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# Assessment of Intra-Urban Traffic-Related Air Pollution on Asthmatic Children's Exposure at Schools in the Paso del Norte Region

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ASSESSMENT OF INTRA-URBAN TRAFFIC-RELATED AIR POLLUTION  
ON ASTHMATIC CHILDREN'S EXPOSURE AT SCHOOLS IN THE PASO del  
NORTE REGION

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## **Dedication**

Late Professor Penelope Simoes Ferreira, H. John Heinz III School of Public Policy & Management, Carnegie Mellon University, Pittsburgh, PA 15213

*‘As long as space endures,  
And as long as there are living beings,  
May I too remain  
To dispel the misery of the world’*

----- Shantideva’s prayer from Tibet



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ON ASTHMATIC CHILDREN'S EXPOSURE AT SCHOOLS IN THE PASO del  
NORTE REGION

by

AMIT U. RAYSONI

DISSERTATION

Presented to the Faculty of the Graduate School of  
The University of Texas at El Paso  
in Partial Fulfillment  
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for the Degree of

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THE UNIVERSITY OF TEXAS AT EL PASO

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*I would maintain that thanks are the highest form of thought, and that gratitude is the happiness doubled by wonder - G.K. Chesterton*

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## **Abstract**

Traffic-related air pollution can be a major public health concern in any urban area. This problem is compounded in the Paso del Norte region that has experienced rapid economic growth, and a substantial number of people living in close vicinity of major roadways. The desert surroundings, arid weather, frequent temperature inversions, heavy border traffic at the international ports of entry between El Paso and Ciudad Juárez, and poorly maintained vehicle fleet further exacerbates this problem. A growing body of air quality and epidemiologic research has discerned the linkage between traffic emissions and respiratory disorders.

Initial health investigations in the Paso del Norte region have found associations between various air pollutant indicators and adverse respiratory outcomes. However, monitoring traffic pollution as an indicator of population health and the subsequent ability to accurately reflect changes in the respiratory health of sensitive populations like school-going asthmatic children has been challenging in this region. Given the substantial amount of time children spend within school microenvironments, assessing children's school-based exposures is essential for preventing children's health risks to air pollutants. Indeed, the importance of characterizing children's exposures in schools corresponds with the US Environmental Protection Agency's recent initiative to promote outdoor air monitoring network near schools.

As part of a binational health effects study investigating the impact of traffic air pollution on asthmatic children, paired indoor and outdoor concentrations of fine and coarse PM (PM<sub>2.5</sub> and PM<sub>10-2.5</sub>), black carbon, and NO<sub>2</sub> were determined for 16 weeks in 2008 at four elementary schools in the international community of El Paso - Ciudad Juárez on the U.S.-Mexico border. Fifty-eight asthmatic subjects from these four schools were recruited. Health outcomes (weekly exhaled nitric oxide [eNO] measurements and daily respiratory symptoms) were recorded for the

study period. Two schools (one in each city) were located in high traffic density zones and the other two in zones of low traffic density.

Strong spatial heterogeneity in air pollutant concentrations existed in the region with all outdoor pollutant concentrations, in general, higher in Ciudad Juarez than in El Paso by two-fold or more. Concentrations of all pollutants, except PM in Ciudad Juarez, at high traffic density zones in both cities were higher than those measured at their respective low traffic density zones. Traffic-related PM pollution in Ciudad Juarez was confounded by the ubiquitous fugitive dust emissions from unpaved roads and regional unprotected bare soil such that both PM<sub>2.5</sub> and PM<sub>10-2.5</sub> measured in the low traffic density zone surpassed those measured in the high traffic density zone. Aided by inter-site and intra-pollutant analyses, concentrations of NO<sub>2</sub> and black carbon were confirmed to be better indicators for traffic-related pollution. Indoor air pollution was found to be well associated with outdoor air pollution, although differences existed among all schools in student activities, building tightness, use of ventilation system, temperature control devices, and building materials. Routine cooking and food preparation in classrooms could result in high level of indoor NO<sub>2</sub> which pose unintended health risks to school children.

Significant associations between the weekly (96-hr) averages of several measured pollutants and eNO with effects estimates ranging from 1 to 3% increases in eNO per interquartile range increases in pollutant concentrations were observed. Effect estimates from models using indoor pollutant school concentrations were generally more robust than corresponding models using outdoor school or ambient concentrations.

This research characterizes the intra-urban variability in traffic-related air pollutants across four schools with potential implications for epidemiological studies basing their exposure variables on those obtained at central monitoring sites. The spatial variability of pollutants

supports the use of spatially resolved environmental indicators of traffic pollutants in range of exposure settings. The results indicate that the adverse impact of air pollutant on the respiratory health of asthmatic children in this border region and substantiates the use of air pollutant monitors in close proximity to schools to track exposure and potential health risk in this border region.



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## **1.0: Introduction**

Rapid industrialization and economic development in any nation have traditionally been considered as the primer for alleviating poverty and improving the quality of life of its citizens. However, anthropogenic and natural activities can lead to a suite of problems like water or air pollution resulting in an increase in the burden of disease for the very individuals enjoying the benefits accrued from these activities. Urban growth can result in increasingly high levels of air pollution around the world leading to deterioration of air quality, smog formation, stratospheric ozone depletion, and subsequent deleterious effects on the health of the individuals (Pennington et al., 2004).

Anthropogenic ambient air pollutants can emanate from traffic, heavy industries, geological sources, and domestic heating and cooking. Of the various sources of air pollution, *motor vehicle emissions* command an important place. It stands to reason that traffic emissions, as opposed to non-combustion sources, have a substantial impact on ambient and indoor air exposures, in addition to personal exposures resulting in substantial detrimental health effects (Janssen et. al., 2001; Laden et. al., 2000). Traffic air pollution is influenced by vehicle emission rates, vehicle use conditions, traffic characteristics, population density, meteorology, and topography (Ashmore and Dimitroulopoulou, 2009). In addition, driving habits, design of motorways (graded or non-graded roads), chemical composition of motor vehicle fuels, and design and technology of motor vehicles are parameters that require consideration (Gwilliam, 2003; Wang et al., 2003). Traffic emissions contribute substantially to ambient pollutant concentrations along with fixed point and area sources in any urban environment.

## **1.1 Major Traffic Air Pollutants**

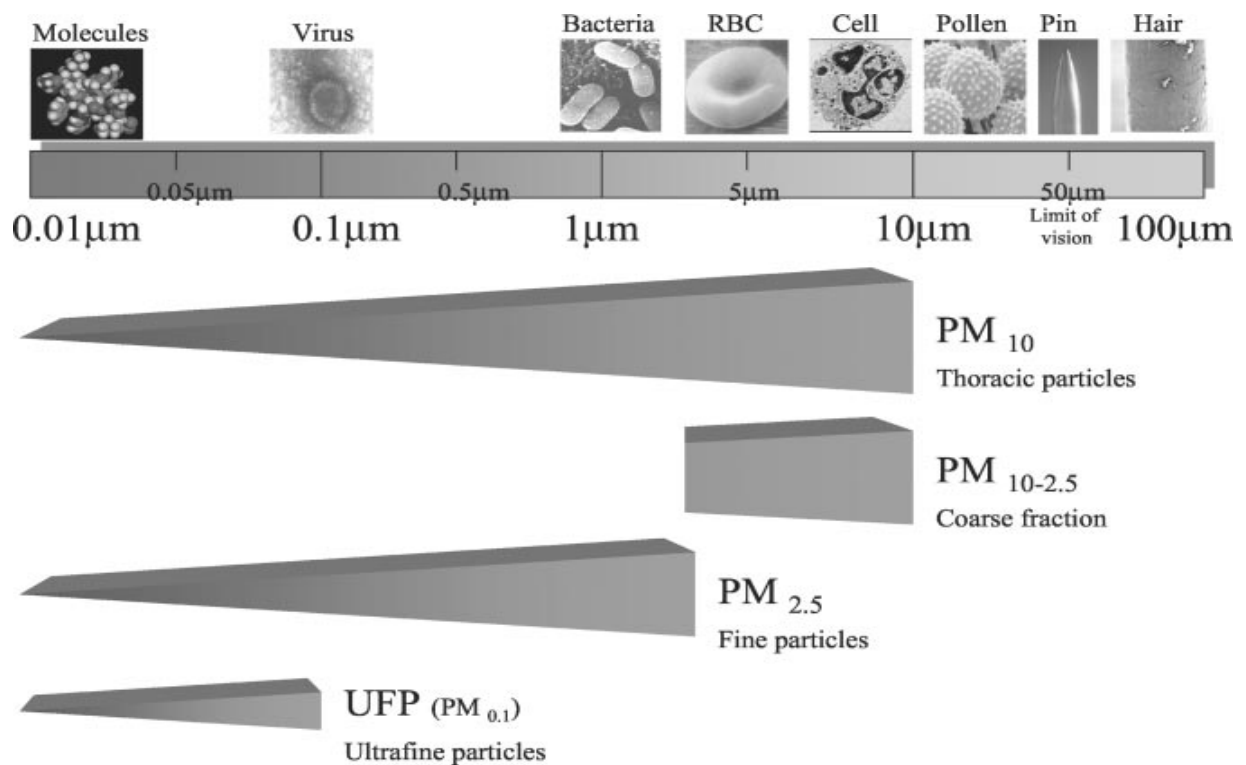
Traffic emissions represent a smorgasbord of air pollutants such as nitrogen dioxide ( $\text{NO}_2$ ), carbon monoxide ( $\text{CO}$ ), particulate matter (PM), volatile organic compounds (VOCs), etc. (Gilbert, 2003). Many researchers have attributed more than 50% of PM emissions to traffic (Briggs et al., 1997; Wrobel et al., 2000). The United Kingdom Department of Transportation (2002), in one of their investigatory reports, attributed 80% of all PM pollution in London to road traffic.

### **1.1.1 Particulate Matter**

Atmospheric PM is a complex and heterogeneous mix of constituents comprising of solid and liquid particles suspended in air. They are made up of a number of components such as acids (nitrates & sulfates), organic chemicals, and soil and dust particles, and have both natural (earthen or biogenic) and anthropogenic sources (Wilson & Spengler, 1996). Atmospheric PM is either emitted directly into the air as primary pollutants or formed through chemical reactions among mixed gas phase materials and sunlight while drifting through the atmosphere as secondary pollutants. The physical and chemical properties of PM generally reflect the contributing point and area sources at local and regional levels. PM comes in various sizes and varies chemically in space and time (Brook et al., 2004). Its composition varies significantly by the size mode and is classified as ultrafine, fine, coarse, and larger. However, PM is by no means homogeneous within these classification levels.

In air quality and epidemiological studies, size-selective sampling of PM is conducted to collect particles below, above, or within a specified aerodynamic range. Particle size is normally defined at a 50% cutoff point of a specific aerodynamic diameter ( $d_a$ ). For particles, aerodynamic diameter is defined as the diameter of the spherical particle with a density of  $1000 \text{ kg/m}^3$  (the

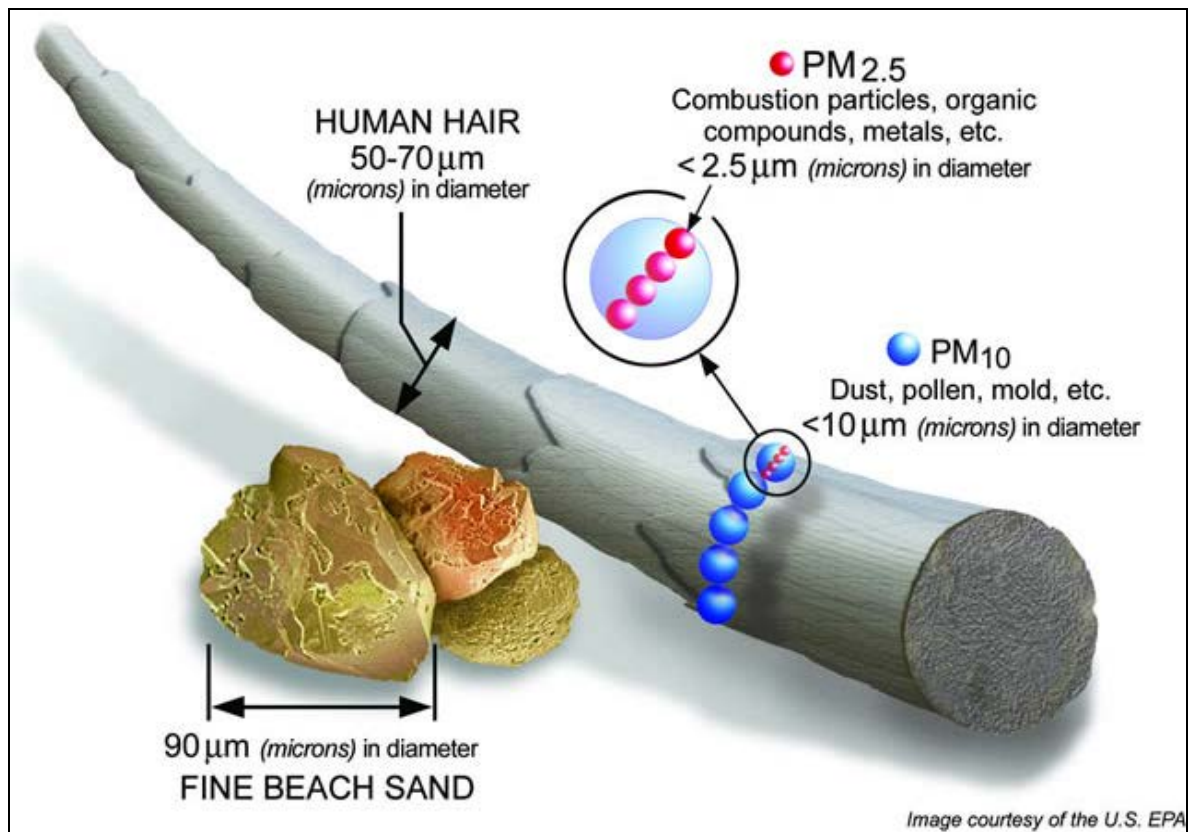
density of a water droplet) that has the same settling velocity as the particle (Hinds, 1999). Size fraction of aerodynamic diameter relates more to the physical behavior of particles rather than to their actual size (Hinds, 1999) and is an important characteristic of particulate matter due to its ability to strongly affect particle behavior and fate in atmospheric systems. In addition, size selective sampling relates to inhalation and deposition of these particles into lungs, sources, and levels of toxicity (Chow, 1995; Mitra et al., 2002; Hinds 1982). Figure 1-1 shows the particulate matter size distribution.



**Figure 1-1: Particulate matter size distribution (Source: Brook et.al, 2004)**

Particles less than 10 μm (PM<sub>10</sub>) can enter the human extra thoracic and upper tracheobronchial region, whereas PM<sub>2.5</sub> is the size fraction (less than 2.5 μm) that can reach the small airways and alveoli- gas exchange portion of the lungs. Figure 1-2 details this distinction very succinctly. Thus, PM represents particles that exhibit a wide-range of physicochemical

properties and considerable heterogeneity that may span five to six orders of magnitude in size. Presently, particles greater than  $10\text{ }\mu\text{m}$  in diameter are not of significant importance in health effects studies due to their limited stability in the atmosphere.



**Figure 1-2: Classification of PM<sub>2.5</sub> and PM<sub>10</sub> fractions of Particulate Matter**

### 1.1.2 Sources of PM Pollution

The PM<sub>2.5</sub> fraction is largely the accumulation mode of ultrafine PM. The primary sources of fine particulate pollution are forest fires, burning of biomass, the reaction of gases in air when emitted from power plants, industries, and automobiles (EPA, 2007). In addition, they are formed from gases through the homogeneous and heterogeneous nucleation processes and/or gas-to-particle conversion. The major chemical components of PM<sub>2.5</sub> are sulfate, nitrate,



ammonium, and carbonaceous materials (organic carbon and elemental carbon or black carbon). Coarse particles are the result of direct emissions, or they may be formed by the breakage of bigger particles into smaller ones (Wilson and Suh, 1997). The composition of coarse PM ( $PM_{10-2.5}$ ) is primarily crustal material, typically oxides or salts of elements found in dirt; e.g., Fe, Ca, Si, Al, as well as sea water species of sodium and chloride (Brasseur et al., 1999). Some natural sources of coarse PM are windblown soil, evaporation of sea-spray, volcanic ash, pollen, mold spores, and parts of plants and insects. Anthropogenic sources of coarse particles comprise dust that is resuspended by vehicles traveling on paved and unpaved roads, tire- wear particles, debris from building demolition, fly ash from industrial boilers, and waste incinerators.

Road-dust emissions are often an important source of PM in urban and rural areas. These particles are mechanically generated from crustal material; therefore, the mass of resuspended road dust is mostly coarse particles: 85-95% of  $PM_{10}$  in the 2.5  $\mu m$  to 10  $\mu m$  size range (Cowherd Jr and Donaldson, 2005, HEI, 2010). The chemical mixture of road dust usually comprises of mineral oxides found in soils plus organic constituents from exhaust, such as polyaromatic hydrocarbons (PAHs), tire wear, elements from break wear and catalysts, and allergens (Whiteley and Murray, 2003; Gillies et al., 2001; Gomez et al., 2002; Rogge et al., 1993). Soil dust is pulverized in the roadway and then resuspended by turbulence in the vehicle wake. Tire-wear particles are generated during the rolling shear of the tire tread against the road surface and are usually in the coarse fraction (less than 10% are in the fine fraction) (Rogge et al., 1993).

### **1.1.3 Nitrogen Dioxide**

Nitrogen dioxide ( $NO_2$ ) is a gaseous air pollutant. It is part of the nitrogen oxides ( $NO_x$ ), a group of air pollutants produced from combustion processes (heating, power generation, and

traffic). Traffic is one of the major contributors of urban NO<sub>2</sub> (WHO, 1997). The primary emission of nitrogen oxides from vehicles is largely nitrogen monoxide (NO). Formation of NO<sub>2</sub> from NO occurs after emissions and depends on the level of ozone. NO<sub>2</sub> is normally used as an indicator of motor vehicle exhaust because it is easy to measure and environmental air quality standards for NO<sub>x</sub> are based on NO<sub>2</sub> (Lewne et al., 2004). In addition, NO<sub>2</sub> has many indoor sources too - especially cooking ranges and kerosene heaters (Traynor et al., 1987), and levels of indoor NO<sub>2</sub> can greatly exceed outdoor levels.

#### **1.1.4 Carbonaceous Particles**

Carbonaceous materials are an important part of PM and play an important role in urban air quality and health research (Chow et al., 2005, Watson et al., 2002). Carbonaceous particles are usually classified into two categories: Organic Carbon (OC) and Elemental Carbon (EC). In highly industrialized and urbanized areas these two categories are a major constituent of fine fraction of PM (Seinfeld and Pandis, 1998; Nunes et al., 1993). Black carbon (BC), or soot, is the non-volatile, light-absorbing portion of OC and is a byproduct of incomplete combustion of organic material (Chow, 1996). Hence, in health effect studies, it has been used as a tracer of primary OC (Turpin et al., 1991). Most diesel emissions are composed mainly of elemental carbon (EC) with adsorbed compounds such as organic carbon (OC), sulfate, nitrate, metals, and other trace elements (Kleeman et al., 2001).

