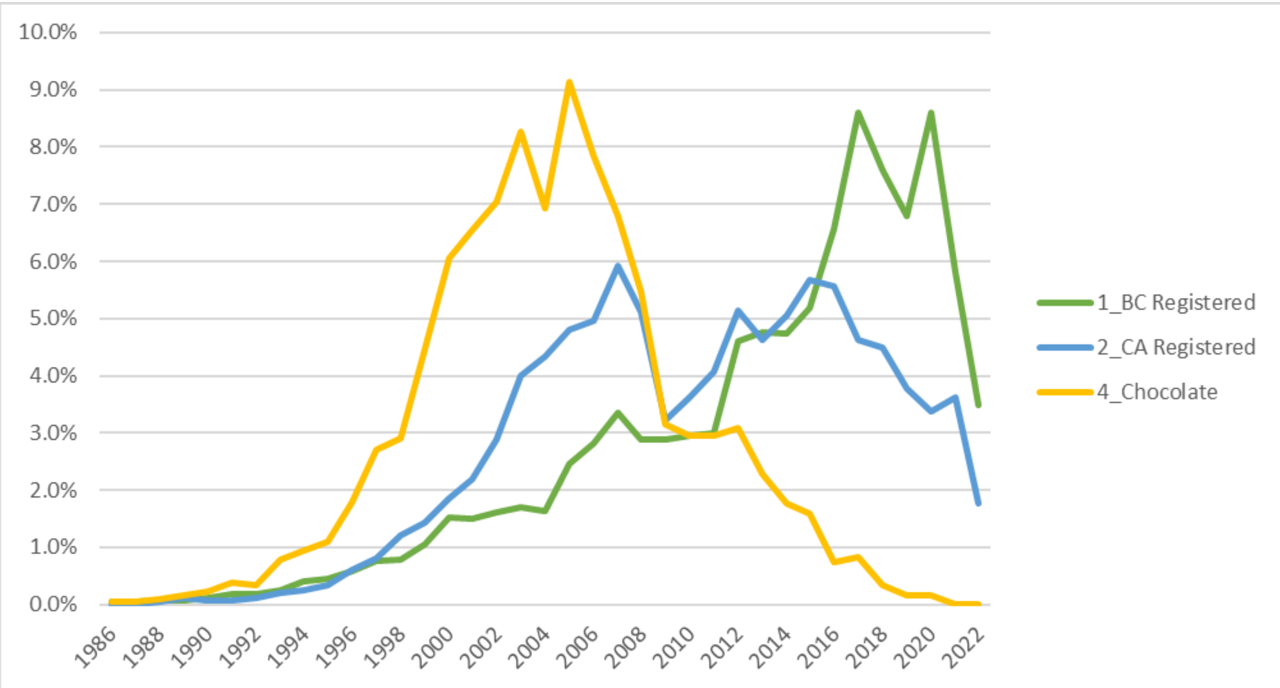


Figure 20. Model year (age) distribution for Baja registered, CA registered, and Chocolate vehicles

Emission Trends by Vehicle Age

Emissions by vehicle age were compared across registration groups to assess if differences still exist when controlling for age. RSD emissions were converted from concentrations to a fuel-specific basis (grams of pollutant per kilogram of fuel)[4] and aggregated by MOVES age groups (0-3 years, 4-5, 6-7, 8-9, 10-14, 15-19, 20+). Conversion to fuel-based rates was done for comparison to RSD emissions measured by INECC in several Mexican cities between 2014-19 that formed the basis of a recent update to MOVES-Mexico (ERG 2022). For the MOVES-Mexico analysis these data were expressed as a range between Mexico City (CDMX), which had the lowest overall emissions in the sample owing to mandatory inspection/maintenance (I/M) programs coupled with a stringent "Hoy No Circula" restrictions on the travel of higher emitting

[4] Expressing RSD on a fuel-specific basis is a common means for comparing across different RSD campaigns, or comparing to mass-based emission inventories.

vehicles;[5] and the average of three cities without these controls (Durango, Monterrey, Saltillo).