### **1.2 Health Effects of Major Traffic Pollutants**

Air quality and epidemiologic scholarship have discerned the linkage between traffic emissions and respiratory disorders (Dubowsky et al., 2005; Finkelstein et al., 2004; Hoek et al., 2002; Jansen et al., 2005; Peters et al., 2004; Schwartz et al., 2005; Medina-Ramon et al., 2008). The association between air pollution and health effects in sensitive populations, like children

and the elderly, has been well documented (McConnell et al., 1999; Hoek et al., 1994; de Hartog et al., 1997; Koenig et al., 2005; Steerenberg et al., 2003; Fischer et al., 2002). Air pollution health effects are also reported to be associated with or confounded by many sociological, economic, and personal physical characteristics such as race, ethnicity, household income/poverty, access to health care, education, neighborhood, diabetes, obesity, among others. A recent report published by the Health Effects Institute posits, with sufficient evidence, the causal relationship between traffic-related air pollution exposures and asthma exacerbation, especially in children (HEI, 2010).

Statistical association between ambient PM concentrations and asthma exacerbation in sensitive populations is strongest for PM<sub>2.5</sub> than other size fractions of PM. Pope and Dockery (2006) have summarized the detrimental impacts of PM on human health, especially for a young vulnerable population like children. Children's exposure to PM is very different from adults. Children's lungs are in the process of development and the higher metabolic rate of children results in a higher breathing rate (Bates, 1995). Children are also more active than adults which results in a higher intake of air into their lungs as compared to adults (Salvi, 2007). This increases the exposure of the airway per unit time (Kulkarni et.al, 2008), resulting in more PM entering and depositing in their lungs. Activities like Physical Education (PE) can increase their breathing rates, thereby increasing their PM exposure as compared to adults. Finally children's defense mechanisms are still evolving, thereby raising their susceptibility to respiratory illnesses due to PM pollution (Schwartz, 2004). Research conducted by Roorda Knappe et al. (1998), Branis et al. (2005), and Wheeler et al. (2000) has shown higher PM concentrations inside classrooms and residences than the corresponding outdoor concentrations.

Exposure to NO<sub>2</sub> may decrease lung function and increase the risk of respiratory problems, particularly in asthmatic children. Short-term exposure to peak levels can increase respiratory allergic reactions (Salvi, 2007). Populations living close to busy roads are particularly susceptible to NO<sub>2</sub> pollution (Gilbert et al., 2003). Positive associations between NO<sub>2</sub> and health effects have been reported by many researchers (Hoek et al., 2002, Chauhan et al., 2003, Gauderman et al., 2004). Fromme et al. 2005, Kinney et al. 2000, and van Roosbroeck et al. 2006 have used BC as a surrogate for diesel emissions in urban environments. Scientific evidence suggests that short-term exposure to diesel emissions can cause acute irritation of the eye, throats, and the bronchial tissues in addition to certain neurophysiological symptoms like nausea, and respiratory symptoms like the formation of cough and phlegm. Dose dependent lung inflammation and cellular changes in the lung were chronic exposures observed in experimental animal inhalation studies (US EPA, 2002).

### **1.3 Intra-urban spatial heterogeneity in air pollutant concentrations**

Ambient air quality is impacted by traffic pollution across various scales: local, urban and regional. Exposure to these pollutants is the highest near roadways and as the distances increase from the traffic source, the pollutants mix with emissions from other sources. Traffic related air pollutants such as PM<sub>2.5</sub>, NO<sub>2</sub> and BC are known to be spatially and temporally heterogeneous and, in particular, exhibit sharp concentration gradients at community levels (Fischer et al., 2000; Hoek et al., 2002; Lewne et al., 2004; Patel et al., 2009; Pinto et al., 2004).

Pollutant concentrations exhibit gradients as a function of distance from roadways (Zhu et al., 2002). PM<sub>2.5</sub> and NO<sub>2</sub> concentrations are the highest near the roadways and decay to background concentrations within a few hundred meters from the emitting source. In air pollution control studies, background level for any pollutant is defined as the concentration of that pollution in a

given area of consideration during a fixed time period prior to the starting up or stoppage of emission sources under control. These concentrations are also impacted by traffic density and meteorological factors like wind speed and wind direction. A 50% decrease in  $PM_{2.5}$  concentration has been reported within 100-150 meters from the road by Hitchins et al. (2000). Distance decay gradients for black smoke,  $PM_{2.5}$ , and  $NO_2$  have been documented in Netherlands by Roorda-Knappe et al. (1998). Pollutant concentrations drop to background levels within 100-150 meters from the roadways where the measurements were conducted. In another study, Titta and colleagues (Titta et al., 2002) reported  $PM_{2.5}$  concentrations to be at the background level within 50 meters of the emitting source.

$NO_2$ , which is a surrogate of choice for traffic pollution, exhibits distance-decay patterns around a busy highway. Research conducted in Montreal, Canada, by Gilbert et al. (2003) corroborates this premise. In their study, concentration of  $NO_2$  reached background levels at a distance of 600 meters from the expressway. Furthermore, these concentrations declined on the downwind side of the expressway. Roadways and expressways with high traffic density have recorded high  $NO_2$  and BC concentrations (Smargiassi et al., 2005; da Silva et al., 2006; Alili et al., 2001; Cape et al., 2004). In a study conducted in northern Californian schools, Singer et al. (2004) found  $NO_2$  levels ranging from 24 to 30 ppb in schools downwind of and close to freeways.

In sum, it can be posited that non-uniformity in spatial gradients for traffic pollutants is influenced by pollutant characteristics, pollutant background levels, meteorological conditions, distance to roadways, topography, and vehicle factors like vehicle types, age and fuel, and background levels.

## 1.4 Air Quality Guidelines for Major Pollutants

As mandated by the federal provisions of the Clean Air Act of 1990, the United States Environmental Protection Agency (USEPA) is required to set National Ambient Air Quality Standards (NAAQS) for major pollutants. These pollutants, principally called the criteria air pollutants, can be harmful to human health. Table 1-1 shows the US EPA Air Quality Primary and Secondary Standards (US EPA 2010) for CO, NO<sub>2</sub>, ozone, SO<sub>2</sub> and PM<sub>2.5</sub>. Primary standards aim to protect the public - including children, the elderly and pregnant women - from any health risks. Secondary standards prevent unacceptable effects on the public welfare, e.g., unacceptable damage to crops and vegetation, buildings and property, and ecosystems. Some pollutants have more than one averaging time. The averaging time is the time frame over which the pollutant concentrations are averaged in order to determine attainment with the NAAQS.

Table 1-2 and 1-3 are the World Health Organization Air Quality Guidelines and Health Based Ambient Air Standards for Mexico, respectively. Although the WHO guidelines, first drafted in 1987 and subsequently updated in 1997, had a European scope, the 2006 guidelines apply worldwide and were based on thorough scientific evidence and up-to-date assessment of health effects of air pollution. These recommendations are intended to guide governments in achieving their air quality targets and help manage health based risks resulting from air pollution. Even though health risks below these recommended air quality targets are lowered, life-long exposure to these pollutants *cannot* be deemed safe. Some of these standards or guidelines are 10-min based (WHO guidelines for sulfur dioxide), some 1-hr based or 8-hr based (carbon monoxide and ozone), while others are 24-hr or annually based.

**Table 1-1: US EPA National Ambient Air Quality Standards (EPA, 2010)**

	Primary Standards		Secondary Standards	
Pollutant	Level	Averaging Time	Level	Averaging Time
Carbon Monoxide	9 ppm (10 mg/m³)	8-hour	None	
	35 ppm (40 mg/m³)	1-hour		
Lead	0.15 µg/m³	Rolling 3-Month Average	Same as Primary	
	1.5 µg/m³	Quarterly Average	Same as Primary	
Nitrogen Dioxide	53 ppb	Annual (Arithmetic Average)	Same as Primary	
	100 ppb	1-hour	None	
Particulate Matter (PM <sub>10</sub> )	150 µg/m³	24-hour	Same as Primary	
Particulate Matter (PM <sub>2.5</sub> )	15.0 µg/m³	Annual (Arithmetic Average)	Same as Primary	
	35 µg/m³	24-hour	Same as Primary	
Ozone	0.075 ppm (2008 std)	8-hour	Same as Primary	
	0.08 ppm (1997 std)	8-hour	Same as Primary	
	0.12 ppm	1-hour	Same as Primary	
Sulfur Dioxide	0.03 ppm	Annual (Arithmetic Average)	0.5 ppm	3-hour
	0.14 ppm	24-hour <sup>a</sup>		
		75 ppb	1-hour	None

<sup>a</sup> Not to be exceeded more than once per year

**Table 1-2: World Health Organization Air Quality Guideline Values (WHO, 2006)**

<b>Pollutant</b>	<b>Averaging Time</b>	<b>AQG value (<math>\mu\text{g}/\text{m}^3</math>)</b>
<b>Ozone (<math>\text{O}_3</math>)</b>	8 h, daily maximum	100
<b>Nitrogen Dioxide (<math>\text{NO}_2</math>)</b>	1 yr	40
	1 h	200
<b>Sulfur Dioxide (<math>\text{SO}_2</math>)</b>	24 h	20
	10 min	500
<b>Particulate Matter</b>		
<b>PM<sub>2.5</sub></b>	1 year	10
	24 h (99 <sup>th</sup> percentile)	25
<b>PM<sub>10</sub></b>	1 year	20
	24 h (99 <sup>th</sup> percentile)	50

**Table 1-3: Health Based Ambient Air Standards for Mexico**

<b>POLLUTANT</b>	<b>Air Quality Standards</b>
<b>Carbon monoxide (CO)</b>	
8-hour Average	11 ppm
1-hour Average	-
<b>Nitrogen dioxide (NO<sub>2</sub>)</b>	
Annual Average	-
1-hour Average	0.21 ppm
<b>Ozone (O<sub>3</sub>)</b>	
8-hour Average	-
1-hour Average	0.11 ppm
<b>Sulfur dioxide (SO<sub>2</sub>)</b>	
Annual Average	0.030 ppm
24-hour Average	0.13 ppm
<b>(PM<sub>2.5</sub>)</b>	
Annual Average	-
24-hour Average	-
<b>(PM<sub>10</sub>)</b>	
Annual Average	50 $\mu\text{g}/\text{m}^3$
24-hour Average	150 $\mu\text{g}/\text{m}^3$
<b>Total suspended particulate matter (TSP)</b>	
Annual Average	75 $\mu\text{g}/\text{m}^3$
24-hour Average	260 $\mu\text{g}/\text{m}^3$
<b>Lead (Pb)</b>	
Quarterly Average	1.5 $\mu\text{g}/\text{m}^3$



## **1.5 Traffic Air Pollution in the Vicinity of Schools**

The location of schools near busy traffic intersections and freeways can be a recipe for high traffic pollution exposure to the children attending these schools. Idling school buses and long lines of parents dropping off or picking up their children in their cars can contribute to high pollution levels at schools. A study done by Green et al. (2004) showed that one in eight California students (721,363 children) attend a school that records more than 25,000 vehicle trips per day on adjacent roads. A smaller group (150,000 children), attends schools located near roads with more than 50,000 vehicle trips each day. In addition, non-white students are more likely to attend schools that experience high outdoor pollution levels due to traffic (Green et al., 2004).

Furthermore, researchers have shown higher levels of air pollutants inside classrooms and residences than the corresponding levels in the outdoor microenvironment (Roorda Knape et al., 1998; Branis et al., 2005, 2009). Individuals are exposed to an assortment of air pollutants in these microenvironments. A microenvironment is defined as a location in time and space within which pollutant concentrations can be assumed to be homogeneous (Duan, 1982). Exposures vary depending on time spent in a microenvironment and are associated with chronic and acute health effects.

Children, on average, spend about eight of their waking hours in schools. Out of these eight hours, a significant amount of time is spent in classrooms. The exposure of these children inside the classrooms can be different from ambient exposures. Characterizing the exposure of sensitive populations to traffic air pollution is challenging due to the lack of a single traffic metric, varying pollutant concentration gradients, and confounding by identical pollutants from non-traffic point and area sources.

Studies in the past have used air pollutant data from central ambient monitoring sites to assess the long term exposure to traffic air pollutants, especially, PM<sub>2.5</sub> and NO<sub>2</sub> (Dockery et al., 1993; Pope et al., 2002). Samet et al., (2000), Wong et al., (2001), and Zanobetti et al., (2003) have assessed air exposure assessment for the entire population of a study area by applying exposure concentrations at a central monitoring site to the studied population. Central monitoring sites may provide reasonable surrogates for short and long term exposure to air pollutants that show no spatial variation across a community. However, traffic related pollutants exhibit strong spatial gradients at the community levels and personal exposures may be much higher at such areas, which are impacted by heavy traffic and located far away from central site monitors. As such, central monitoring sites may not be an appropriate proxy for personal exposures, especially for sensitive populations like school going asthmatic children, thereby leading to potential exposure misclassifications (Pinto et al., 2004; Schwartz, 2004; Ito et al., 2004; Dominici et al., 2003; Kousa et al., 2002; Adgate et al., 2002).

Therefore, it becomes imperative to measure these pollutant concentrations in multiple microenvironments (like indoor and outdoor school locations), as these are integral to more accurate assessment of asthmatic children's personal exposure to traffic related air pollution in an urban area.

## **1.6 Compendium of Air Quality Studies conducted at Schools**

Many studies, nationally and internationally, investigating the indoor and outdoor characterization of PM and NO<sub>2</sub>, outside and inside schools have shown a myriad range of concentrations. The following is a comprehensive list of some of these studies:

- A study in Hong Kong documented PM<sub>10</sub> daily mean concentrations (inside classrooms) to be as high as 617 µg/m<sup>3</sup>. This violated the region's 24 hr average standard of 180

$\mu\text{g}/\text{m}^3$  by almost threefold (Lee and Chang, 2000). The study was done in five classrooms with air-conditioning and ceiling fan ventilation.

- Roorda-Knape et al. (1998) studied indoor and outdoor concentrations of  $\text{PM}_{10}$  in six city districts near motorways in West Netherlands. The indoor concentrations were measured in twelve schools in these districts. The outdoor sampling was conducted at four different distances from the roadside in two of the six city districts. The mean  $\text{PM}_{10}$  concentrations varied from 50.9 to 165.6  $\mu\text{g}/\text{m}^3$  across the four schools.
- In another study conducted in the Netherlands, Janssen et al., (2001) measured  $\text{PM}_{2.5}$  inside and outside 24 schools located within 400 m of motorways. The weekly indoor and outdoor  $\text{PM}_{2.5}$  concentrations ranged from 7.7 - 52.8  $\mu\text{g}/\text{m}^3$  and 5.2- 60.8  $\mu\text{g}/\text{m}^3$  respectively. Furthermore, the researchers reported increased  $\text{PM}_{2.5}$  and soot concentrations with high truck traffic and roadway proximity. The annual averages (SD) for  $\text{PM}_{2.5}$  were 20.5 (2.20)  $\mu\text{g}/\text{m}^3$ , indoors, and 20.3 (2.7)  $\mu\text{g}/\text{m}^3$ , outdoors. The annual averages, indoor and outdoor, for  $\text{NO}_2$  were 18.8 (5.3) and 34.8 (5.2)  $\mu\text{g}/\text{m}^3$ , respectively.
- A study conducted by Ali and Athar (2008) at three Pakistani schools along a national highway showed  $\text{NO}_2$  concentrations ranging from 20.0-80.0 ppb.
- A winter indoor elementary school sampling program in Libby, Montana, reported 24-hr average values ranging from 14.2 to 54.0  $\mu\text{g}/\text{m}^3$  (Ward et al., 2007).
- Fromme and colleagues reported high indoor concentrations of  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  in two classrooms at a school in Munich. The  $\text{PM}_{10}$  concentrations were 118.2  $\mu\text{g}/\text{m}^3$  (indoors) and 24.2  $\mu\text{g}/\text{m}^3$  (outdoors). The corresponding results for  $\text{PM}_{2.5}$  were 37.4  $\mu\text{g}/\text{m}^3$  indoors and 17.0  $\mu\text{g}/\text{m}^3$  outdoors (Fromme et al., 2008).

- In a study conducted at seven primary schools in the Athens, Greece, Diapoulli et al. (2008) reported high 8-hr PM<sub>10</sub> and PM<sub>2.5</sub> mean indoor and outdoor concentrations. Mean 8-hr PM<sub>10</sub> concentration measured was equal to 229 (182) µg/m<sup>3</sup> indoors and 166 (133) µg/m<sup>3</sup> outdoors. The respective PM<sub>2.5</sub> concentrations were 82(56) µg/m<sup>3</sup> indoors and 56(26) µg/m<sup>3</sup> outdoors.
- A wintertime study conducted in UK schools by Wheeler and colleagues reported mean 80 µg/m<sup>3</sup> (PM<sub>10</sub>) and 30 µg/m<sup>3</sup> (PM<sub>2.5</sub>) concentrations.
- A study conducted in Prague, Czech Republic (Braniš et al., 2009), has shown high levels of coarse PM inside the high school during periods of high pollution. This is in addition to elevated levels of fine PM that was attributed to automobile exhaust.
- Keeler et al. (2002) sampled indoor and outdoor PM<sub>2.5</sub> and PM<sub>10</sub> at two elementary schools and homes in the eastside and southwest communities of Detroit. High concentrations were observed in the southwest communities due to close proximity to roadways and industrial areas.
- Poupard et al. (2005) documented NO<sub>2</sub> levels ranging from 1.0- 27.0 ppb (outdoors) and 1.2- 26.9 ppb (indoors) at eight schools in La Rochelle, France.
- In a study conducted at 10 schools in Shanghai, China between November-December 2000, Mi et al. (2006) reported NO<sub>2</sub> levels that ranged from 50.0-58.0 µg/m<sup>3</sup> and 53.0-73.0 µg/m<sup>3</sup>, indoors and outdoors, respectively.
- In a Dutch study validating the exposure classification of school children to fine PM, NO<sub>2</sub> and BC, van Roosbroeck et al. (2006) found that the outdoor BC concentrations was 52 % higher at the two freeway schools compared to the two background schools. The contrast for NO<sub>2</sub> and PM<sub>2.5</sub> was minor.

- In a study conducted between November 1996 and February 1997 at two urban and one rural school in the Medway district of Kent, England, Peacock et al. (2003) reported rural PM<sub>10</sub> concentration of 18.7 µg/m<sup>3</sup> and the urban concentration ranging from 18.4- 22.7 µg/m<sup>3</sup>. The rural NO<sub>2</sub> concentration was 16.5 ppb.
- Goyal and Khare (2009) monitored RSPM (Respirable Suspended Particulate Matter) for a year in a classroom of naturally ventilated school building adjoining a major roadway in New Delhi, India. The environmental exposure sampling campaign lasted for one year and the researchers documented indoor RSPM concentrations exceeding the permissible limits during all monitoring hours of weekdays and weekends for all the seasons.
- Ekmekcioglu and Keskin (2007) reported average PM<sub>2.5</sub> and PM<sub>10</sub> concentrations ranging from 13.3- 95.2 µg/m<sup>3</sup> and 27.9- 289 µg/m<sup>3</sup>, respectively. These measurements were conducted in the indoor microenvironment of five elementary schools that experienced varying traffic intensities in the city of Istanbul, Turkey. The sampling was conducted during the hours of 8:00 am to 6:00 pm.
- For a study conducted in the San Francisco Bay Area of California, Singer et al. (2004) documented average outdoor NO<sub>2</sub> concentrations from 19.6 -26.0 ppb, across ten schools with varying distances from major highways.
- High outdoor NO<sub>2</sub> levels in contrariety to indoor levels were reported by Rijnders et al. (2001) in Netherlands, at three schools experiencing varying traffic levels. This study was conducted between autumn 1997 and summer 1998. The indoor and outdoor concentrations were 14.4 µg/m<sup>3</sup> and 33.4 µg/m<sup>3</sup>, respectively, at the lower traffic school in comparison to 24.3 µg/m<sup>3</sup> and 47.0 µg/m<sup>3</sup> recorded, indoors and outdoors respectively, at the high exposure school.

## **1.7 Air Pollution in the Paso del Norte Region**

The US-Mexico border region stretches nearly 2000 miles across four US states and six Mexican states. This region comprises a population of approximately 12 million that is expected to double by the year 2030 (Peach and Williams 2004). Sensitive populations along the U.S.-Mexico border are particularly subjected to the deteriorating air quality due to rapid urbanization and improved economy.

The Paso del Norte (PdN) region is a prime example of this scenario. The PdN border region (comprising the cities of El Paso, Texas, Ciudad Juárez, Chihuahua, and Sunland Park, New Mexico) has experienced significant population and economic growth since the passage of the North American Free Trade Agreement (NAFTA) in 1994, which accelerated binational commerce between the U.S. and Mexico. This region has also seen an increase in the overall number of motor vehicles in the cities as well as at the international border crossings (15 to 16 million passenger cars and 750,000 commercial vehicles across the four international ports of entry between El Paso and Ciudad Juárez each year according to the U.S. Department of Transportation). The El Paso-Ciudad Juárez border crossings are one of the busiest border crossings along the US-Mexico border (BTS, 2009). The border crossing takes approximately 10 minutes for every vehicle during which time the requisite paper work is processed by the US immigration officials. This leads to long waiting periods, and subsequent vehicle idling at the border crossings, thereby resulting in high vehicular emissions and subsequent border congestions (Currey et al., 2005). In addition, 40 percent of these vehicles have Mexican license plates and these vehicles tend to be high emitters due to an older Mexican fleet and less stringent maintenance and regulatory emission controls.

The PdN region, situated approximately 3,800 feet above sea level, represents a paradigmatic exposure-air pollution challenge in an international setting due to a large segment of its citizenry residing adjacent to congested roadways and a further exacerbation of their corresponding health exposures to arid weather, unique topography (Franklin Mountains in El Paso and Sierra de Juárez in Ciudad Juárez), desert surroundings, common air shed in a valley characterized by the Rio Grande river, occasional sand storms and frequent temperature inversions that strongly affects the mixing and dispersion of pollutants in this region (Li et al., 2001).

Furthermore, Ciudad Juárez is the colossus of Mexican *Maquiladoras* industry (Sanchez 1990). The ubiquity of the *Maquiladoras*, or the final assembly plants, which are almost all owned by transnational corporations, on the Ciudad Juárez terrain have added to the environmental burden of this region (Frey 2003, Grineski 2008, William and Homedes 2001). The transport of finished goods from these *Maquiladoras* to El Paso has contributed to heavy motorized traffic pollution.

The city of El Paso was designated moderate nonattainment for carbon monoxide (CO), ozone (O<sub>3</sub>), and PM<sub>10</sub> upon enactment of the Clean Air Act Amendment of 1990. CO pollution in El Paso has been substantially reduced since 1992 as a result of implementation of an oxygenated fuel program and a vehicle inspection/maintenance program. Subsequently the city was redesignated CO attainment in 2007. The area was redesignated ozone attainment when the NAAQS for ozone was revised from the one-hour standard of 0.12 ppm to an eight-hour standard of 0.08 ppm in 2004. However, the city is expected to be nonattainment for ozone when EPA lowers the eight-hour ozone standard to 0.075 ppm in the coming years. The city of El Paso has

been PM<sub>10</sub> nonattainment since 1980, although PM emissions from the adjacent city of Ciudad Juárez, Chihuahua was suspected to be a major contributor to the PM pollution in El Paso.

PM pollution in the PdN region is a major cause of concern, especially in the South-west United States and presents a unique air pollution problem different from other urban areas in the nation. A multiplicity of factors contributes to and exacerbates the PM problems in the region (Li et al., 2001). Emissions resulting from the fleet of newer U.S. vehicles could easily exceed that of the generally older Mexican vehicles (Rincon et al., 2005) due to the high vehicle miles traveled per vehicle and the large number of vehicles utilized. Ciudad Juárez is almost four times densely populated than El Paso, whereas El Paso has nearly three times the daily vehicle miles traveled (VMT) of Ciudad Juárez with a much lower population (Gonzalez-Ayala, 2006). Indeed, the daily VMT for El Paso ( $15.8 \times 10^6$ , reported by El Paso MPO, 2007) is likely to be at least three times higher than that reported for Ciudad Juárez ( $4.1 \times 10^6$ , Wolf et al. 2003).

Initial health effects investigations in the PdN region have found associations between traffic-related air pollutants and adverse respiratory outcomes in children (Holguin et al., 2007; Romieu et al., 2003). Increases in hourly ozone (O<sub>3</sub>) levels of 20 parts per billion by volume (ppb), for example, were associated with a 5.1% increase in respiratory related emergency department visits for children in Ciudad Juárez (Romieu et al., 2003). Interquartile range increases in PM<sub>10</sub> (approximately  $40 \mu\text{g}/\text{m}^3$ ) were related to a 20% increase in asthma-related emergency department visits for children in El Paso, as reported by Hart et al. (1999). A time-series study in Ciudad Juárez reported a  $20 \mu\text{g}/\text{m}^3$  increase in PM<sub>10</sub> to be associated with a 9% increase in pediatric asthma emergency department visits (Hernandez-Cadena et al., 2000). In addition, asthmatic children living in the border region are reported to be hospitalized at a rate 36% greater than off-border children (Grineski, 2007). Most recently, Holguin et al. (2007)



found associations between acute pulmonary inflammation, as expressed by levels of exhaled nitric oxide (eNO), and traffic-related ambient nitrogen dioxide (NO<sub>2</sub>) concentrations for asthmatic children in Ciudad Juárez.

Despite these suggestive initial findings, monitoring environmental health and the impact from traffic in El Paso and Ciudad Juárez is difficult due to the lack of sensitive environmental health indicator data. Of the 12 continuous ambient monitoring stations (CAMS) in El Paso and Ciudad Juárez, that measure some of the criteria air pollutants ( e.g., O<sub>3</sub>, NO<sub>2</sub>, CO ) few are located in the immediate vicinities of roadways for measuring direct mobile emissions or near schools for monitoring children's exposure to traffic emissions. In addition, there exists an additional uncertainty concerning the exposure risk to these pollutants borne by those who are susceptible (e.g., individuals with asthma) and vulnerable (e.g., those residing near busy roadways, individuals with limited or low access to health care services).

Moreover, it is currently unclear which environmental health indicators best reflect actual exposure to traffic-related pollution among children. As stated by Briggs (2000), environmental health “indicators should be accurate, so that they provide an undistorted picture of the condition of interest.” The primary environmental indicators for air pollution for the U.S.-Mexico border defined by Pan American Health Organization (PAHO) are the U.S. criteria pollutant concentrations as measured by an existing network of ambient central site monitors. However, it is unlikely that the existing ambient monitors in El Paso and Ciudad Juárez are able to capture adequately temporal and spatial trends in traffic-related emissions. Consequently, the limited criteria pollutant concentrations from these monitors are not likely to comprise adequate environmental health indicators for traffic-related exposures. Therefore, assigning a central site exposure variable to investigate traffic-mediated health effects may not mirror the actual

pollutant concentration variability that exists at intra-urban levels leading to exposure misclassifications in this region.

It, therefore, becomes imperative that, in addition to traditional ambient central monitoring sites, indoor and outdoor monitoring strategies be employed to winnow the best possible environmental health indicator for characterizing traffic exposure of children who bear the disproportionate burden of urban air pollution. This methodology is in line with one of the goals of US-Mexico Border 2012 program (U.S. EPA, 2002), which aims at reducing air pollution in this region.

### **1.8 Thesis Goals and Hypothesis**

In order to determine the appropriate environmental health indicators that would best capture the health effects of traffic-related air pollutants for children, a binational health effects and air pollution study in El Paso and Ciudad Juárez was undertaken in 2008 that concurrently measured traffic-related air pollution in multiple microenvironments and examined the corresponding health effects for a cohort of asthmatic children living in high and low traffic exposure zones on both sides of the border. School children spend approximately eight hours in school each day; therefore, understanding their exposure in this microenvironment is critical to the field of air epidemiology. Thus, the aims of the environment monitoring were to demonstrate that an intra-urban spatial variation existed for traffic pollutants in the PdN region and that Texas Commission on Environmental Quality (TCEQ) CAMS central monitoring sites do not accurately capture changes in local or indoor pollutant concentrations and may, therefore, not be a true representation for children's exposure to traffic-related air pollutants. In addition, each of the examined environmental health indicators of traffic pollution was assessed to predict children's respiratory health. Another aim of this study was to show that children in high traffic

exposure zones would be exposed to more pollutants as compared to children in low exposure zones in both cities. This thesis characterizes the concentration gradients, both indoors and outdoors, for PM (in PM<sub>2.5</sub>, PM<sub>10-2.5</sub>, and PM<sub>10</sub>), NO<sub>2</sub>, and BC across multiple microenvironments, investigates the spatial variation that exists in the concentration gradients, and analyzes the inter-pollutant and inter-site pollutant correlation statistics within and across the two largest cities (El Paso and Ciudad Juárez) of the PdN, and examines the ability of specific environmental indicators to accurately characterize the impact of traffic exposures on the respiratory health of asthmatic children in the Paso del Norte border region

This research was grounded on the following four hypotheses:

- Traditional central site ambient monitoring does not accurately reflect changes in local or indoor pollutant concentrations, nor adverse health associated with exposure to traffic pollutants; and
- Targeted neighborhood ambient and indoor monitoring of traffic-related pollutants can be used as a sensitive environmental health indicator of children's exposures to traffic emissions and of children's subsequent traffic-related respiratory morbidity;
- Asthmatic children in specific neighborhoods of Ciudad Juárez and El Paso are exposed to high levels of traffic-related air pollutants and experience increases in pollution-mediated pulmonary inflammation, medication usage, and respiratory symptoms;
- Exposures to low as compared to high concentrations of traffic related air pollution are associated with lower incidence of respiratory morbidity in asthmatic children.

In order to examine these hypotheses, specific research was conducted to:

- Measure the background and in-school levels of traffic-related pollutants in areas of low and high traffic pollution in El Paso and Ciudad Juárez,

- Compare spatial and temporal air monitoring results with values obtained from existing environmental health indicators,
- Follow the health status of a selected cohort of asthmatic children in both cities,
- Examine the associations between pollutant concentrations and acute respiratory health outcomes across cohorts in each city, and
- Assess the ability to detect these associations using available environmental health indicators.

## **2.0 Study Design and Methods**

### **2.1 High Exposure vs. Low Exposure Zones**

Four elementary schools within distinct traffic pollution exposure zones, with one in high and one in low exposure zones in each city, were chosen. Selecting zones that differed substantially in levels of ambient traffic pollution provided the necessary exposure gradient to examine spatial epidemiologic associations within the study area. Selection of zones and school study sites were based on previously collected PM<sub>2.5</sub> and NO<sub>2</sub> data at various locations throughout each city, as well as data detailing residential and school distances to major roadways and traffic pollution sources. In addition to their geographical location, criteria for school participation in the study included their willingness to allow study staff access to outdoor (rooftops) and indoor (classrooms, library or computer room) secure space for setting up air pollution sampling instruments. Also, while choosing the indoor site location within the schools, it was deemed necessary that the site should be representative of the actual indoor exposures of the students.

An ARC-GIS map was obtained from the GIS Department of the City of El Paso in July 2007 for defining high or low exposure zones and for the selection of schools in El Paso. This map detailed the locations of the 128 elementary schools in the city of El Paso. Also featured in this map were other important geographic locations like the Ascarate Park, Sunrise Park, Interstate Highways and other major arterial roads in the city of El Paso. This map aided the researchers in identifying a High Exposure Zone school near Ascarate Park and a Low Exposure Zone near Sunrise Park.

## **2.2 Site Selection**

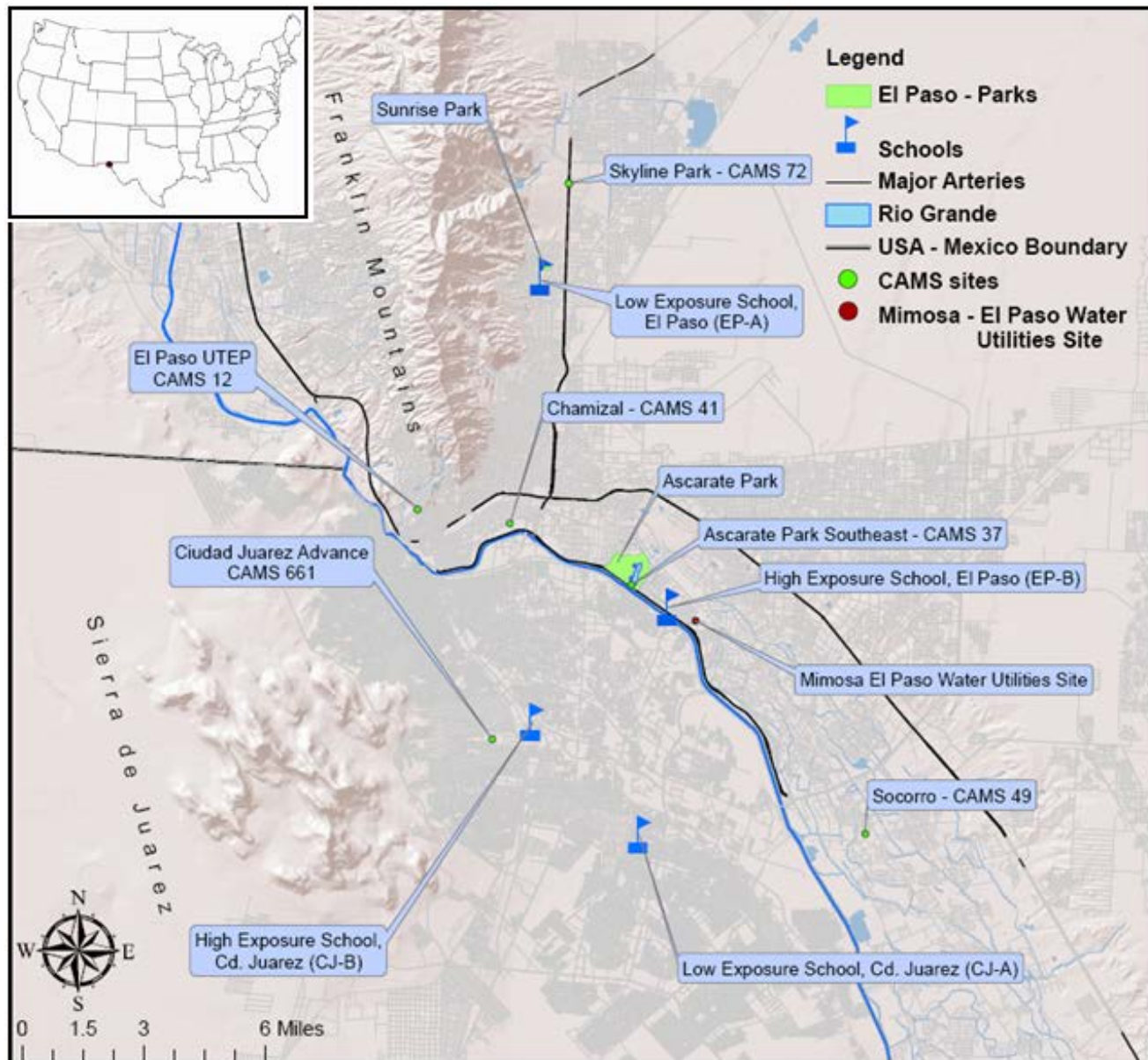
Three schools were identified in the High Exposure Zone in El Paso. All these schools were under the jurisdiction of Ysleta Independent School District. Similarly, four schools were identified in the Low Exposure Zone of El Paso. These schools were under the jurisdiction of El Paso Independent School District. Once the schools were identified, necessary documents and research protocols were submitted to the concerned officials and approval to conduct the study was finally obtained in August 2007 from both the school districts. Necessary telephone conversations were then initiated with the Principals from the selected schools in both the school districts.

The research crew fixed meetings with the Principals and the nurses of these seven schools and submitted the necessary research protocol for the study. Two out of the three schools in the High Exposure Zone area expressed keen interest in being a part of the study. The first school had only 300 students and was close to the Western Refinery. Hence to avoid possible confounders at the later stage of the study, this school was not selected. The second school was situated immediately adjacent to the Border Highway (Route 375), which runs along the US-Mexico Border fence. Route 375 is a major arterial highway for northbound commercial trucks as well as local commuter vehicles at all hours. The school had approximately 700 children on the roll. Ultimately, this school was chosen to be the High Exposure Zone School in El Paso.

Out of the four schools approached in the Low Exposure Zone, two schools declined to participate without citing any reasons. The other two expressed interest in the study. One of these schools did not have sufficient number of asthmatic children (fewer than 15) hence all further communications with this school were stopped. The fourth school had the requisite number of students and both the Principal and the school nurse promised full co-operation at all stages of

the project. Hence this school was chosen to be the designated low exposure zone school in El Paso. This school was located in a residential area with minimal traffic in northeastern part of the city. The low and high exposure schools in El Paso were designated as EP-A & EP-B respectively.

The schools in Ciudad Juárez were selected based on previous traffic counts obtained from the Instituto Municipal de Investigación y Planeación, (IMIP), Ciudad Juárez, Chihuahua and the PM<sub>2.5</sub> results measured during EVA study by Hogluin and colleagues (Hogluin et al., 2007). Four schools (two in each exposure zone) were identified. Necessary permission was obtained from the Secretaria de Educacion Publica de Ciudad Juárez, Chihuahua, Mexico to invite these schools to participate in the study. Once the requisite permission was obtained, the research crew contacted the Principals, submitted the research protocols and obtained their consent to participate in the study. In Ciudad Juárez, the low traffic exposure school (CJ-A) was located in a residential area surrounded by unpaved streets whereas the high traffic exposure school (CJ-B) was located adjacent to two major highways that might have experienced heavy volumes of diesel and motor traffic at all hours. A gas station and the largest bus terminal in Ciudad Juárez were located in close proximity to CJ-B. The location of the four schools is indicated in Figure 2-1. Figures 2-2, 2-3, 2-4, 2-5 are the Google Earth Images of schools EP-A, EP-B, CJ-A, and CJ-B, respectively.