The comparison of HC, CO and NO by age between Baja RSD and the CDMX and "No I/M" city RSD averages is shown in Figure 21 through Figure 23 (opacity could not be directly compared due to differences in UV index reporting). Highlights on this comparison are the following:

- Legally registered vehicles in Baja California are generally lower than CDMX. This may reflect six additional years of turnover to cleaner vehicle standards (most CDMX data were gathered in 2015-17), as well as a higher prevalence of Baja California vehicles purchased in the U.S. and complying with U.S. emission standards relative to other parts of Mexico.
- Chocolate vehicle emissions are significantly higher than registered vehicles in the same age range in many cases, especially in the 5-15 year range, though as shown in Figure 20 there are relatively few Chocolate vehicles in this age range. A potential explanation for higher emissions for vehicles over 8 years old (when California Smog Check is required) is that their exit from California was triggered by a failing I/M test, and lack of any sort of maintenance or inspection once in Mexico.
- Chocolate vehicle emissions generally fall within the range of CDMX and No I/M cities, though for HC and CO are also lower than CDMX in the oldest age categories. As the majority of vehicles identified as Chocolate originated in California, this trend may indicate some benefit from early years spent on California's reformulated low-sulfur gasoline and strict inspection/maintenance program.
- California-registered vehicles generally have lower emissions than Baja-registered vehicles across all ages and pollutants.

[5] For more information on Hoy No Circula visit https://en.wikipedia.org/wiki/Hoy_No_Circula

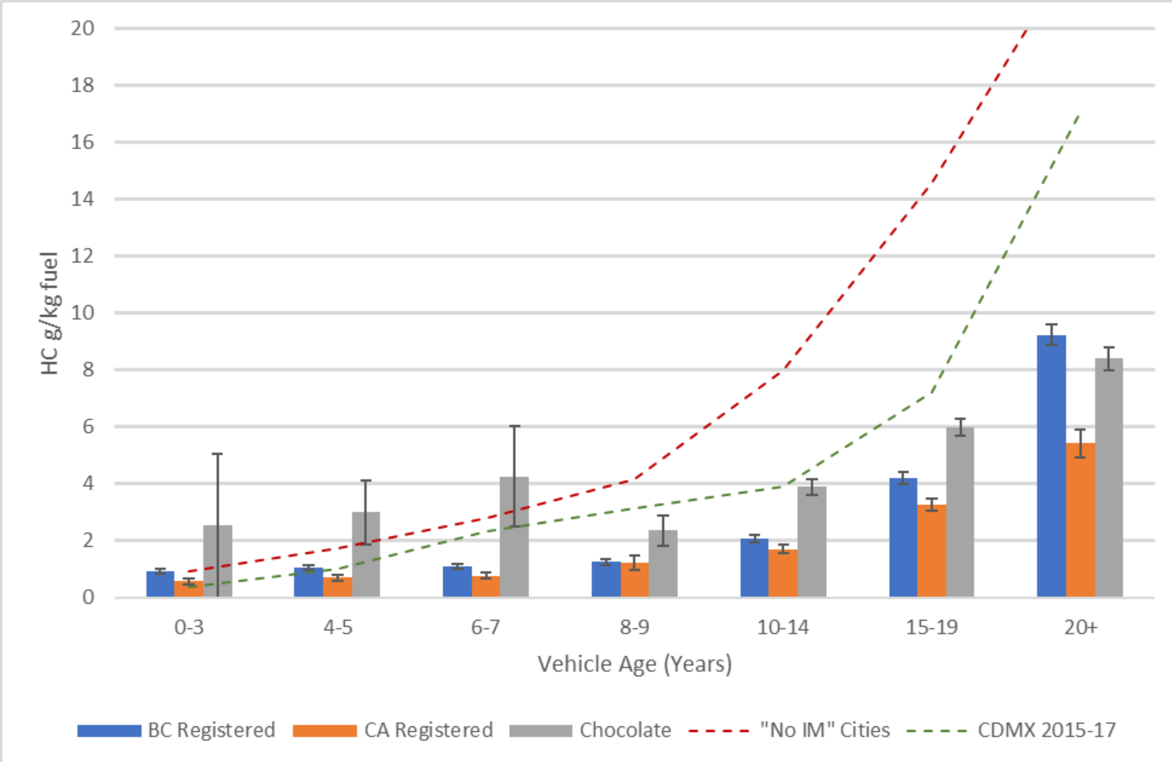


Figure 21. HC emissions by age group for BC-registered, CA-registered, and Chocolate vehicles. Average trends of recent RSD from other Mexican cities superimposed.