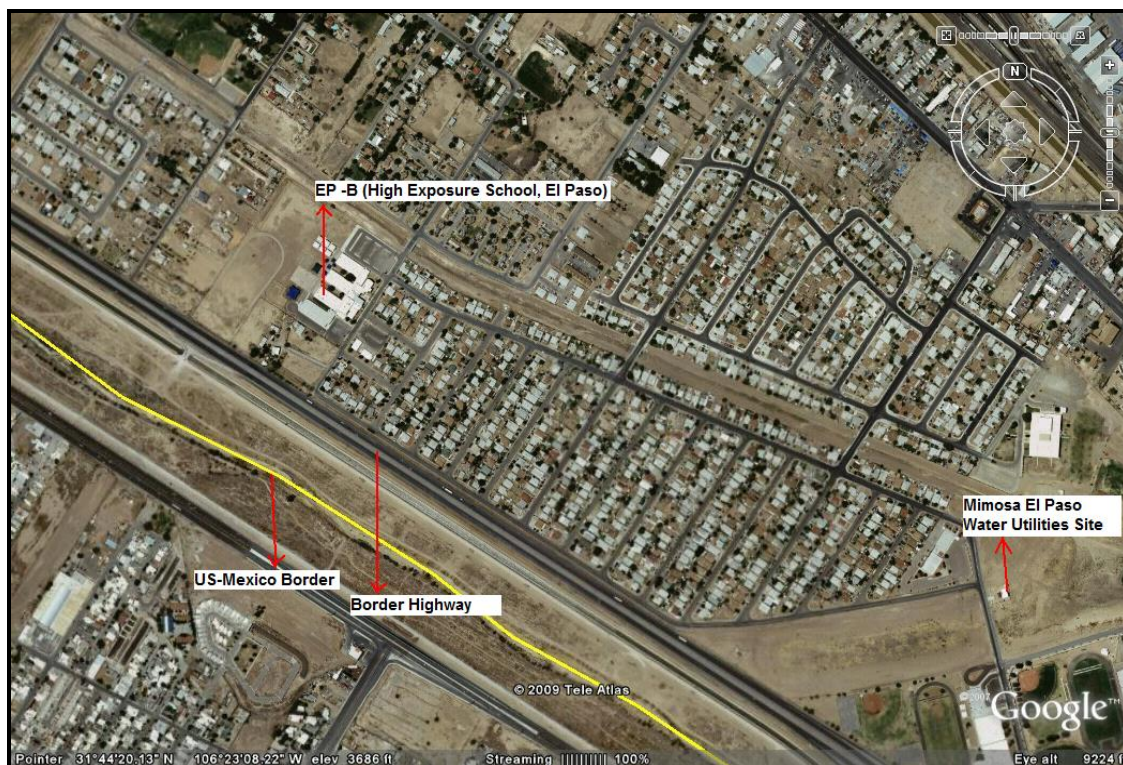


**Figure 2-1: Map of the study area including school locations and TCEQ CAMS sites**





**Figure 2-2: Google Earth Image of the Low Exposure School (EP – A) in El Paso, TX**



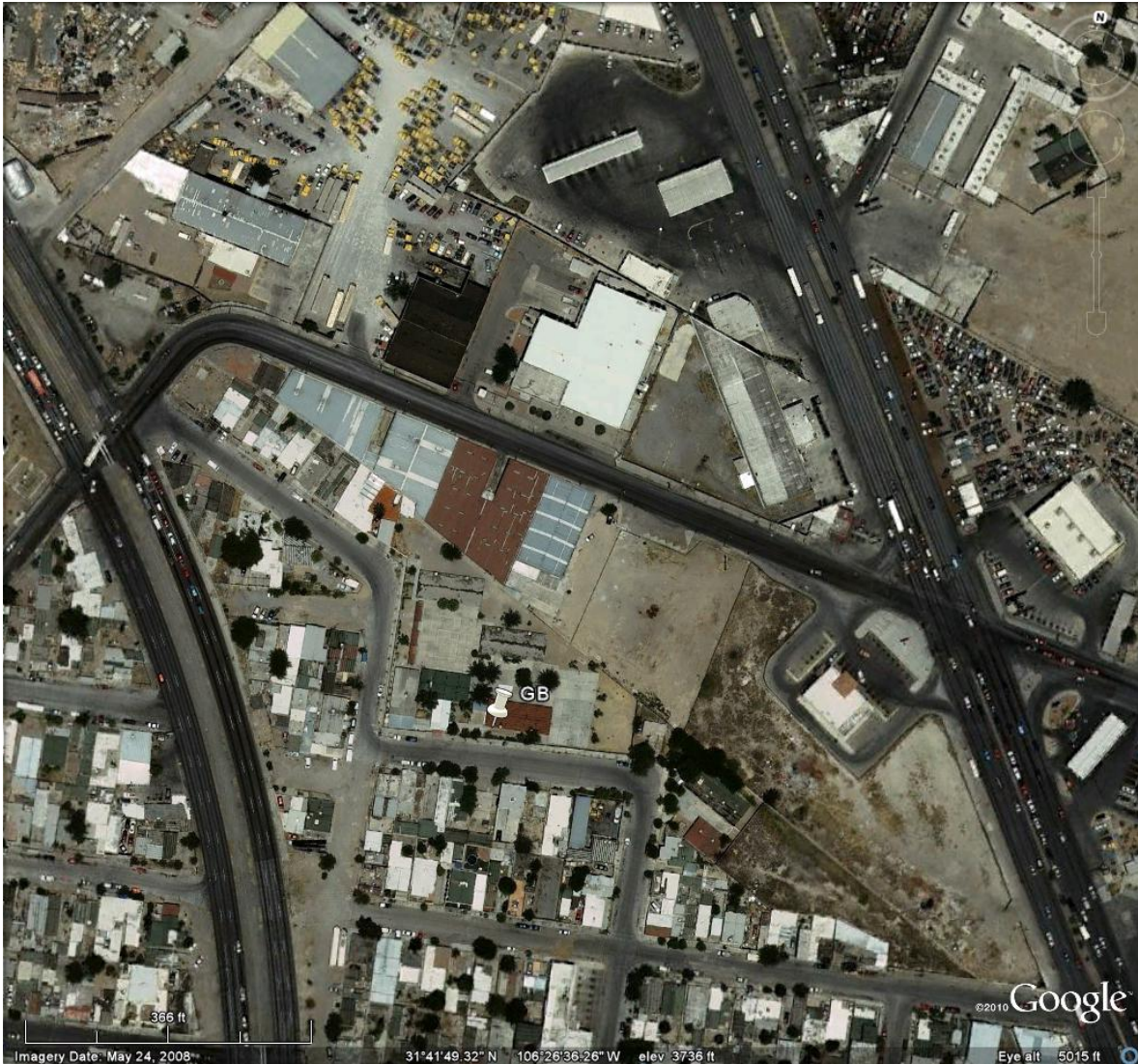
**Figure 2-3: Google Earth Image of the High Exposure School (EP- B) in El Paso, TX**





**Figure 2-4: Google Earth Image of school CJ-A in Ciudad Juárez, Chihuahua**





**Figure 2-5: Google Earth Image of school CJ-B in Ciudad Juárez, Chihuahua**

### **2.3 Panel Selection**

With the help of the school nurses and principals, around 15 physician-diagnosed asthmatic children were identified in each of the four schools. A total of 58 children were enrolled and participated throughout the duration of the study at the four schools. The parents of these children were sent a cover letter and the study flyer explaining the purpose of the study. Parents were invited for a presentation by the research staff at each of the four schools. The

presentations elicited great interest and enthusiasm among the parents, and their questions were satisfactorily answered by the research staff. The name and telephone numbers of the parents were recorded after every presentation. The screening questionnaire was administered to the parents who expressed an interest in the study. In general, prospective participants were screened for the following:

- Age - Since many health effects studies found air pollution-mediated asthma effects among children, our sample was restricted to individuals between six and 12
- Health Status - a physician's diagnosis of asthma
- Parent's consent
- Living in a non-smoking household
- Willingness and ability to complete (with the help of field staff) weekly questionnaires and eNO measurements
- Residence near the school (in a corresponding pollution exposure zone)

Once the participants met the initial inclusion criteria, a formal baseline questionnaire was administered to all their guardians. The baseline questionnaire took approximately 30 minutes to administer. Parental consent forms and the Health Insurance Portability and Accountability Act (HIPAA) forms were also signed by these guardians. The children participating in the study were matched on age, gender, ethnicity, and asthma severity in order to minimize the potential for spatial confounding in the epidemiological analyses. As an incentive, a \$50 gift card was offered to all the participants at the end of the study. The panel selection process went smoothly, and we were able to recruit enthusiastic and committed students for the study. Documents related to the health recruitment are included in Appendix C.

## **2.4 Environmental Exposure Measurement Concentrations**

Ambient air concentrations of PM ( $PM_{2.5}$  and  $PM_{10-2.5}$ ) and  $NO_2$  were measured concurrently, both indoors and outdoors, at the four schools during the study period. Both 48-hr integrated PM and 96-hr integrated  $NO_2$  samples were collected. Field sampling was conducted for sixteen weeks between January 7 and May 9, 2008. All indoor air samplers were mounted on a sampling manifold at an inconspicuous location in the room and the noise level was muffled with noise reduction devices. The ambient monitoring campaign was temporarily suspended whenever schools were not in session, namely weekends, spring break, and holidays or when distraction was deemed significant during the TAKS (Texas Assessment of Knowledge and Skills) tests. The samplers were set up either on the roof or in a fenced area for outdoor measurements. For quality assurance purposes, additional PM samplers were collected at the Mimosa El Paso Water Utilities Site, which is located approximately one mile southeast of the High Exposure School (EP-B) in El Paso. Deploying of ambient air monitors at each school as well as at the quality assurance site was performed between 8:30 and 11:30 am such that sampler collection was limited to  $48 \pm 1$  hrs for PM and  $96 \pm 1$  hrs for  $NO_2$  at all time.

### **2.4.1 Particulate Matter**

#### **2.4.1.1 Integrated $PM_{2.5}$ and $PM_{10-2.5}$ sampling**

The Harvard cascade impactors (Demokritou et al., 2002) were used to measure 48-hour integrated  $PM_{2.5}$ ,  $PM_{10-2.5}$  mass concentrations, both indoors and outdoors at each of the four schools and at the quality assurance site. Filter samples were collected twice a week (Monday-Wednesday, Wednesday-Friday). The sampling duration for the pollutant measurements was selected to overcome potential school site access limitations during the weekends, provide sufficient quantity of mass for gravimetric analysis and to provide sufficient fine-scale, time-

resolved data for health effects study. Thus, a 48-hr sampling duration was preferred to a 24-hr or a 7-days sampling period. New samplers were deployed every Monday and Wednesday mornings and completed samples were retrieved on Wednesday and Friday each week.

The Harvard cascade impactors are based on the principle of impaction, separate the particles according to their aerodynamic size. The basic mechanism for inertial deposition of particles is the specific motion of aerosol particles in the impaction zone or stagnation point. The streamlines change abruptly in this region. Particles larger than the impactor's cutsize will impact onto the plate while smaller particles will remain in the streamlines and not be collected (Demokritou et. al., 2001a, b).

As per the impaction theory, the Stoke's number, Stk, is the governing parameter for impaction and is defined as follows:

$$\text{Stk} = \frac{\rho_p d_p^2 U C_c}{9\mu W}$$

where,

$\mu$  is the dynamic viscosity of the air (g/cm)

$d_p$  is the particle density (g/cm<sup>3</sup>)

W is the nozzle diameter (cm)

U is the jet velocity (cm/sec)

Cc is the Cunningham slip correction factor

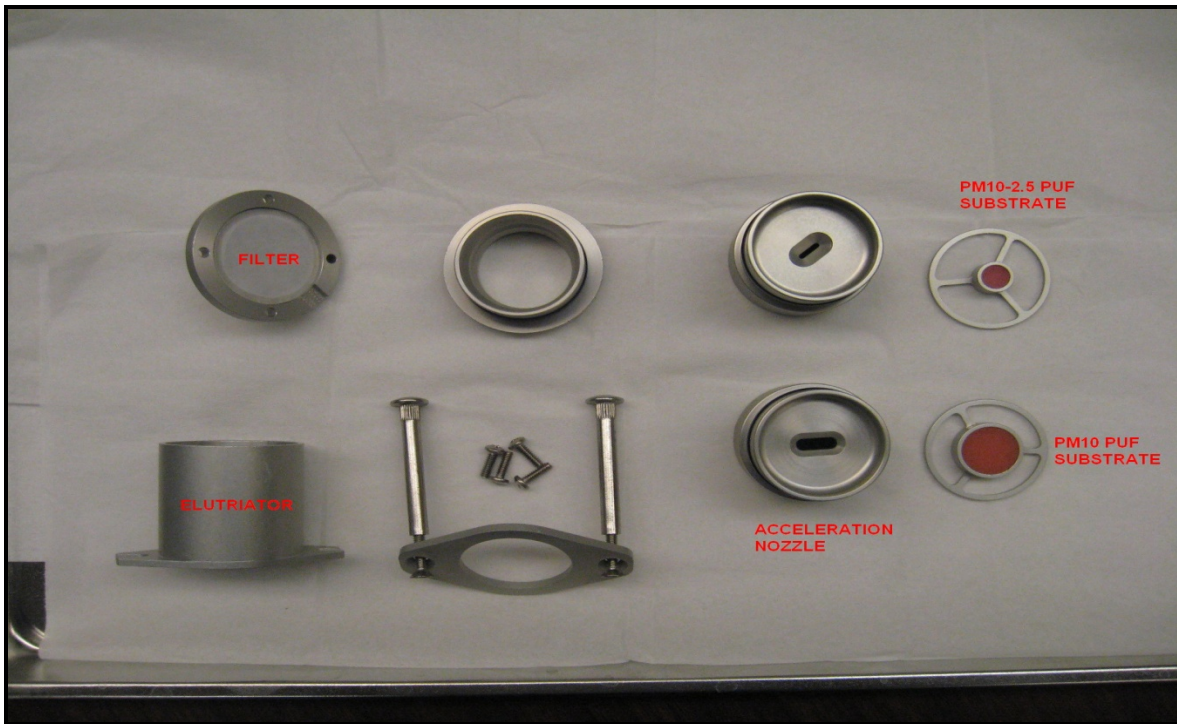
The Harvard Cascade Sampler operates at a flow rate of 5 liters per minute (LPM) and consists of two impaction stages (PM<sub>10+</sub>, PM<sub>10-2.5</sub>). These impaction stages are equipped with slit-shaped acceleration nozzles. PM<sub>10+</sub> and PM<sub>10-2.5</sub> were collected on individual polyurethane foam (PUF) impaction plugs. The final fine fraction was collected onto Teflon filter. The filters used were 37 mm diameter, 2  $\mu$ m pore size PTFE (Polytetrafluoroethylene) filters (Pall Life

Sciences, Ann Arbor, MI). MEDO Pumps (Model No.VP0125) were employed to generate a constant air stream of  $5 \pm 5\%$  LPM into the cascade samplers.

$PM_{2.5}$  and  $PM_{10-2.5}$  concentrations were determined based on the volume of air that passed through the Teflon filter and polyurethane foam during the sampling period respectively. Sampler flow rates were measured both before and after each 48-hr sampling period, in triplicate, using a Buck flow calibrator (Model no: M-30, 0.1-30 LPM, A.P.Buck, Inc). The target flow rate at the start of sampling was 5 LPM. The acceptable flow range at the end of 48-hr sampling was  $\pm 5\%$  of 5 LPM (4.75 to 5.25 LPM).

Figure 2-6 shows the various components of a disassembled cascade impactor. Figure 2-7 shows a fully assembled cascade impactor which is ready to be deployed in the field for PM sampling. Figure 2-8 shows the PM sampling setup at school EP-B. Medo Pumps (VP0125) were affixed inside an ice-chest, and the flow rate was adjusted using a needle valve. In order to reduce the amount of noise emitted due to the running of the pumps, a heavy object was positioned on top of the ice chest. This considerably reduced the noise emanating from the ice-chest. This action was deemed necessary to minimize the inconvenience to the school teachers and students.



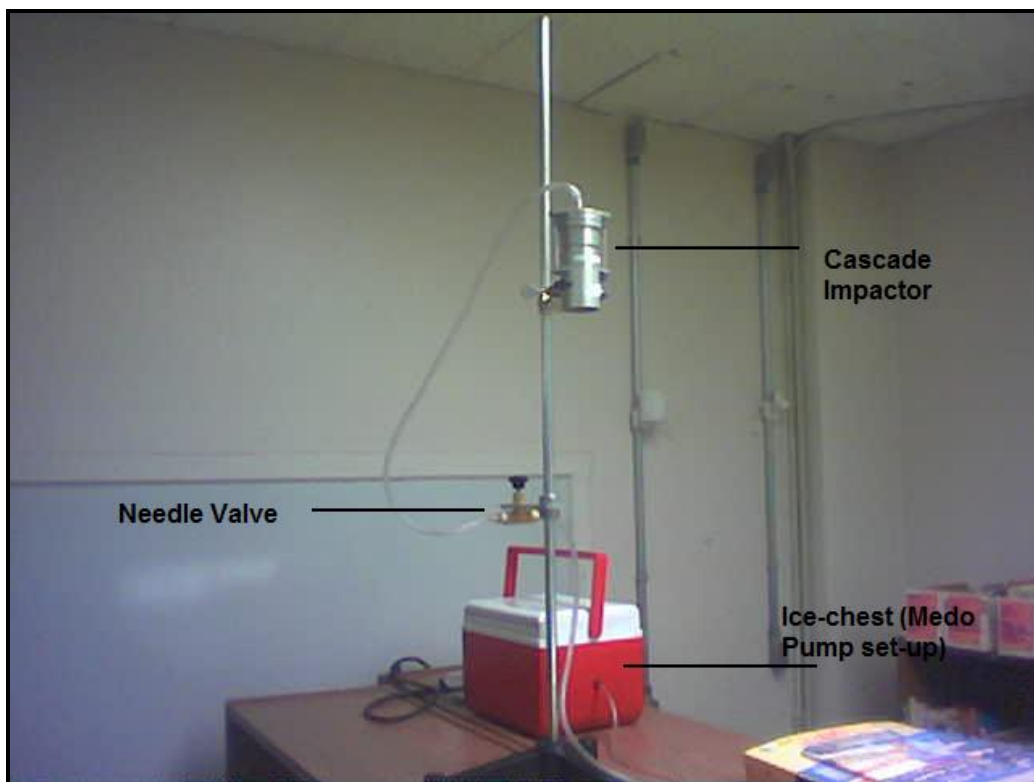


**Figure 2-6: Various components of the 5 LPM Cascade Impactor**



**Figure 2-7: A fully assembled cascade impactor ready for deployment in the field**





**Figure 2-8: PM Sampling set up at school EP-B**

All the components of the cascade impactor were washed thoroughly with soap and water before any use. Approximately, three to four days prior to their deployment, they were washed and set to dry under pristine conditions at the UTEP Air Quality Laboratory. After drying, the cascade impactors were assembled and leak-tested and then stored in Ziploc bags before being sent for deployment at the various study locations in El Paso & Ciudad Juárez. Chain of custody forms were prepared and maintained for these impactors. After the sampling period, the cascade impactors were retrieved and brought by the research crew to the UTEP Air Quality Laboratory. The log-sheets and chain of custody forms were perused for any possible discrepancies. The cascade impactors were then disassembled, and the filter media was stored in the designated petri-dishes. The same procedure was adopted for the rest of the study period. Two teams were

formed to conduct the environmental field sampling, one for El Paso and the other for Ciudad Juarez. The PM samplers were kept in the lab till the day when the teams were dispatched to the field.

#### **2.4.1.2 PM Sampling Locations**

The monitoring units were set up on the roofs of each elementary school for outdoor PM measurements. For indoor measurements, the samplers were located in a school room reflecting the general indoor environment of the schools where students were likely to spend substantial amount of time.

**School EP-A** The indoor sampler was located in the computer room at school EP-A. All the students, depending on their academic schedule, are required to do computer labs at least once a week. Therefore, this indoor location was considered a good location that would reflect the actual indoor exposures of the school students. The PM monitoring set-up was placed near the teacher's work desk. Figure 2-9 shows the indoor location of the PM instrumentation set-up at school EP-A. This gave us the assurance that the instrumentation would not be tampered with or touched by the young students.



**Figure 2-9: Indoor PM sampling at school EP-A**

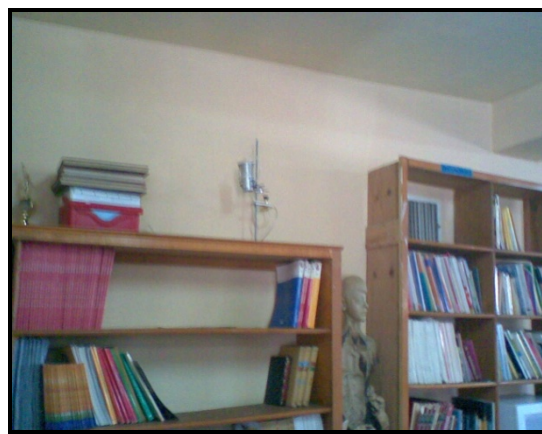
**School EP-B** At school EP-B, a library reference room was selected for the indoor monitoring (Figure 2-8). This indoor location was constantly visited by school teachers for course preparation. The PM sampler was positioned on top of one of the book shelves. The book shelves were approximately 1.5-2 meters in height.

**School CJ-A** At school CJ-A, the PM sampler was installed on top of a locker in a classroom (Figure 2-10).

**School CJ-B** Indoor monitoring at school CJ-B was performed in the library, which was visited by students and teachers on a regular basis. The instrumentation set-up was on top of a book shelf (Figure 2-11).



**Figure 2-10: Indoor PM sampling at CJ-A**



**Figure 2-11: Indoor PM sampling at CJ-B**

The cascade impactors deployed on Monday were retrieved after recording the necessary flow rates and put into Ziploc bags. Immediately after this procedure, new cascade impactors for the Wednesday- Friday run were deployed. Necessary flow rate adjustments were made. These cascade impactors were then retrieved on Friday during the health monitoring sessions at each of the four schools.

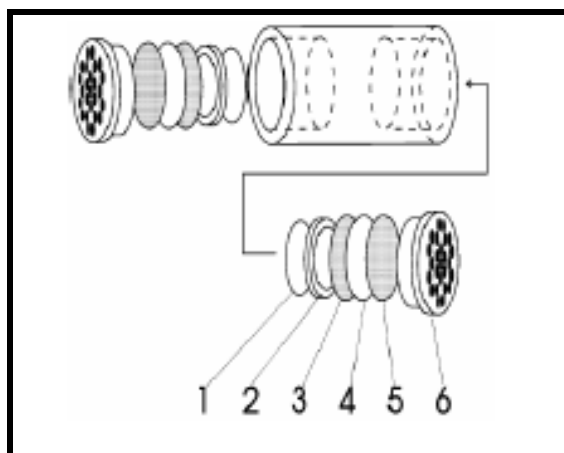
## 2.4.2 Nitrogen Dioxide

### 2.4.2.1 96-hr Integrated NO<sub>2</sub> Sampling

Ninety-six hour integrated (Monday- Friday) NO<sub>2</sub> concentrations were measured at each of the four schools using passive badge samplers (Ogawa & Company, Pompano Beach, FL, USA). A typical passive badge sampler is shown in Figure 2-12. These samplers have a cylindrical body composed of two chambers and each chamber has six parts as shown in Figure 2-13. These samplers work by passive diffusion of NO<sub>2</sub> onto a single cellulose filter pre-coated with triethanolamine. NO<sub>2</sub> was extracted from the filters and quantified via ion chromatography. The samplers were prepared (labeled and filled with coated filters) prior to sampling and analyzed post-sampling at the Environmental Science & Engineering Laboratory at the Harvard School of Public Health, Boston, MA. The NO<sub>2</sub> samplers were shipped in two batches from the Harvard School of Public Health to the UTEP Air Quality Laboratory.



**Figure 2-12: Ogawa Passive Monitor (Ogawa & Company, 1999)**



**Figure 2-13: Chamber parts of an Ogawa passive monitor: 1- Solid Pad, 2- Pad retaining ring, 3- Stainless screen, 4- Coated Collection Filter, 5- Stainless Screen, and 6- Diffuser end cap (Ogawa & Company, 1999)**

#### **2.4.2.2 Nitrogen Dioxide Sampling Location**

The samplers were attached over a support bracket and this bracket was fastened to iron fences and poles above ground with white plastic cords. In order to protect the samplers from the vagaries of nature, a weather shelter was used. This weather shelter conveniently slips over the sampler support bracket (Figure 2-14). The samplers were always sealed in screw-top, air-tight vials. The nitrogen dioxide sampling locations, both indoors and outdoors, was the same as the PM sampling set-up. The location for placing all the equipments for the field study had to be unobtrusive to students, protected from theft & weather and out of sight of passers-by. It also needed to allow adequate air circulation. Figure 2-15 shows the location of the passive sampler at school EP-B (outdoors).



**Figure 2-14: Weather shelter and support Bracket for the Ogawa Passive Sampler**



**Figure 2-15: Passive sampler at school EP-B (Outdoor Microenvironment)**

Similar to PM sampling, necessary log-sheets and chain of custody forms were prepared and used for NO<sub>2</sub> for the whole study period. Following collection, the samplers were refrigerated until shipment to the Harvard School of Public Health.

The general description and ventilation conditions at each school are shown in Table 2-1.

**Table 2-1: Heating, Cooling and ventilation at each school**

<b>City</b>	<b>Schools</b>	<b>General Description of School</b>	<b>Jan07- April 15, 2008</b>	<b>April 15- May 09, 2008</b>
El Paso	Low Exposure School: EP-A	49 years old school; individual evaporative coolers throughout	Closed-loop radiant heater, with minimum fresh air from outside	Evaporative cooler with 100% fresh make-up air for cooling
	High Exposure School: EP-B	50 years old school; individual evaporative coolers used except a new wing which uses refrigerated air	Closed-loop radiant heater, with minimum fresh air from outside	Individual evaporative cooler with 100% fresh make-up air for cooling
Ciudad Juarez	Low Exposure School: CJ-A	29 years old school; natural ventilation throughout the school	Kerosene gas heaters used throughout the winter season	Natural ventilation with doors and windows to classroom kept open during school sessions.
	High Exposure School: CJ-B	19 years old school; natural ventilation throughout the school	Kerosene gas heaters used in the indoor microenvironment	Natural ventilation with doors and windows kept open during the school sessions.

## **2.5 Laboratory Analysis**

### **2.5.1 Gravimetric Analysis**

The collected PM<sub>2.5</sub> and PM<sub>10-2.5</sub> mass on each filter sample and PUF respectively were quantified via gravimetric analysis at the UTEP Air Quality Laboratory. Mass concentrations for PM<sub>2.5</sub> were determined by using a 6-digit CAHN model C-33 microbalance (Orion Research, 1997). This microbalance has an accuracy of 2 µg and ultimate precision of 1 µg. A Mettler MX5 microbalance (Mettler-Toledo, Greifensee, Switzerland) was used to gravimetrically weigh the coarse PUFs (PM<sub>10-2.5</sub>). This instrument has a precision of 1 µg. The filters were stored in the gravimetric weighing room at the Air Quality Laboratory, Department of Civil Engineering prior to weighing.

Filters were conditioned, pre-weighed, and stored in petri dishes for a period not more than 30 days prior to be mounted into the PM samplers. Loaded filters were carefully removed from the field and transported to the laboratory at UTEP for gravimetric analysis. All samples were pre-conditioned to room temperature ( $20\pm5^{\circ}\text{C}$ ) and relative humidity ( $20\pm5\%$ ) for at least twenty-four hours by storing them in a custom-made storage cabinet in the laboratory prior to weighing. The effects of static were eliminated by using a static neutralizing bar (MEB Shockless Static Neutralizing Bar, SIMCO, Hartfield, PA, USA).

The average of three consecutive weight measurements was used as the final weight of the sampling media. If the consecutive measurements were not all within  $10\text{ }\mu\text{g}$ , then the media was reweighed. The accuracy of the microbalance was checked with a certified mass prior to each session of weighing filters and PUFs. Also, for each weighing run, laboratory blank filters were weighed. Utilizing the net weights of the filters (before and after the monitoring), the difference in mass was recorded for each sample (Orquiz, 2001). Detailed laboratory procedures are provided by Li et al. (2001) and Orquiz, (2001). Mass concentrations were reported as micrograms of PM per cubic meter of air ( $\mu\text{g}/\text{m}^3$ ).

### **2.5.2 Reflectance Analysis**

After post-weighing of  $\text{PM}_{2.5}$  filters, “blackness” or loss of reflectance on the filter was measured as a proxy for “soot” or black carbon (BC). Black carbon is a strong indicator of traffic-related emissions and the dominant light absorbing substance in airborne particulate matter. It has been reported that a high correlation exists between absorption coefficients of  $\text{PM}_{2.5}$  filters and measurement of black carbon (Van Roosbroeck et.al, 2006, Janssen et.al, 2001, Janssen et.al, 2000, Kinney et.al, 2000). Therefore, reflectance analysis of PM samples has been accepted as an expeditious and economical surrogate matter for quantifying BC in combustion-



related PM (Chaloulakou et.al, 2005; Penttinen et.al, 2000). Black Carbon is thermally stable; therefore, evaporation from filters during sampling, transport, or storage is not an issue (Fischer et.al, 2000).

Reflectance was measured using a Digital Smoke Stain Reflectometer (Model No: EEL 43D, Diffusion Systems Ltd). The lab blank filters were used to set reflectance at 100 percent, and the sampled filter was measured five times on different locations (5-point method), and the average was used in the calculations. The reflectances obtained from the filter measurements were transformed into absorption coefficients using the following formula (ISO 9835, 1993(E)):

$$a = \frac{A}{2V} \ln \frac{R_o}{R}$$

where,

R = Reflectance of the sampled filter

R<sub>o</sub> = Reflectance of the field blank filters

A is the loaded filter area (m<sup>2</sup>)

V is the volume sampled (m<sup>3</sup>)

a is the absorption coefficient (m<sup>-1</sup>\* 10<sup>-5</sup>).

The absorption coefficient is multiplied by 10<sup>-5</sup> for purposes of reporting (Cyrus et al., 2003; Fischer et al., 2000). These coefficients were converted to BC mass concentrations (µg/m<sup>3</sup>) assuming a conversion factor of 1 (Wilson and Liu, Harvard School of Public Health, personal communication). Calculations are explained in Appendix K.

## **2.6 Health Data Collection Procedure**

Throughout the sampling period, data on each child's daily symptoms (i.e., cough, wheeze, shortness-of-breath, and congestion), medications use, school absenteeism, health care utilization, and time-activity patterns were obtained via weekly morbidity questionnaires and

symptoms diaries administered to the subjects and their legal guardians respectively. The collection of the health data took place weekly. Each Friday morning, the current week's questionnaire was administered and reviewed with each child by the study field staff (Appendix F). Symptoms diaries, kept by the guardians, provided detailed information about the child's day to day activities and health (Appendix G). These too were collected every Friday, and new diaries were given to the children for the following week.

Also, on Friday morning, Exhaled Nitric Oxide (eNO) measurements for each child were collected using a portable, non-invasive NIOX MINO<sup>®</sup> Airway Inflammation Monitor (NIOX MINO, Aerocrine AB, Solna, Sweden) (Khalili et al., 2007). This monitor (dimensions: 240 x 130 x 100 mm) measures eNO in the exhaled breath from humans and was chosen to determine how environmental indicators associate with quantifiable and standardized clinical asthma measures of control. eNO is a sensitive and non-invasive biomarker of airway inflammation , which is an important determinant in the causal pathway of asthma and other lung diseases. (Dupont et al., 2003, CDC, [http://www.cdc.gov/nchs/data/nhanes/nhanes\\_07\\_08/ENO.pdf](http://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/ENO.pdf), accessed February 12, 2011). Figure 2-16 shows a typical NIOX MINO<sup>®</sup> Airway Inflammation Monitor.

Nitric oxide (NO) is usually produced and detected in the exhaled breath from the respiratory tract where it serves certain important regulatory function (Kharitonov and Barnes, 2002; Nevin and Broadley, 2002). Elevated NO values indicate airway inflammation or other pathological respiratory conditions and frequently increase in inflammatory processes such as asthma (Barraza-Villareal et al., 2008; Holguin et al., 2007; Steerenberg et al., 2003). In addition, eNO levels are approximately three to ten times greater in asthmatics than healthy controls (CDC, 2008). Exhaled nitric oxide measurements have been previously measured in

large epidemiological studies (van Amsterdam et al., 2000) and have been adopted by researchers to elucidate the deleterious impacts of air pollution on pulmonary inflammation in asthmatic children (Delfino et al., 2006; Holguin et al., 2007; Liu et al., 2009).

Hemmingway et al (2004) succinctly explained the NIOX-MINO sampling procedure. First, the subjects empty their lungs by exhaling the air and then inhale to total lung capacity NO-scrubbed air through a disposable filter attached to the NIOX-MINO sensor. Once this maneuver is accomplished, the subject exhales into the device for 10 seconds at a specified 5-20 cm H<sub>2</sub>O counter pressure. This is to ensure soft palate closure and minimize the risk of contamination of the exhaled gas from nasal NO originating from the paranasal sinuses (Silkoff et al., 1997). The exhaled flow rate is 50 ml/s as per the guidelines. In-built audio and graphical features in the device aid the subjects to perform the tests with minimal hassles.

Exhaled NO measurements were performed according to the American Thoracic Society and European Respiratory Society guidelines (ATS/ERS recommendations, 2005). Each eNO measurement took approximately one minute. Each subject performed the tests twice. Consumption of green leafy vegetables like spinach and of corned meat, as well as physical exercises are known to affect eNO measurements (Personal communication with Dr. Holguin, University of Pittsburgh Medical Center). Hence, the measurements were conducted at least one hour after either the intake of these food items or after any strenuous physical activity. The timing of the health measurements on Friday mornings corresponded to the proposed pollutant sampling regimen (weekdays only). Furthermore, repeated measurements on each child on the same day and time each week minimized fluctuations in participants' eNO due to natural variability and enabled each child to serve as his/her own control in longitudinal data analyses. Also, it is imperative to mention here that our target number of person-days of sampling ( $n = 960$

for eNO) were comparable to, and in most cases greater than, previous studies examining children's pulmonary inflammatory response (Koenig et al., 2005; Steerenberg et al., 2003; Fischer et al., 2002; Steerenberg et al., 2003; Adamkiewicz et al., 2004).

Through the course of the study, both in El Paso and Ciudad Juarez, the field crew developed an excellent rapport with the school authorities. The field crew involved with health monitoring was able to develop a trusting relationship with the participants that, in turn, facilitated the collection of data every week.



**Figure 2-16: NIOX MINO<sup>®</sup> Airway Inflammation Monitor**

## 2.7 Meteorological and Pollutant Data from TCEQ CAMS Sites

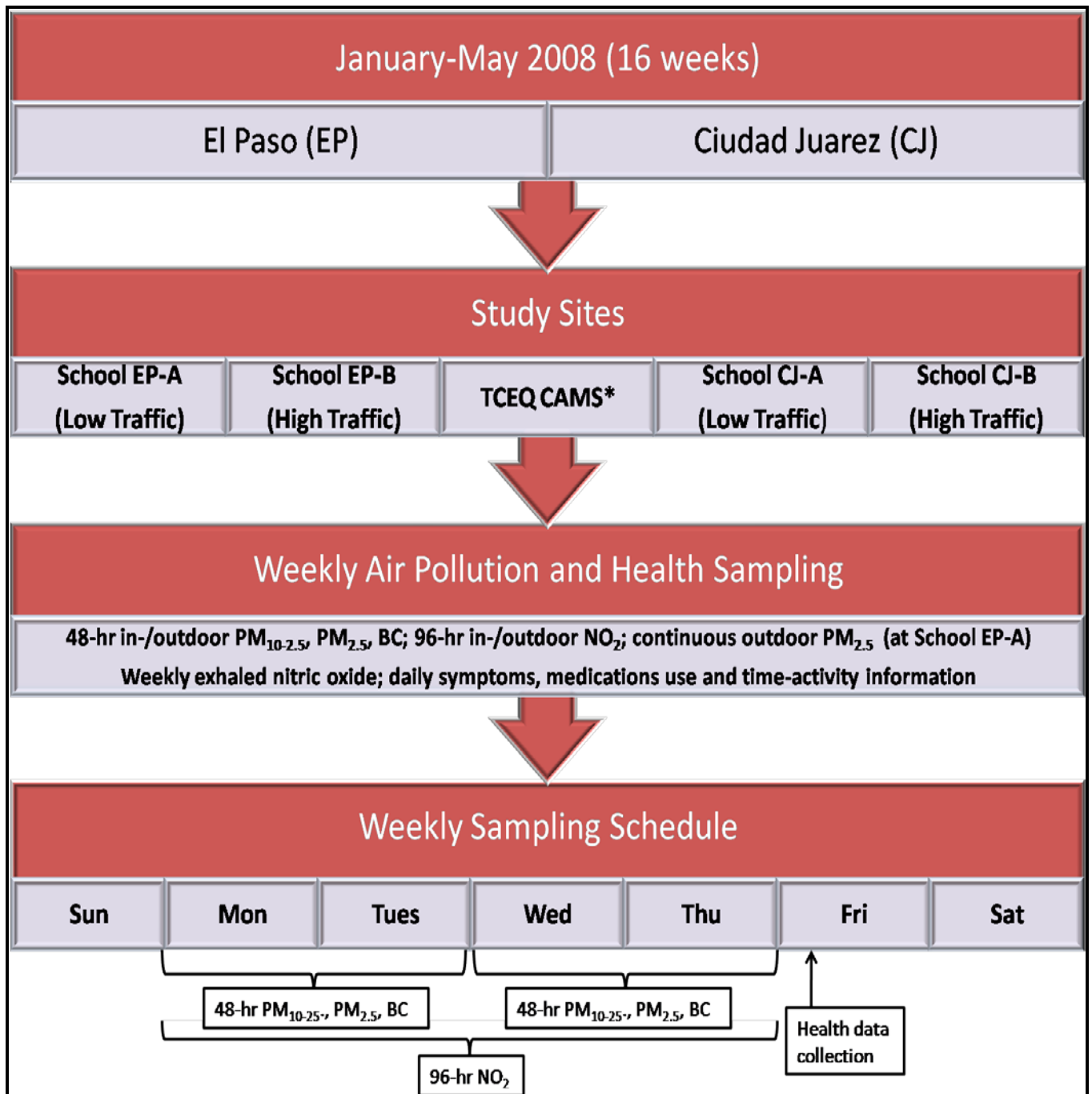
The Texas Commission on Environmental Quality (TCEQ) operates monitoring stations known as Continuous Air Monitoring Stations (CAMS) throughout the city of El Paso to measure various air pollutants and meteorological parameters. These stations were identified near each school, and data from these stations was and compared to the air quality data collected from the four schools. This comparison would explain if any intra-urban spatial variability exists in ambient air pollution in this region. Also, meteorological data like relative humidity, temperature, wind speed, wind direction, and wind gust were obtained from these stations. Data from six CAMS sites were obtained. These are CAMS 12, 37, 41, 49, 72 and 661. The locations of these TCEQ CAMS stations are included in Figure 2-1. The geo co-ordinates and addresses of these CAMS sites are shown in Table 2-2.