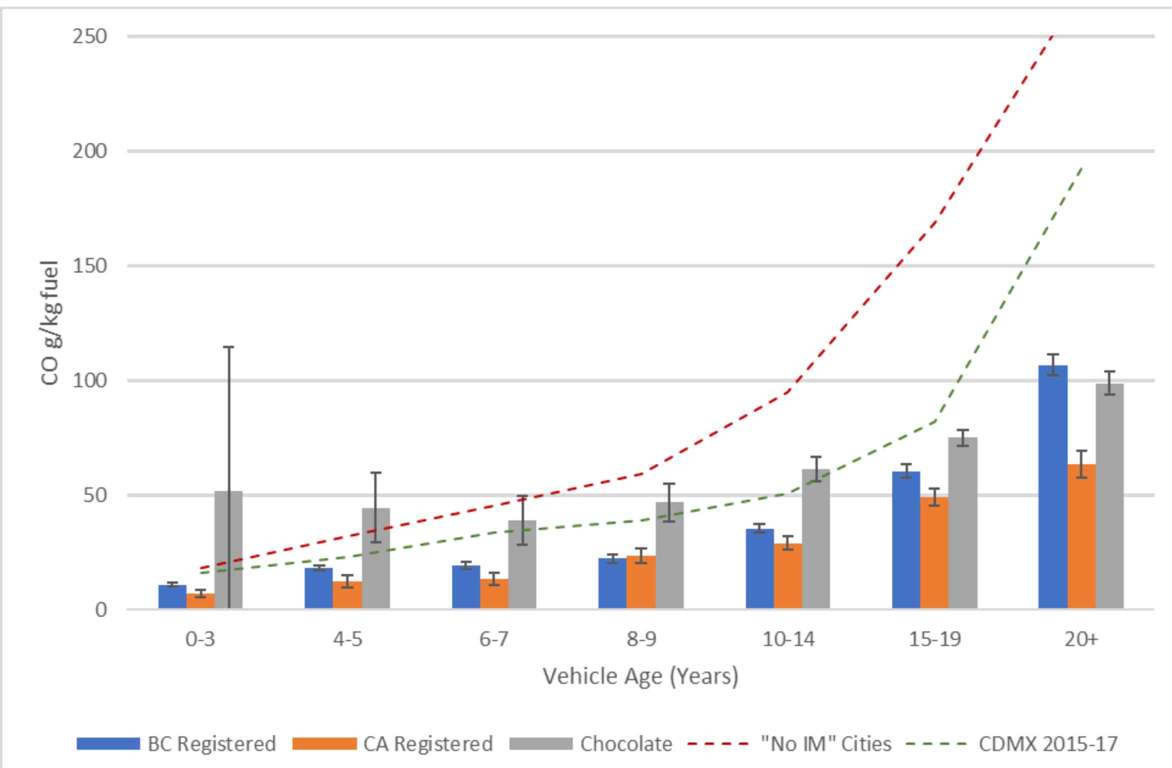


Figure 22. CO emissions by age group for BC-registered, CA-registered, and Chocolate vehicles. Average trends of recent RSD from other Mexican cities superimposed.

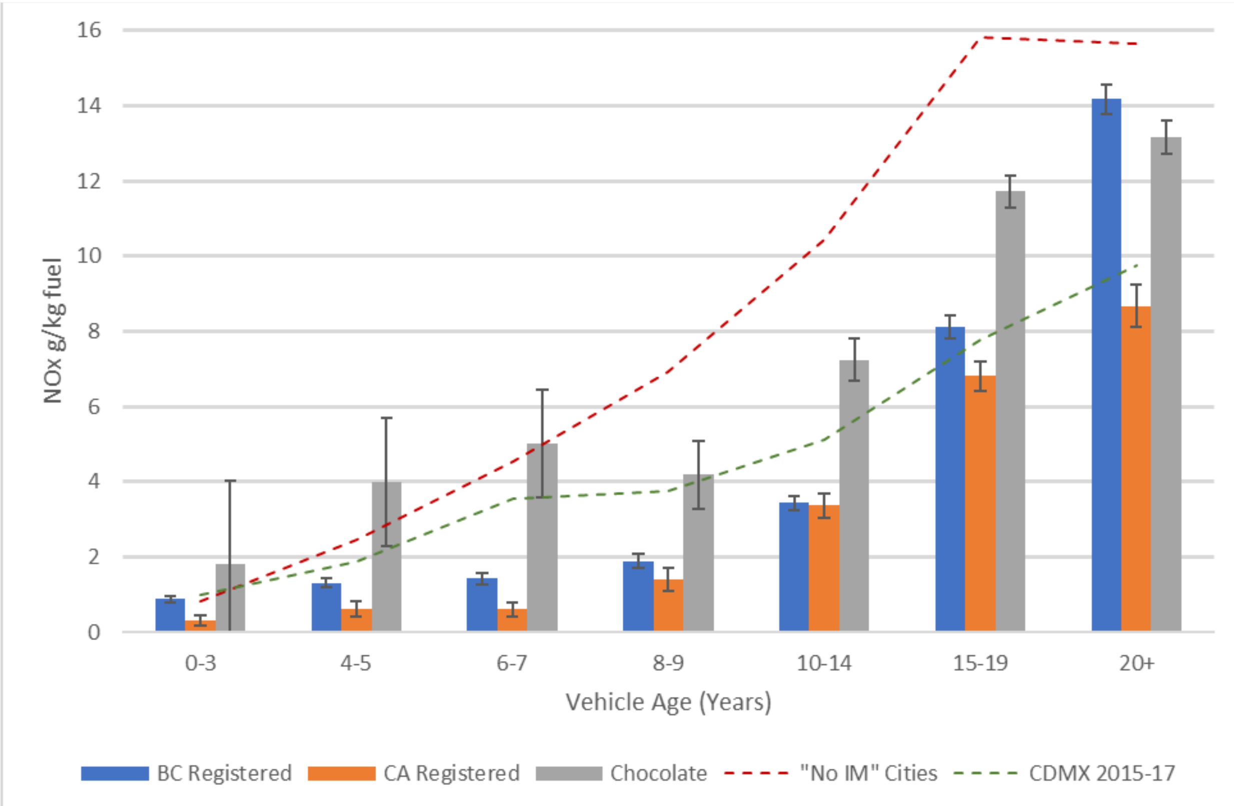


Figure 23. NO emissions by age group for BC-registered, CA-registered, and Chocolate vehicles. Average trends of recent RSD from other Mexican cities superimposed.

Emissions by City

Average LD emissions by city are shown in Table 4. Mexicali has the highest emissions among Baja cities, while Tijuana has the lowest. The fleet makeup of these cities may explain this difference – as shown in Figure 15, Mexicali has the highest rate of Chocolate vehicles, while Tijuana has the highest rate of California-registered vehicles. While fleet age is generally an important contributor to overall emissions, no age difference is evident between the cities; the average age of RSD vehicles in Mexicali and Tijuana is 11 years, vs. 13 years for Tecate.

Table 4. Mean RSD emissions by city for LD vehicles

	HC (ppm)	CO (%)	NO (ppm)	Opacity (UV Smoke)
Mexicali	278.5 ± 7.4	0.49 ± 0.011	488.5 ± 8.8	0.42 ± 0.011
Tecate	185.6 ± 7.2	0.39 ± 0.014	436.5 ±1 1.9	0.28 ± 0.011
Tijuana	116.9 ± 3.7	0.28 ± 0.008	332.4 ± 7.4	0.22 ± 0.008

7. MOVES-MEXICO SENSITIVITY ANALYSIS

MOVES-Mexico is a version of the U.S. EPA's MOVES2014a vehicle emissions model adapted to Mexico (USAID 2016). MOVES-Mexico has the capability to produce comprehensive national vehicle emission inventories, and to provide a framework for users to create detailed regional emission inventories and microscale emission assessments. MOVES was adapted to Mexico based on Mexico national default vehicle fleet and activity data, accounting for significant differences in vehicle emissions standards between Mexico and the U.S. An update was commissioned by CAMe in 2022, led by LT Consulting and supported by ERG. This version incorporates significant updates to emission rates nationwide, based on an analysis of RSD across multiple cities, and extensive updates to vehicle fleet inputs in the Mexico City megalopolis. Vehicle fleet and activity data for Baja California are unchanged from the 2016 version of MOVES-Mexico, however, and remain derived from national averages rather than local data. A sensitivity analysis was conducted to assess how updating MOVES-Mexico with Baja-specific vehicle fleet data would affect Baja California's emissions inventory. To accomplish this, an auxiliary MOVES database for Baja California (**baja_updates_in**) was created to reflect the following updates:

- **Vehicle Population** (MOVES database table *sourceTypeYear*), updated based on Baja registration records supplemented with estimates of Chocolate vehicles from RSD, as well as new source types not included the original model (taxis and microbuses).
- **Vehicle Miles Traveled** (*sourceTypeYearVMT,*) updated based on the updated population estimates and supplemented further with estimate of vehicles visiting (or passing through) from other states from RSD.
- **Age Distribution** (*sourceTypeAgeDistribution*), updated based on RSD observations and accounting for different profiles for registered vs. Chocolate vehicles.

These updates are detailed in the following section.