CAMS 12 site is surrounded by an urban environment and desert landscape. The University of Texas at El Paso campus lies to the north-northwest of this site. There is a residential area to the south and other commercial areas toward the east. The approximate distance of Interstate 10 to CAMS 12 is around 0.42 miles west. CAMS 37, located inside Ascarate Park, is 1.62 mi northeast of the Bridge of the Americas and 0.56 mi north of the Border Highway, that runs adjacent to the International Border in El Paso. CAMS 41 is located in the Chamizal National Monument, a park located 0.2 mi north of the Bridge of the Americas. The Bridge of the Americas is one of the principal border crossing for passenger vehicles and diesel trucks. CAMS 41 is 0.2 mi south of I-10. CAMS 49 is located in Socorro in the lower valley area of El Paso. CAMS 72 is located in Skyline Park in Northeastern Part of El Paso. It is located very close to Ft. Bliss Military Base. CAMS 661 is the Advanced Transformer site in Cd. Juarez. It is located near a neighborhood of brick kilns and *maquiladoras*. Figure 2-17 is the

flowchart elucidating all the environmental and health measurements undertaken during the study.

**Table 2-2: Geo co-ordinates and addresses of the various TCEQ CAMS sites**

TCEQ Site	Latitude	Longitude	Address
CAMS 12	31°46' 05" N	106°30'04" W	250 Rim Road, El Paso, TX
CAMS 37	31 44 48 N	106 24 10 W	650 R E Thomason Loop
CAMS 41	31 45 56 N	106 27 18 W	800 S.San Marcial Street
CAMS 49	31 39 43 N	106 18 11 W	201 South Nevarez Road
CAMS 72	31 53 38 N	106 25 32 W	5050 A.Yvette
CAMS 661	31 41 23 N	106 27 35 W	Calle El Cid



**Figure 2-17: Study Design Flowchart of all the environmental and health measurements undertaken during the study period.**

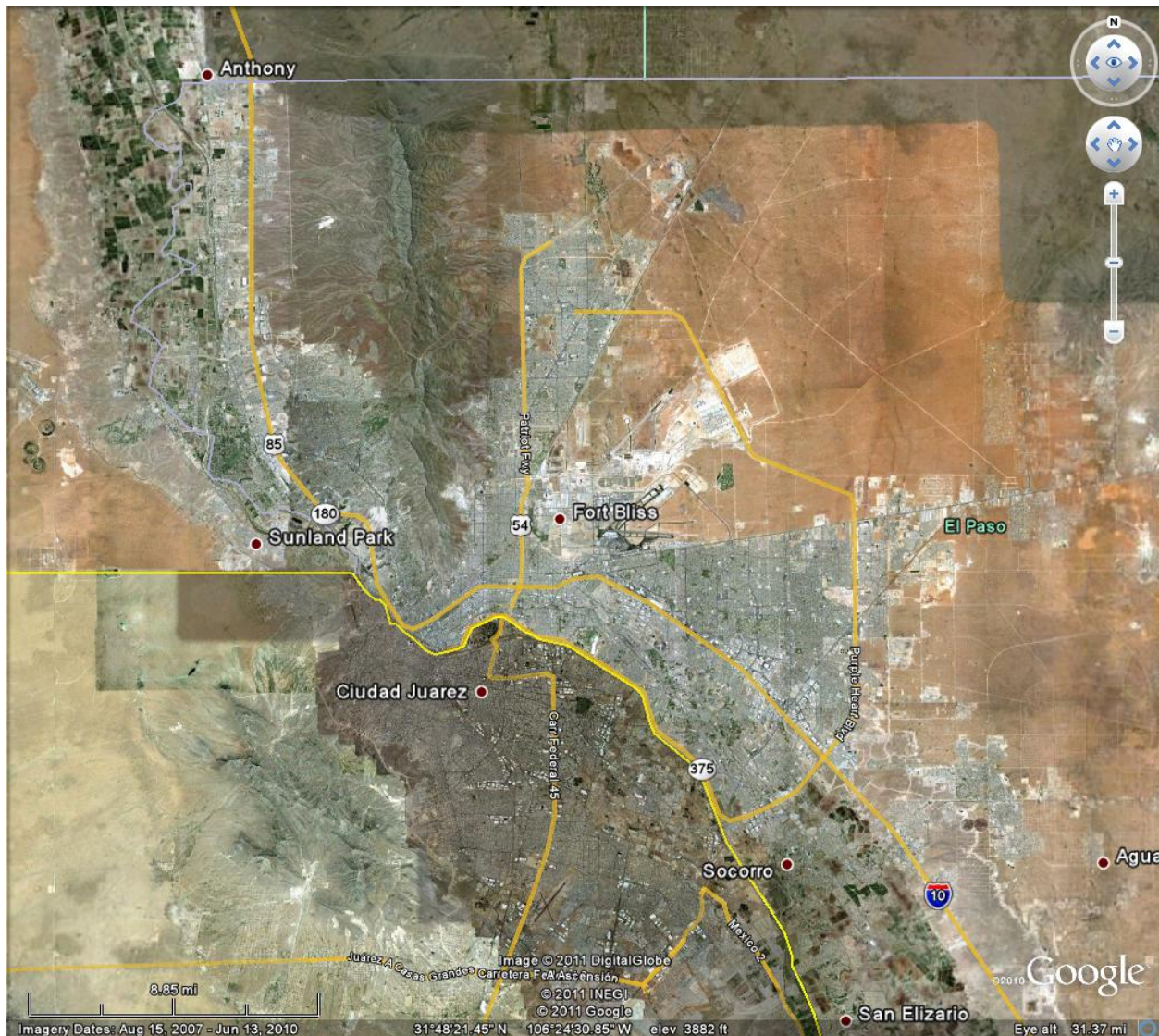
## 2.8 Topography and Meteorology of the Paso del Norte Region

Figure 2-18 is a satellite imagery of the Paso del Norte region. The cities of El Paso and Ciudad Juarez share the same air shed but separated by an international boundary. El Paso is

located at 31°47'25"N and 106°25'24" W. The Rio-Grande River serves as the international boundary between both these cities. El Paso is approximately 3,800 feet (1,140 m) above sea level and is currently the sixth-largest city in Texas and 22<sup>nd</sup> largest city in the United States. El Paso is a geographically isolated metropolitan area, more than 550 km (342 miles) east of the nearest large metropolitan city of Phoenix, Arizona. The metropolitan areas of El Paso and Ciudad Juarez are part of the Chihuahuan desert, the easternmost section of the Basin and Range physiographic region. The North Franklin Mountains, with the highest peak at 7,192 feet (2,192 m) above sea level, cleave the city of El Paso into the western one-third and the central and eastern two-third of the whole metropolitan area. These mountains are a north-south oriented mountain chain that is approximately 23.1km(14.4 miles) long and 5.0 km (3.1 miles) wide (Harbour, 1972).

This region experiences a warm, arid climate experiencing very hot summers with little precipitation, and mild, dry winters. The average rainfall for this region is around 9.4 inches (240 mm) per year. The precipitation normally occurs in late summer and early fall, around July-September. The region receives an average of 7.9 hours of sunshine in December to 12.8 hours of sunshine during June with 85.8% of possible sunshine per annum. The record high temperature for El Paso is 114 °F (46 °C) and the record low is -8 °F (-22 °C). Temperatures range from an average high of 57.2 °F (14.0 °C) and an average low of 32.9 °F (0.5 °C) in January to an average high of 95.3 °F (35.2 °C) in June and an average low of 72.0 °F (22.2 °C) in July.

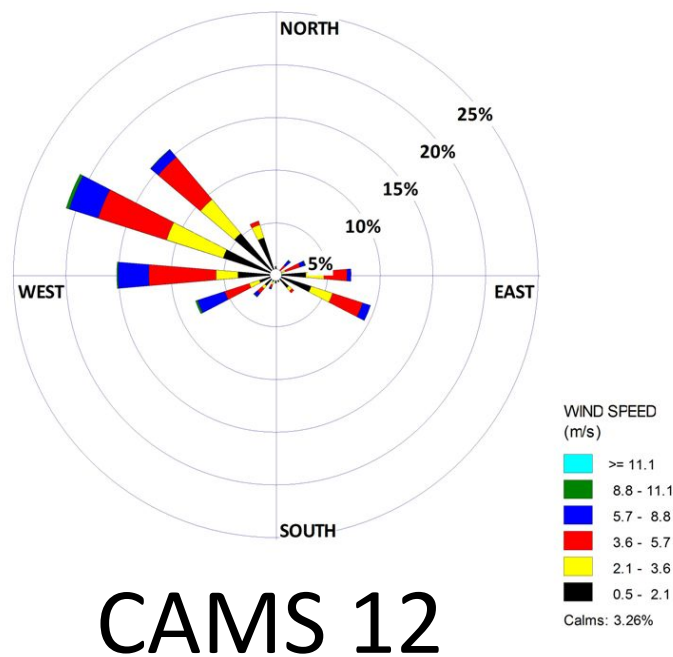




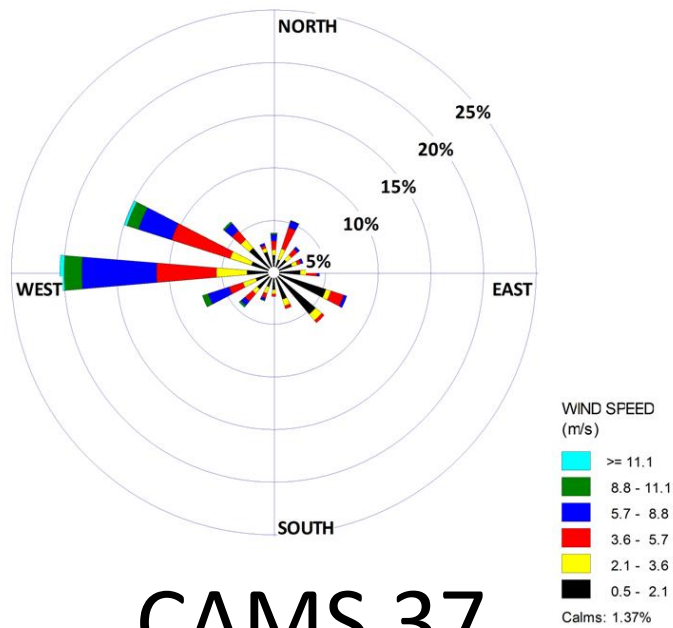
**Figure 2-18: Satellite imagery of the Paso del Norte region**

Wind roses for the study period were plotted using the Wind rose software from Lakes Environmental, Inc. CA. Wind rose diagrams provide a graphical means of displaying the joint probability density function of wind speed and wind directions. The data to plot the wind roses was obtained from the TCEQ CAMS stations. Wind speed and wind direction are important meteorological parameters that influence the concentrations of the PM concentrations (Pleijel et al., 2004, Baxter et al., 2008). These parameters might influence the spatial differences in the

pollutant concentrations. The wind roses for the six CAMS stations for the study period (January 01-May 31, 2008) are shown in Figure 2-19 to 2-. For the study period, the prevalent wind direction was north-westerly across all the six sites. We observe higher ambient concentrations of PM at low and high wind speeds (wind erosion threshold wind speed  $\sim 7$  m/s) than at moderate wind speeds (Baxter et al., 2008, Elminir et al., 2005, Li et al., 2001). The greatest frequency of winds occurred at 4-6 m/s.

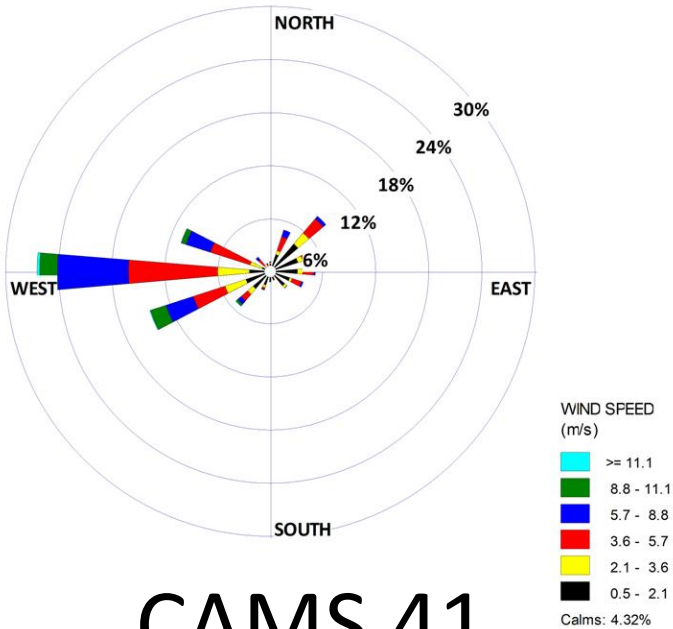


**Figure 2-19: Wind rose diagram for CAMS 12 station (January 01- May 31, 2008)**



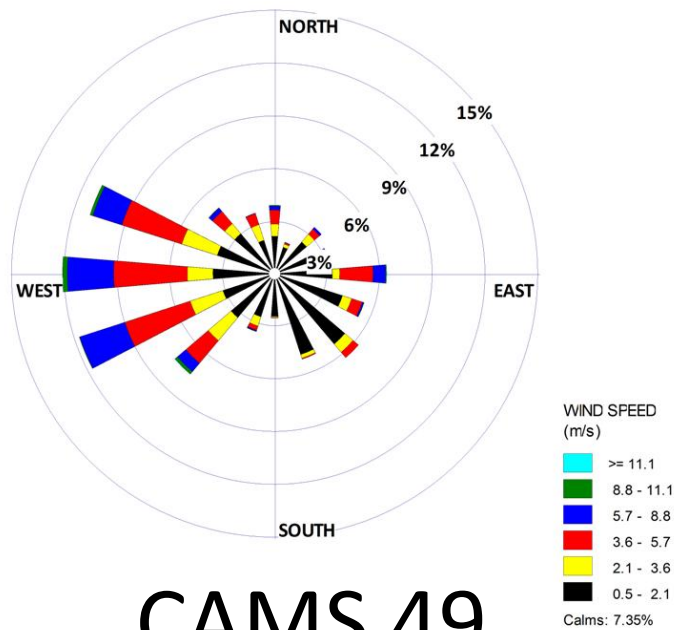
# CAMS 37

Figure 2-20: Wind rose diagram for CAMS 37 station (January 01- May 31, 2008)



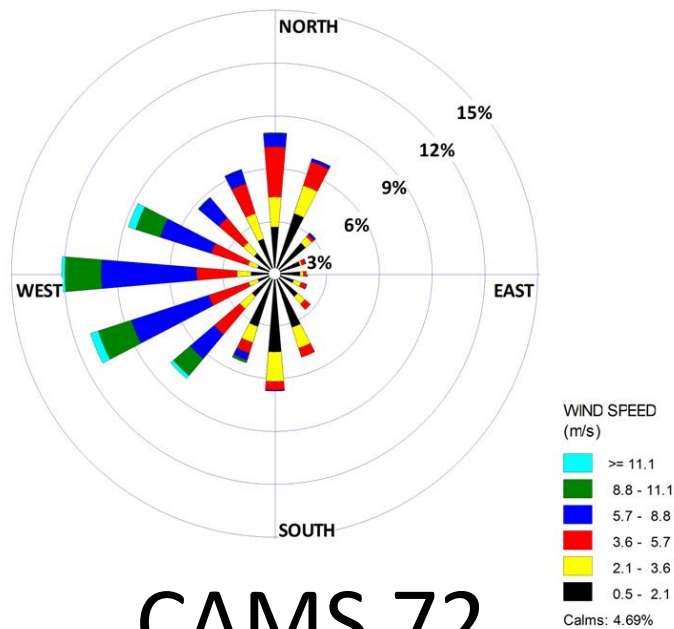
# CAMS 41

Figure 2-21: Wind rose diagram for CAMS 41 station (January 01-May 31, 2008)



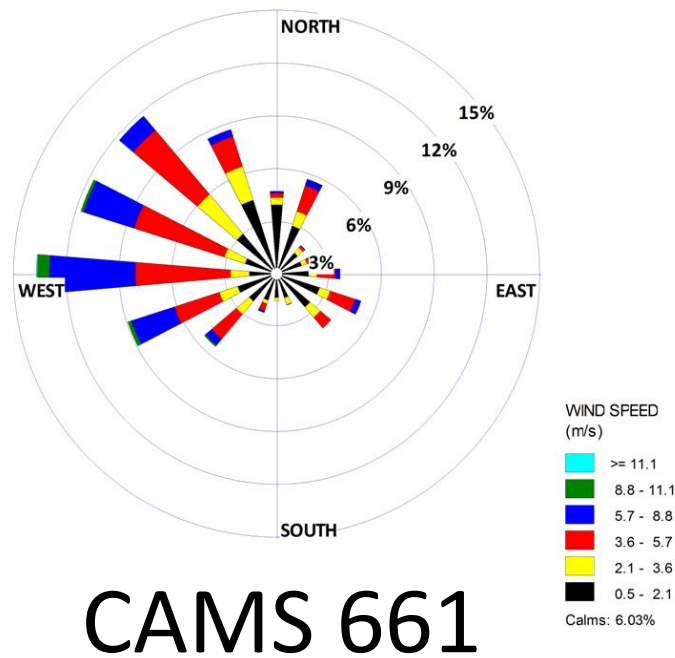
CAMS 49

Figure 2-22: Wind rose diagram for CAMS 49 station (January 01-May 31, 2008)



CAMS 72

Figure 2-23: Wind rose diagram for CAMS 72 station (January 01-May 31, 2008)



**Figure 2-24: Wind rose diagram for CAMS 661 station (January 01-May 31, 2008)**

Frequent dust storms, especially in the early spring months of March, April, and May, are a common phenomenon of the Paso del Norte region. El Paso averages 14.5 significant dust events per year with moderate to severe repercussions for the local community in terms of adverse respiratory conditions, especially for the sensitive populations like the elderly, pregnant women and asthmatic children. In addition, near zero visibility during such events can be fatal to motorists on the roadways in this region. Table 2-3 summarizes the major high wind events during the study period reported by The National Oceanic and Atmospheric Administration (NOAA) (Southwest Weather Bulletin 2008). Wind storms are quite prevalent during the months of March and April with wind speeds in excess of 80 mph in some cases. The last column of the table indicates the remarks made by the field operators during the sampling session.



**Table 2-3: Reported high wind events during the study period**

Date	Event	Operator Remark
01/07/2008	Strong wind gust to near 50 mph across the region	High wind, dusty
02/04/2008	Wind gusts to 76 mph over the region	High wind, dusty
03/16/2008	Very windy across southern New Mexico and western Texas with widespread blowing dust and sand.	High wind
04/09/2008- 04/10/2008	High winds and blowing dust and sand across the region with gusts around 50 mph occurring both days. Building damages reported in the eastern part of El Paso	Dust storm

### 3.0 Statistical Methods and Data Analyses

#### 3.1 Environmental Exposure Concentration Characterization

Descriptive statistics for characterizing environmental exposure concentrations was calculated using SPSS for Windows, v. 15.0, 17.0 (SPSS, Inc., Chicago, IL), or Microsoft Excel 2007. Time series graphs and boxplots were plotted to characterize the pollutant concentrations at various sites and microenvironments. Specifically, Spearman's correlation coefficients were computed to assess the inter-side associations for each pollutant and the intra-pollutant associations at each site, which helped understand any temporal similarity in pollutant concentrations at the paired sites (Pinto et. al., 2004; Wilson et al., 2005). Indoor-outdoor relationships among the pollutants studied were determined by Pearson Correlation Coefficients. Also, the correlations between the pollutant concentrations from schools and meteorological parameters from the various CAMS sites (located nearest to the respective schools) were studied by Spearman's correlation coefficients.

Spatial variability of the monitored pollutants like PM and its components and NO<sub>2</sub> across all the sampling and CAMS sites was assessed using coefficients of divergence (COD). COD values provide indication of the differences between the absolute concentrations of pollutants at simultaneously sampled monitoring sites (Pinto et al., 2004; Krudysz et al., 2008). The COD provides degree of uniformity between simultaneously sampled sites, j and k by:

$$COD_{i,k} = \sqrt{\frac{1}{p} \sum_{i=1}^p \left[ \frac{x_{i,j} - x_{i,k}}{x_{i,j} + x_{i,k}} \right]^2}$$

where  $x_{i,j}$  is the  $j^{\text{th}}$  concentration measured at site j over the sampling period, and p is the number of observations. A small COD ( $r < 0.2$ ) indicates similar pollutant concentrations between two sites, whereas a value approaching unity indicates significant difference in the absolute

concentrations and subsequent spatial non-uniformity between the sites.  $j$  &  $k$  are two different sites, and  $p$  is the number of observations.

Smaller COD values indicate similarities between pollutants concentrations measured as various sites, while COD values approaching unity indicate vast differences in the absolute concentrations between the sites. COD values  $> 0.20$  are defined as relatively heterogeneously spatially distributed. COD values elucidate the differences between the absolute concentrations among simultaneously sampled sites (M.A. Krudysz et al., 2008). In addition, the 90<sup>th</sup> percentile of absolute pollutant concentration differences ( $\delta P_{90}$ ) between two paired sites is an additional measure that indicates the level of spatial uniformity.

### **3.2 Environmental Data Quality Assurance and Quality Control (QA/QC) Procedures**

Throughout the study period, standard data quality assurance procedures (U.S.EPA 2001) were adopted to ensure the highest quality of data achievable. Lab blanks and field blanks were used to ensure this procedure. Field blanks, both for PM and NO<sub>2</sub>, were transported with the designated field samples. Field blanks were momentarily exposed to ambient air (approximately for five seconds) before being completely resealed. The PM field blank was sealed in a Ziploc bag and kept beside the designated field sample for the entire sampling period. Similarly, the NO<sub>2</sub> field samplers were momentarily exposed to ambient air, put in the small zip-lock bag and then stored in a dark brown vial. Additionally, duplicate samples were deployed every week in both microenvironments at various schools for accuracy and precision.

For this study, 30 field blanks were collected for PM and 12 were collected for NO<sub>2</sub>. Field blanks and duplicate samples were collected for every sampling run starting the first week of February 2008. Taking into account the fact that this study was binational, it was decided to collect field blanks and duplicates for every sample run to ensure that there was no



contamination while the samplers were transported to and fro from the lab to the study sites. The number of field blanks collected were 69% and 81% for PM and NO<sub>2</sub> respectively for quality insurance purposes. Results from the field blank analyses helped in defining contamination resulting from field sampling and transport activities.

### 3.2.1 Limit of Detection

Limit of Detection (LOD) is the low range critical value that a method-specific procedure can reliably discern. Analytical procedures and sampling equipment impose specific constraints on the determination of limits of detection. For filter (or cartridge)-based methods, the LODs are determined by the use of field and laboratory blanks. For this study, LOD was determined as three times the standard deviation of the field blanks. The field blank means, standard deviation and LOD for PM<sub>2.5</sub>, PM<sub>10-2.5</sub>, NO<sub>2</sub> and BC are shown in Table 3-1. Table 3-2 shows the same parameters for the monitored pollutants but excluding outliers. The LOD in µg/m<sup>3</sup> is obtained by assuming a flow rate of 5 LPM for 48 hours.

**Table 3-1: Field Blank and Limit of Detection for collected data (one outlier included for PM<sub>2.5</sub>, & NO<sub>2</sub> each and 2 outliers for PM<sub>10-2.5</sub>)**

Pollutant	n	Mean	Std. Dev	LOD	LOD
PM <sub>2.5</sub>	30	18.8 µg	28.0 µg	84.0 µg	5.8 µg/m <sup>3</sup>
PM <sub>10-2.5</sub>	30	16.1 µg	13.9 µg	41.7 µg	3.0 µg/m <sup>3</sup>
NO <sub>2</sub>	14	0.40 ppb	1.6 ppb	4.7 ppb	-
BC	30	-1.6 µg	2.0 µg	6.0 µg	0.4 µg/m <sup>3</sup>

The mean of the field blanks for PM<sub>2.5</sub> was 18.8 µg. However, if one outlier was excluded from this analysis, the mean reduced to 15.5 µg. The mass difference between pre- and post-weight for this outlier was 114 µg. This was due to possible field contamination or, perhaps, some contamination while assembling or disassembling the cascade impactor. Similarly, for PM<sub>10-2.5</sub>, the mean of the field blanks was 16.1 µg. But if two outliers were excluded from the

analysis, the mean reduced to 14.3  $\mu\text{g}$ . The difference in the gravimetric weight for these two outliers was 41.0  $\mu\text{g}$  and 41.3  $\mu\text{g}$ . Also, the LOD reduced from 4.7 to 2.9 ppb when one of the outliers was excluded from the field blank analysis.

It would be prudent to mention here that the analysis of the field blanks pointed towards some negative mass that was obtained for the  $\text{PM}_{2.5}$  and  $\text{PM}_{10-2.5}$  field samples. This was because of the post-weights being less than the pre-weights. There were three field blank samples that had negative mass for  $\text{PM}_{2.5}$  and three for  $\text{PM}_{10-2.5}$ . Many factors can account for this, some of which are changes in temperature, humidity, static charges and vibrations etc. (Jantunen et al, 2002).

The pre-weighing and post-weighing of filters and pufs were accomplished at the UTEP Air Quality Laboratory and reweighing of filters demonstrated a high reliability of the weighing process. Considering the high concentrations observed during the study period, it can be very conservatively assumed that the negative mass did not have any veritable impact on the final results. Therefore, analyses of the blank filters did not suggest the need for adjustment for filter contamination.

**Table 3-2: Field Blank and Limit of Detection for collected data (one outlier excluded for  $\text{PM}_{2.5}$  &,  $\text{NO}_2$  each and 2 outliers for  $\text{PM}_{10-2.5}$ )**

Pollutant	n	Mean	Std. Dev	LOD	LOD
$\text{PM}_{2.5}$	29	15.5 $\mu\text{g}$	21.8 $\mu\text{g}$	65.5 $\mu\text{g}$	4.6 $\mu\text{g}/\text{m}^3$
$\text{PM}_{10-2.5}$	29	14.3 $\mu\text{g}$	12.4 $\mu\text{g}$	37.2 $\mu\text{g}$	2.7 $\mu\text{g}/\text{m}^3$
$\text{NO}_2$	13	0.1 ppb	1.0 ppb	2.9 ppb	-
BC	30	-1.6 $\mu\text{g}$	2.0 $\mu\text{g}$	6.0 $\mu\text{g}$	0.4 $\mu\text{g}/\text{m}^3$

The above field blank values represent an error of less than 0.04 %, 0.04%, 0.1%, and 0.002% in the respective  $\text{PM}_{2.5}$ ,  $\text{PM}_{10-2.5}$ , BC, and  $\text{NO}_2$  measurements. Similarly, precision was assessed by collected duplicate or co-located samples for every study run of the monitored

pollutants. Valid field data was assessed for precision, completeness, and accuracy (if reference methods were available) for each pollutant. The duplicate samples were collected in conjunction with the field samples and underwent the same handling and transportation procedure.

### 3.2.2 Precision

Precision represents the reproducibility of measurements as determined by collocated sampling using the same methods or by propagation of individual measurement errors determined by replicate analysis, blank analysis, and performance tests (Watson et al., 2011).

Precision for a set of repeated data,  $s_i$ , is defined as deviation from the average response to the same measurable quantity as follows:

$$s_i = \left[ \frac{\sum_{j=1}^m \{C_{i,j} - C_{i,average}\}^2}{m} \right]^{1/2}$$

where  $C_{i,j}$  is the  $j^{\text{th}}$  measured concentration for the  $i^{\text{th}}$  set of data;

$C_{i,average}$  is the average concentration for the  $i^{\text{th}}$  set of data; and

$m$  is the number of repeated measurements for the selected sample set  $i$ .

For a particular set of paired duplicate samples,  $j = 2$  and  $C_{i,average} = (C_{i,1} + C_{i,2})/2$

$$s_i = \left[ \frac{\sum_{j=1}^2 \{C_{i,j} - \frac{C_{i,1} + C_{i,2}}{2}\}^2}{2} \right]^{1/2} = \left[ \frac{(C_{i,1} - C_{i,2})^2}{2} \right]^{1/2} = \left[ \frac{\Delta_i^2}{2} \right]^{1/2}$$

where,  $\Delta_i$  is the difference between the two collocated samples for set  $i$ .

The absolute precision for a group of data that is composed of multiple sets of duplicate samples collected from different locations at different time,  $s$ , is defined as (Lewne et al 2004; Hoek et al, 2002; Sarnat et al 2000):

$$s = \left[ \frac{\sum_{i=1}^n \frac{\Delta_i^2}{2}}{n} \right]^{1/2} = \left[ \frac{\sum_{i=1}^n \Delta_i^2}{2n} \right]^{1/2}$$

The overall relative precision,  $p$ , can be expressed in percentage of the mean observations and the goal is set at  $\pm 10\%$ ,

$$p = \frac{s}{\left( \sum_{i=1}^n \frac{C_{i,average}}{n} \right)} \times 100 \%$$

Overall the precision of the pollutant measurements were robust. The absolute and relative precision values are given in Table 3-3. The CV was 11.7% ( $n=22$ ) for  $PM_{2.5}$ , 15.7% ( $n=22$ ) for  $PM_{10-2.5}$ , 11.7% ( $n=12$ ) for  $NO_2$  and 8.5% ( $n=22$ ) for BC.

**Table 3-3: Precision Values for the Pollutants measured during the study period**

Pollutant	No. of paired samples	RMSD	Absolute Precision	Relative Precision, $p$ (%)
$PM_{2.5}$	22	2.45	$1.8 \mu\text{g}/\text{m}^3$	0.117
$PM_{10-2.5}$	22	5.02	$3.6 \mu\text{g}/\text{m}^3$	0.157
$NO_2$	12	1.74	1.2 ppb	0.117
BC	22	0.12	$0.1 \mu\text{g}/\text{m}^3$	0.085

A Paired-Samples 't' test was also performed to study the precision of the co-located samples. The tests showed that for all the pollutants, the duplicate samples were not statistically different from one another ( $p > 0.05$ ). The Pearson's ' $r$ ' was greater than 0.94 for all the pollutants. This vindicated the robustness of our results and provided us the assurance that the

sampling and lab procedures were done with utmost precision. The results of this t- test are tabulated in Table 3- 4.

**Table 3-4: Paired-Samples ‘t’ test for field and duplicate samples**

Pollutant	Paired Differences					t	Pearson's r	t-test p-value
	Mean	Std. Dev	Std. Error	95% CI of the difference				
				Lower	Upper			
PM <sub>2.5</sub>	0.02	2.56	0.55	-1.11	1.15	0.04	0.938	0.9700
PM <sub>10-2.5</sub>	-1.38	4.94	1.05	-3.57	0.81	-1.31	0.947	0.2037
NO <sub>2</sub>	0.22	1.81	0.52	-0.92	1.37	0.43	0.975	0.6766
BC	0.02	0.12	0.03	-0.04	0.07	0.60	0.994	0.5582

Although it is important to handle and prepare the instruments for PM monitoring with utmost care and precision for robust results, the proper measurements of the air flow rate into the cascade impactors is of paramount importance. The MEDO pumps were very reliable throughout the study period and our flow rates were in the acceptable range of 4.75 to 5.25 LPM. In addition, throughout the course of the study period, we did not face any inclement weather except for some dust- storm events in the month of April. However, these storm conditions did not affect our field sampling.

Precision for all pollutant concentrations, in general, were well within (or close to) the target precision goal of 10% set for this study. The measured environmental quantities were considered reliably precise, as judged from the precisions derived from the large number of duplicate samples collected in the study.

### 3.2.3 Data Completeness

Completeness is the percentage of valid data reported compared to the total number of samples that are scheduled to be collected during the sampling period. Completeness was determined using the following:

$$\text{Completeness} = [(N_x - N_c)/N_c] \times 100$$

With regard to discrete measurements,  $N_x$  is the number of samples for each species that valid results are obtained and  $N_c$  is the number of samples that scheduled to be collected and analyzed. Completeness for continuous methods is the percentage of valid data obtained from the total amount possible, over a given time period. For this project, the completeness objective for all species and measurements is 75%.

For all measured species and microenvironments, the percentage of valid samples was generally high (> 90 %), showing that samples were successfully collected and analyzed (Table 3-5). Completeness was calculated as the number of samples collected divided by the target number of samples.

**Table 3-5: Data Completeness: Valid Samples as Compared to Total Collected Samples**

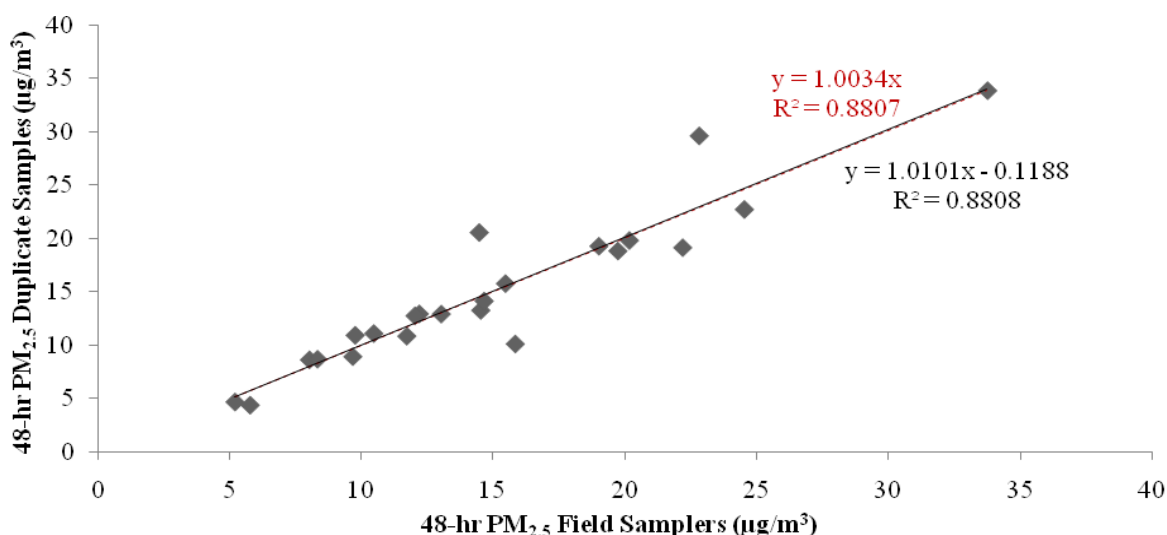
Microenvironment	Pollutant	School	Total Collected	Valid (n %)	n ≥ LOD (%)
Indoor	PM <sub>2.5</sub>	EP-A	31	29 (94%)	25 (86%)
		EP-B	31	30 (97%)	23 (77%)
		CJ -A	29	29 (100%)	29 (100%)
		CJ -B	28	28 (100%)	28 (100%)
	PM <sub>10-2.5</sub>	EP-A	31	31 (100%)	31 (100%)
		EP-B	31	31 (100%)	30 (97%)
		CJ-A	29	28 (97%)	28 (100%)
		CJ-B	28	27 (97%)	27 (100%)
	NO <sub>2</sub>	EP-A	16	16 (100%)	12 (75%)
		EP-B	16	16 (100%)	16 (100%)
		CJ-A	16	16 (100%)	16 (100%)
		CJ-B	16	16 (100%)	16 (100%)
	BC	EP-A	31	31 (100%)	3 (10%)
		EP-B	31	31 (100%)	19 (61%)
		CJ-A	29	29 (100%)	26 (90%)
		CJ-B	28	28 (100%)	28 (100%)
Outdoor	PM <sub>2.5</sub>	EP-A	31	29 (94%)	24 (82%)
		EP-B	31	31 (100%)	30 (97%)
		M	32	32 (100%)	30 (94%)
		CJ-A	29	29 (100%)	29 (100%)
		CJ-B	28	28 (100%)	28 (100%)
	PM <sub>10-2.5</sub>	EP-A	31	31 (100%)	31 (100%)
		EP-B	31	31 (100%)	31 (100%)
		M	32	32 (100%)	32 (100%)
		CJ-A	29	28 (97%)	28 (100%)
		CJ-B	28	27 (97%)	27 (100%)
	NO <sub>2</sub>	EP-A	15	15 (100%)	9 (60%)
		EP-B	16	16 (100%)	16 (100%)
		CJ-A	16	16 (100%)	16 (100%)
		CJ-B	16	16 (100%)	16 (100%)
	BC	EP-A	31	31 (100%)	8 (26%)
		EP-B	31	31 (100%)	25 (81%)
		M	32	32 (100%)	25 (78%)
		CJ-A	29	29 (100%)	29 (100%)
		CJ-B	28	28 (100%)	29 (100%)

We observed a high number of BC samples below the LOD. There were just three indoor BC samples which were above the limit of detection at the Low Exposure School in El Paso. Similarly, there were only eight outdoor BC samples above the limit of detection at the Low

Exposure School in El Paso. These accounted for just 10% and 26 % of indoor and outdoor samples collected at that school respectively. However, these were still included in the analysis.

### 3.2.4 Comparison of Duplicate Samples

Collocated samples for PM, NO<sub>2</sub> and BC were further analyzed with the Pearson correlation analysis to evaluate possible bias resulted from the field protocols or laboratory analytical processes. For each set of the duplicate measurements, a best straight-line fit was always achieved with a slope and an intercept. However, a straight-line fit with an intercept may unintentionally imply the existence of a measurement drift, such as drifting of zero a few minutes after the zero calibration for an electronic measurement device.