Vehicle Population & VMT

Baja California registration records for 2022 were compiled by SMADS from state and federal registration agencies (for a full list see Section 9), and provided to our team for this analysis. The registration records were mapped to MOVES source types which is prone to some uncertainty as the registration doesn't provide all detail necessary to distinguish between an intercity bus and transit bus, a passenger truck from light commercial truck, single unit vs. combination and short haul vs. long haul. The comparison in Table 5 shows total population in source type groups (aggregates of MOVES source types) across Baja California. MOVES-Mexico defaults are based on national population totals allocated to Baja California based on human population, and do not reflect actual Baja registration data. Raw registration counts are about 260,000 vehicles less than the MOVES-Mexico default estimate, with the biggest difference in motorcycles and lights trucks. These counts do not account for Chocolate vehicles or visiting vehicles, however.

Table 5. Baja Raw Registration Counts (2022)

Source Group	MOVES-Mexico Default	Raw Reg. Counts
Motorcycle	71,006	37,870
Passenger Car	751,975	826,183
Taxi	-	23,521
Light Truck	552,180	236,103
Bus	10,543	9,251
Microbus	-	2,173
Metrobus	-	-
Single Unit Truck	38,350	4,899
Combination Truck	13,917	24,990
Grand Total	**1,437,971**	**1,164,990**

Baja registrations records showed a significant fraction of vehicles aged 30 years or older: 10 percent of LD vehicles and over 30 percent of HD trucks in the registration database were over 30 years old. This does not align with RSD observations, where less than 5 percent of the sample is over 30 years old. We suspect this discrepancy is due to obsolete registration records for vehicles no longer in circulation. These records remain in the registration database until an owner goes through an administration process to request removal from the database. Since there is no incentive or enforcement to do so when a vehicle is scrapped rather than sold, obsolete records build up in the registration data (LT Consulting 2022). We therefore developed updated population estimates to drop assumed obsolete records, and to account for Chocolate vehicles as follows:

1. Since RSD found a low prevalence of vehicles on-road over 30 years old, these vehicles were dropped from raw registration counts. This removed 125,530 vehicles from the registration-based population.

2. Added an estimate of Chocolate vehicles, assumed native in the area. This was estimated by multiplying adjusted registration counts from Step 1 by a "Chocolate Vehicle Factor" = ratio of (Chocolate Vehicles : Registered Vehicles) from the RSD, by source type. This added 418,881 vehicles to the population

Updated population estimates by MOVES source type (disaggregated from Table 5) are shown in Table 6. The updated population estimates were loaded in *SourceTypeYear* table in the **baja_update_in** database.

Table 6. Vehicle Population Update (2022)

Source Type	Age<30 Reg Counts	Chocolate Vehicle Factor	Updated Population
Motorcycle	37,199	1.14	42,513
Passenger Car	758,888	1.45	1,098,114
Taxi	23,521	1.00	23,521
Passenger Truck	140,282	1.39	194,444
Light Commercial Truck	49,288	1.35	66,303
Intercity Bus	5,736	1.23	7,074
Urban Bus	3,515	1.00	3,515
School Bus	0		-
Microbus	2,173	1.04	2,257
Metrobus	0		-
Refuse	0		-
Motorhome	0		-
Single Unit Short Haul Truck	2,997	1.05	3,145
Single Unit Long Haul Truck	0		-
Combination Short Haul Truck	7,930	1.10	8,727
Combination Long Haul Truck	7,930	1.10	8,727
Total Population	**1,039,460**		**1,458,341**
		Chocolate vehicle total:	**418,881**

The population estimates from Table 6 were in turn used to update VMT inputs for Baja California. MOVES-Mexico default VMT estimates are the product of (Vehicle Population x Annual Mileage). Baja-specific VMT was estimated the same way using the updated population from Table 6 and default annual mileage by source type provided by INECC for MOVES-Mexico (Table 7). VMT from vehicles visiting/passing-through was then added via a multiplicative "visiting vehicle factor" calculated as the ratio of (All Vehicles: Resident Vehicles) from the RSD, by source type ("Resident Vehicles" are Baja-registered + Chocolate). The underlying assumptions with this approach are that a) Chocolate vehicles accrue mileage at the same rate as registered vehicles; b) the rate of visiting vehicles observed in the RSD will continue year-round; and c) daily mileage accrued in Baja for a visiting vehicle will equate to daily VMT for a resident vehicle (e.g. 27.2 miles per day for autos), meaning VMT will scale according to the rate of visiting vehicles observed in the RSD. For intercity bus and long haul combination trucks no "visiting vehicle factor" was applied; it was assumed that their annual VMT did not all occur in Baja, but was made up for my visiting trucks travelling in the area. The resulting VMT (Table 7) was input into the *SourceTypeVMTYear* table in the **baja_input_in** database.

Table 7. Vehicle Miles Travelled Update (Annual 2022)

Source Type	Population	Annual VMT	Visiting Vehicle factor	Updated VMT
Motorcycle	42,513	17,917	2.05	1,564,230,983
Passenger Car	1,098,114	9,943	1.42	15,488,365,157
Taxi	23,521	43,579	1.00	1,025,022,325
Passenger Truck	194,444	10,648	1.51	3,122,598,860
Light Commercial Truck	66,303	10,648	1.54	1,087,618,788
Intercity Bus	7,074	29,031	1.00	205,365,006
Urban Bus	3,515	29,031	2.68	273,808,363
School Bus	-			-
Microbus	2,257	29,031	2.04	133,505,226
Metrobus	-			-
Refuse	-			-
Motorhome	-			-
Single Unit Short Haul Truck	3,145	24,809	1.42	110,487,000
Single Unit Long Haul Truck	-			-
Combination Short Haul Truck	8,727	40,973	2.50	894,387,530
Combination Long Haul Truck	8,727	91,139	1.00	795,410,873
Total				**24,700,800,109**

Age Distribution

Because of obsolete records in the Baja registration database, RSD was judged more representative of on-road vehicle age distribution and used to update the Baja inputs for MOVES-Mexico. LD source types were compiled as a weighting of registered vehicles (combined Baja and California from Figure 20), and Chocolate vehicles (using the subset of Chocolate vehicles with model years via California DMV). The weighting factors were based on the prevalence of Chocolate vehicles in the RSD: 20 percent for cars, and 18 percent for trucks. The resulting age distributions were input into the *SourceTypeAgeDistribution* table in **baja_update_in.** The median ages of these distributions are shown in Figure 24, compared to MOVES-Mexico defaults. For LD vehicles the median age of the registered (BC and CA), Chocolate, and weighted distributions are shown (the latter were used for the sensitivity analysis inputs). Overall, the LD median ages align well with the MOVES-Mexico defaults, but motorcycles, buses and heavy trucks are much younger than the defaults. The median age of 1.8 years observed for motorcycles is consistent with a low median age for the registration data, even considering the possible presence of obsolete records (3.5 years). This is attributed to the rapid market growth and affordability of new motorcycles in Mexico.[6]

[6] https://www.motorcyclesdata.com/2023/02/03/mexico-motorcycles/

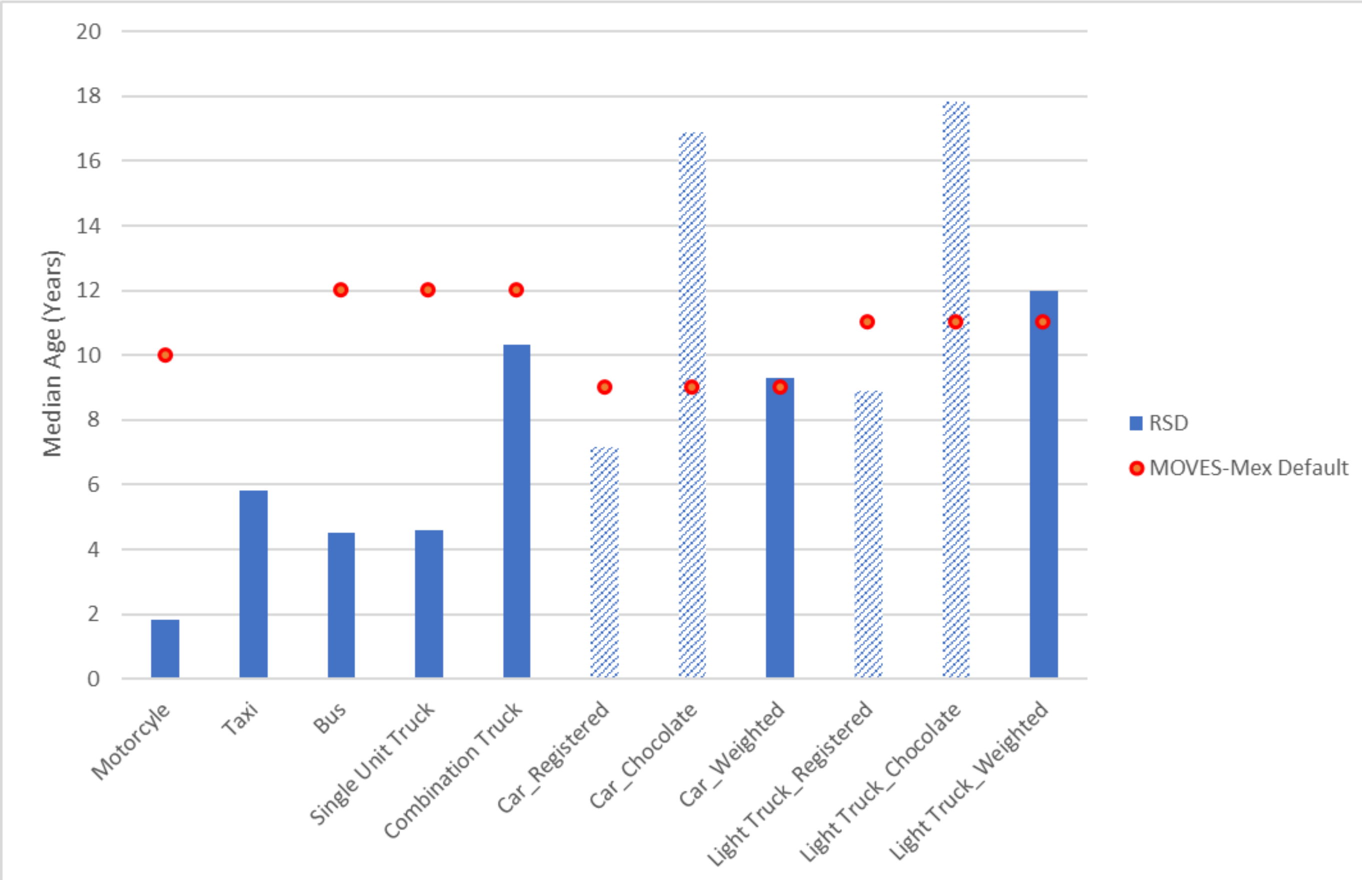


Figure 24. Median age for updated age distributions

Model Runs and Results

To assess the impact of these updates on Baja California emissions inventory, MOVES-Mexico was run to generate annual Baja California emissions for 2022 with default inputs and with the updates detailed above. The run specifications are shown in Table 8.

Table 8. Sensitivity Analysis Parameters

Input	Parameter
Scale	National
Geography	5 Baja California municipios (Tijuana, Tecate, Mexicali, Ensenada, Rosarito)
Time Scale/Year	Annual / 2022
	For evaporative VOC, single-day January/July runs were scaled to annual to reduce model execution time
Emissions	VOC, CO, NOx, Direct PM2.5
Vehicles/Fuels	All
Scenarios	MOVES-Mexico 2022 Beta Default
	MOVES-Mexico 2022 Beta with Baja Inputs (baja_input_in)
	MOVES-Mexico 2022 Beta with isolating Chocolate vehicles (baja_chocolate_in)

The third scenario shown was run with only Chocolate vehicles to quantify the contribution of these vehicles to total inventory.

Resulting annual emissions for the two scenarios are summarized in Table 9. The Baja updates increased emissions from 14 percent for VOC to over 50 percent for NOx. Chocolate vehicles contribute about 1/3 of total motor vehicle emissions in Baja.

Table 9. Sensitivity Analysis Results: 2022 onroad emissions in Baja California

	MOVES-Mexico Default	MOVES-Mexico Updated Inputs	Percent Change	Chocolate Vehicle Contribution
CO	621,082	759,673	+22%	28%
NOx	445,463	674,513	+51%	30%
VOC	78,684	89,783	+14%	23%
$PM_{2.5}$	2,958	3,796	+28%	35%

Conducting the MOVES-Mexico sensitivity analysis on the final 2022 version (not complete at the time of this publication) to account for the emissions comparison between Baja California, CDMX and No I/M cities.

8. CONCLUSIONS & AREAS FOR FURTHER RESEARCH

Roadside remote sensing measurements taken on over 85,000 vehicles in the Baja California border region found that about one-half of vehicles circulating in the area are either illegal "Chocolate" vehicles, or domiciled in the U.S. or other Mexican states. Average fleet emissions for cars and light trucks showed significant drops of 50-70 percent from observations taken in 2010, likely influenced by the introduction of low sulfur gasoline and fleet turnover to vehicles complying with Mexico's NOM-42 emission standards. Despite an overall drop in emissions, wide disparities were observed between legal and illegal vehicles in the 2022 observations. Plate matching with registration data found that legally registered Baja California vehicles are relatively young, with the average emissions of these vehicles within 5-15 percent of the fleet average emissions for legally registered vehicles visiting from California. Conversely, Chocolate vehicles showed a median age of 17 years and emit at a rate roughly three times higher than legally registered vehicles. Though high emissions of Chocolate vehicles are driven by their older age, their emissions are also generally higher than registered vehicles when compared at the same age.

Emissions for legally registered vehicles in Baja are lower than RSD emissions measured in several Mexican cities between 2014-19 that formed the basis of a recent update to MOVES-Mexico. This may reflect additional years of turnover to cleaner vehicle standards, as well as a higher prevalence of U.S. vehicles certified to tighter U.S. emissions standards in the border region relative to other parts of Mexico. Chocolate vehicle emissions generally fall within the range of other Mexico cities, though for HC and CO are also lower than other Mexico cities in the oldest age categories. As the majority of vehicles identified as Chocolate had California plates, and appear to have been registered in California at one time, this trend may indicate some benefit from early years spent on California's reformulated low-sulfur gasoline and strict inspection/maintenance program before moving into Mexico.

A sensitivity analysis conducted with MOVES-Mexico found that Baja California's vehicle emissions inventory is estimated to increase 14 percent for VOC, 22 percent for CO, 28 percent for $PM_{2.5}$ and 51 percent for NOx when updating from default inputs to fleet inputs derived from the RSD and registration data. Vehicle populations were updated to account for Chocolate vehicles; VMT was updated accordingly, and to also add travel from vehicles from outside Baja California. Our analysis finds that, as a whole, emissions have dropped substantially in the border region over the past decade, and that legally registered are lower on average than other Mexican cities, perhaps benefitting from U.S. vehicles built to more stringent emission standards. However, these gains are undermined by a large number of illegal vehicles which are old and evade emissions. Chocolate vehicles are estimate to account for about one-third of annual on-road emissions in Baja California, providing an opportunity for emissions reduction via stricter enforcement and monitoring of vehicles circulating illegally.

These findings raise a number of questions that are candidates for further research, including:

- Trends in Chocolate vehicle prevalence and emissions over time, which could be assessed by matching 2010 RSD data to California and Baja California registration data from 2010 to determine which plates were expired at that time;
- The prevalence of U.S.-certified vehicles registered in Baja California compared to non-border areas, which could be assessed with analysis of vehicle sales, registration or import records;
- The prevalence and emissions of Chocolate vehicles in other Mexican cities (especially at the border), which could be assessed with RSD measurement and registration matching;
- The drivers of higher emissions in Mexicali, and air quality/health implications;
- The effect of recent policies to regularize Chocolate vehicles in Baja California;
- The influence of factors such as vehicle operation, meteorology etc. on emissions variability.
- Emissions of Mexican tractor trucks with high exhaust stacks, which were excluded from this program due to logistical limitations.

9. ACKNOWLEDGEMENTS

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- Secretaría de Infraestructura, Comunicaciones y Transportes Gobierno de México
- Secretaría de Hacienda Gobierno del Estado de Baja California
- Secretaría de Medio Ambiente y Desarrollo Sustentable Gobierno del Estado de Baja California
- José Andrés Aguilar Gómez, Instituto Nacional de Ecología y Cambio Climático
- Secretaría de Medio Ambiente y Recursos Naturales Gobierno de México

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APPENDIX A : INECC VEHICLE CLASSIFICATIONS

ANEXO 1. CATÁLOGO DE CLASIFICACIÓN VEHICULAR

Clave	Tipo de vehículo	Ejemplo
A1	AUTO DE PASAJEROS (De uso particular)	
A2	SUV (Vehículo utilitario de uso particular)	
A3	PICK UP (Usos varios)	 
A4	TAXI (Varios tipos de vehículo)	
A5	VAN (Particular carga)	
A6	VAN (Colectivo)	

Clave	Tipo de vehículo	Ejemplo
B1	MICROBÚS (Servicio de pasajeros)	
B2	AUTOBÚS URBANO (Servicio de pasajeros local)	
B3	AUTOBÚS DE TURISMO (Foráneo)	
C1	CAMIÓN LIGERO (Doble rodada)	
C2	CAMIÓN MEDIANO (Torton)	
C3	CAMIÓN PESADO (Tractocamión)	

Clave	Tipo de vehículo	Ejemplo
D1	MOTOCICLETAS (Dos ruedas)	
D2	MOTOS (Tres o cuatro ruedas)	

Fuente: INECC, 2009. Elaboración propia.