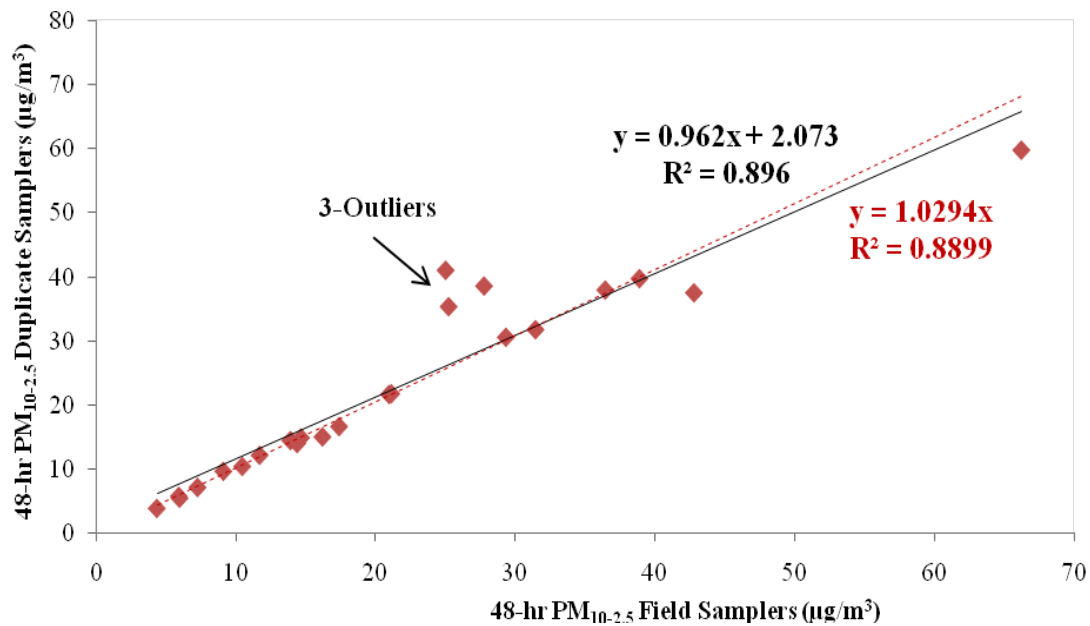


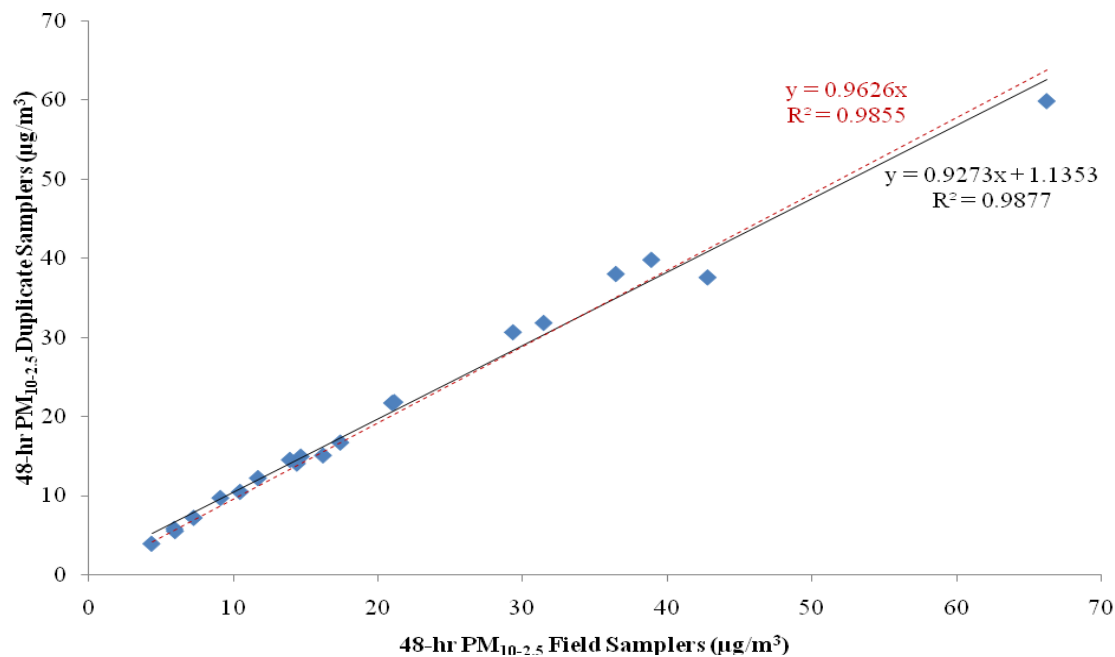
**Figure 3-1 : Scatter plot for Indoor and Outdoor PM<sub>2.5</sub> Collocated samples (µg/m³)**

The scatter plot for Indoor and Outdoor PM<sub>2.5</sub> is shown in Figure 3-1. The R<sup>2</sup> value is 0.880 with a slope of 1.01. Figure 3-2 is the scatter plot for the PM<sub>10-2.5</sub> collocated samples. This figure includes the three outliers. However, when these outliers are removed from the analysis, the R<sup>2</sup> value improves drastically from 0.896 to 0.988 (Figure 3-3). Excellent correlation values were observed for the BC and the NO<sub>2</sub> collocated samplers too. Figure 3-4 is the scatter plot for

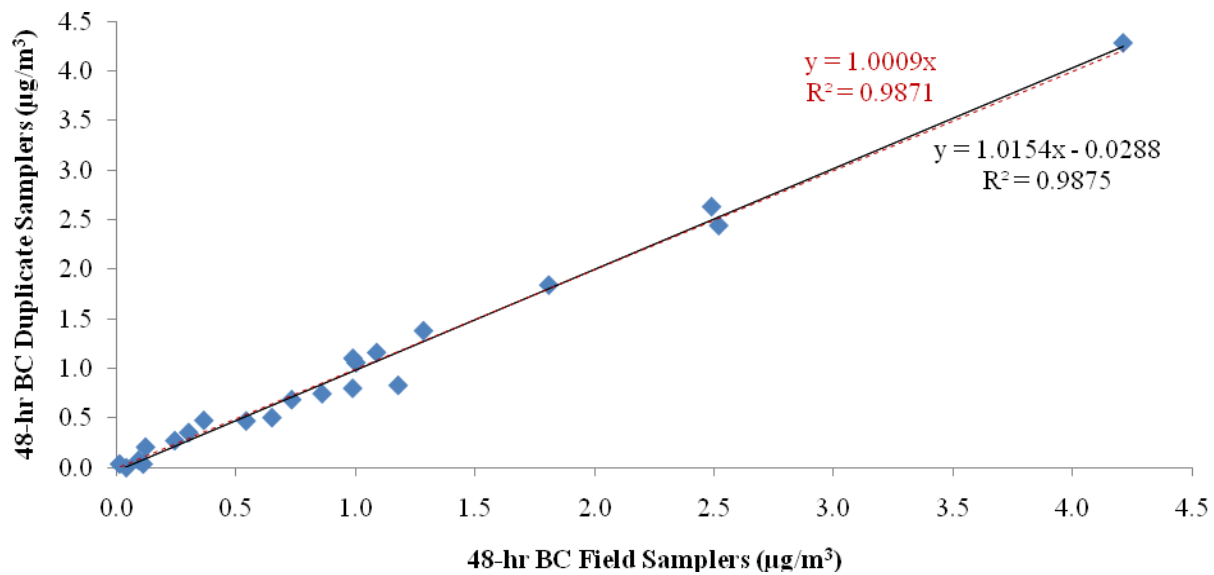


the collocated BC samples (deployed both indoor and outdoors). An excellent slope of 1.015 and  $R^2$  value of 0.9875 for both indoor and outdoor collocated samples was obtained. Similarly, Figure 3-5 is the scatter plot for both indoor and outdoor collocated  $\text{NO}_2$  samples. A slope of 0.9511 and  $R^2$  value is 0.9511.

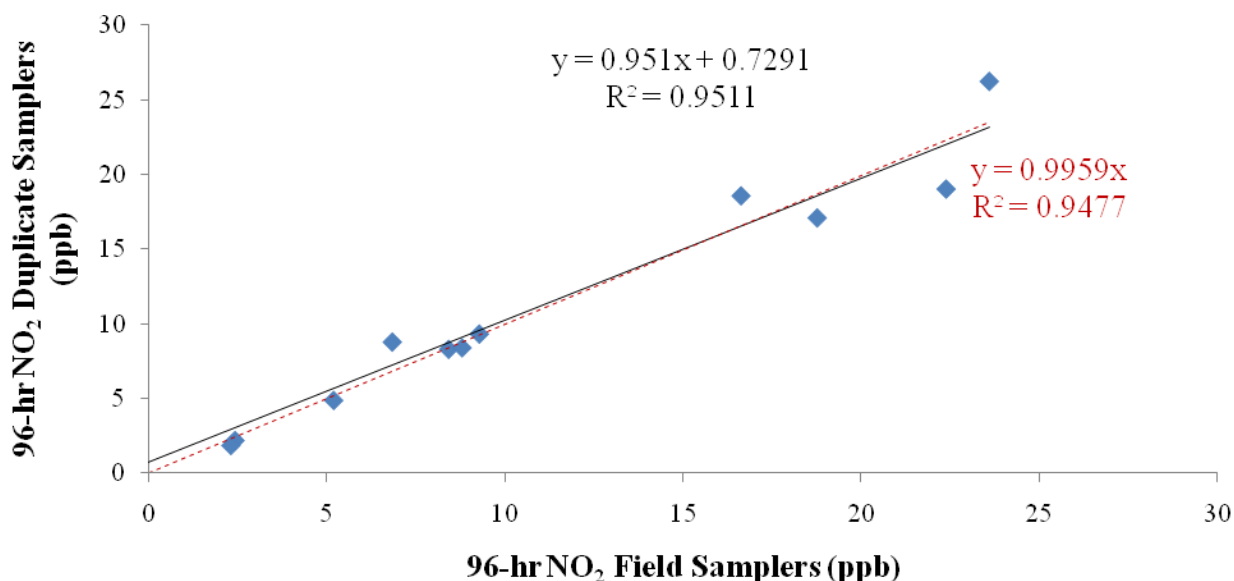




**Figure 3-3: Scatter plot for Indoor & Outdoor PM<sub>10-2.5</sub> Collocated samples (with three outliers removed)**



**Figure 3-4: Scatter plot for Indoor & Outdoor BC Collocated samples (µg/m³)**



**Figure 3-5: Scatter plot for Indoor and Outdoor NO<sub>2</sub> Collocated samples (ppb)**

However, a slope varying from 0.93 (PM<sub>10-2.5</sub>) to 1.02 (BC) with an intercept as high as 2.07 may invalidate the observed concentration variations between indoor and outdoor environments where the difference may be as small as 10%. Therefore, the data was reevaluated by a straight-line fit with zero intercept (no drift expected). The straight-line fit is seen as dashed red lines in the above figures. The  $R^2$  values stay almost indistinguishable: 0.88 (PM<sub>2.5</sub>), 0.89 (PM<sub>10-2.5</sub>), 0.95 (NO<sub>2</sub>), and BC (0.99) with the slopes converging from 0.88 (PM<sub>2.5</sub>) to 1.00 (NO<sub>2</sub>). It appears that the best straight-line fit may generate the best mathematical results with two variables, yet the improvement is minimal and may generate false interpretation of the results.

The  $R^2$  values for these collocated samples for every monitored pollutant are shown in Table 3-6. The  $R^2$  values were all very high indicating a high data quality for all the monitored pollutants. Overall, the duplicate samples compare extremely well and do not show any systematic bias.

**Table 3-6: R<sup>2</sup> values of the collocated samples for monitored pollutants**

Microenvironment	Pollutant	R <sup>2</sup> values
Indoor	PM <sub>2.5</sub>	0.974
	PM <sub>10-2.5</sub>	0.985
	BC	0.975
	NO <sub>2</sub>	0.988
Outdoor	PM <sub>2.5</sub>	0.93
	PM <sub>10-2.5</sub>	0.813
	BC	0.996
	NO <sub>2</sub>	0.957
Indoor & Outdoor	PM <sub>2.5</sub>	0.880
	PM <sub>10-2.5</sub>	0.896 (outliers included)
	PM <sub>10-2.5</sub>	0.988 (outliers excluded)
	BC	0.988
	NO <sub>2</sub>	0.951

### **3.2.5 One-sampled Kolmogorov-Smirnov Non-Parametric Test for Indoor and Outdoor Pollutant Concentrations**

The one-sampled Kolmogorov-Smirnov Non-Parametric test was used to test the null hypothesis that the pollutant concentrations followed a normal distribution. The results of this test are shown in Table 3-7. The results show that all the pollutants, both indoors and outdoors, are normally distributed for the study period at  $p < 0.01$  level. The non-significant  $p$  values suggest that the assumed normal distribution is indeed a good fit for the data collected in this study (SPSS, Inc., version 17.0).

**Table 3-7: Kolmogorov-Smirnov ‘Z’ Non-Parametric Test Results for indoor and outdoor pollutant concentrations**

Pollutant	Location	EP-B Indoor	EP-B Outdoor	EP-A Indoor	EP-A Outdoor	CJ-B Indoor	CJ-B Outdoor	CJ-A Indoor	CJ-B Outdoor
PM <sub>2.5</sub>	Kolmogorov-Smirnov ‘z’	.887	.780	.781	.699	1.023	1.095	.995	.874
	P- value	<b>.411</b>	<b>.576</b>	<b>.575</b>	<b>.713</b>	<b>.246</b>	<b>.182</b>	<b>.276</b>	<b>.429</b>
PM <sub>10-2.5</sub>	Kolmogorov-Smirnov ‘z’	1.444	.976	.835	.847	.785	.936	.740	.772
	P- value	<b>.031</b>	<b>.296</b>	<b>.489</b>	<b>.469</b>	<b>.568</b>	<b>.346</b>	<b>.644</b>	<b>.590</b>
PM <sub>10</sub>	Kolmogorov-Smirnov ‘z’	1.180	.908	.673	.785	.743	.959	.725	.788
	P- value	<b>.123</b>	<b>.382</b>	<b>.756</b>	<b>.568</b>	<b>.639</b>	<b>.316</b>	<b>.670</b>	<b>.564</b>
NO <sub>2</sub>	Kolmogorov-Smirnov ‘z’	0.57	0.339	0.725	0.807	0.759	0.833	0.804	0.875
	P- value	<b>0.901</b>	<b>1</b>	<b>0.669</b>	<b>0.532</b>	<b>0.611</b>	<b>0.492</b>	<b>0.537</b>	<b>0.429</b>
BC	Kolmogorov-Smirnov ‘z’	.680	.800	1.166	.944	.748	.738	.916	1.008
	P- value	<b>.744</b>	<b>.544</b>	<b>.132</b>	<b>.335</b>	<b>.631</b>	<b>.648</b>	<b>.371</b>	<b>.261</b>

### 3.2.6 Paired sampled t-tests for pollutant concentrations between the four schools

Paired sampled t-tests for pollutant concentrations monitored in this research were computed between all the four schools. This analysis was done for both indoor and outdoor concentrations. The assumption of normal distribution was satisfied from the Kolmogorov-Smirnov ‘Z’ test. The null hypothesis was that the sample means were equal, and the alternate hypothesis was that the means were unequal (2-tailed). The confidence interval (CI) was set to 95% ( $\alpha = 0.05$ ). The t-test p –value suggests that for all the pollutants, the difference between the sample means were statistically significant from each other for the various school pair sites, except for indoor PM<sub>10-2.5</sub> and indoor PM<sub>10</sub> between EP-A and EP-B. The results, therefore, indicate that the null hypothesis may be rejected expect for indoor PM<sub>10-2.5</sub> and indoor PM<sub>10</sub> between EP-A and EP-B. Tables 3-8 to 3-12 show the analysis and the subsequent t-test ‘p’ value for the various school pairings.

**Table 3-8: Paired t-tests of 48-hr indoor and outdoor PM<sub>2.5</sub> concentrations between the four schools**

Microenvironment	School Pair	Paired Differences for PM <sub>2.5</sub>					t	df	t-test p-value
		Mean	Std. Dev	Std. Error	95% CI of the difference				
					Lower	Upper			
Indoor	EP-B - EP-A	2.23	4.95	0.94	0.31	4.15	2.38	27	0.0246
	EP-B - CJ-B	-11.39	8.06	1.58	-14.65	-8.14	-7.20	25	0.0000
	EP-B - CJ-A	-18.09	9.35	1.80	-21.79	-14.39	-10.05	26	0.0000
	EP-A - CJ-B	-13.48	8.15	1.63	-16.84	-10.12	-8.27	24	0.0000
	EP-A - CJ-A	-20.52	11.65	2.28	-25.22	-15.81	-8.98	25	0.0000
	CJ-B - CJ-A	-8.00	11.78	2.23	-12.56	-3.43	-3.59	27	0.0013
Outdoor	EP-B - EP-A	6.87	5.91	1.10	4.63	9.12	6.27	28	0.0000
	EP-B - CJ-B	-9.09	8.32	1.60	-12.38	-5.80	-5.68	26	0.0000
	EP-B - CJ-A	-18.06	11.63	2.20	-22.57	-13.55	-8.21	27	0.0000
	EP-A - CJ-B	-15.14	10.31	2.06	-19.39	-10.88	-7.34	24	0.0000
	EP-A - CJ-A	-23.55	13.36	2.62	-28.95	-18.15	-8.99	25	0.0000
	CJ-B - CJ-A	-8.92	8.49	1.60	-12.21	-5.62	-5.56	27	0.0000

**Table 3-9: Paired t-tests of 48-hr indoor and outdoor PM<sub>10-2.5</sub> concentrations between the four schools**

Microenvironment	School Pair	Paired Differences for PM <sub>10-2.5</sub>					t	df	t-test p-value
		Mean	Std. Dev	Std. Error	95% CI of the difference				
					Lower	Upper			
Indoor	EP-B - EP-A	0.99	6.90	1.24	-1.54	3.52	0.80	30	0.4289
	EP-B -CJ-B	-15.38	9.79	1.92	-19.33	-11.42	-8.01	25	0.0000
	EP-B -CJ-A	-32.31	12.25	2.36	-37.15	-27.46	-13.70	26	0.0000
	EP-A -CJ-B	-16.14	8.48	1.66	-19.57	-12.72	-9.71	25	0.0000
	EP-A - CJ-A	-33.13	15.37	2.96	-39.21	-27.05	-11.20	26	0.0000
	CJ-B - CJ-A	-17.18	16.28	3.13	-23.62	-10.74	-5.48	26	0.0000
Outdoor	EP-B - EP-A	14.59	7.43	1.33	11.86	17.32	10.93	30	0.0000
	EP-B -CJ-B	-12.10	14.24	2.79	-17.85	-6.35	-4.33	25	0.0002
	EP-B -CJ-A	-32.27	13.46	2.59	-37.59	-26.94	-12.45	26	0.0000
	EP-A -CJ-B	-26.56	16.26	3.19	-33.13	-19.99	-8.33	25	0.0000
	EP-A - CJ-A	-46.84	17.14	3.30	-53.62	-40.05	-14.20	26	0.0000
	CJ-B - CJ-A	-19.56	11.96	2.30	-24.29	-14.83	-8.50	26	0.0000

**Table 3-10: Paired t-tests of 48-hr indoor and outdoor PM<sub>10</sub> concentrations between the four schools**

Microenvironment	School Pair	Paired Differences for PM <sub>10</sub>					t	df	t-test p-value
		Mean	Std. Dev	Std. Error	95% CI of the difference				
					Lower	Upper			
Indoor	EP-B - EP-A	3.45	11.66	2.20	-1.07	7.97	1.57	27	0.1289
	EP-B - CJ-B	-26.18	16.14	3.23	-32.84	-19.52	-8.11	24	0.0000
	EP-B - CJ-A	-50.15	20.66	4.05	-58.50	-41.81	-12.38	25	0.0000
	EP-A - CJ-B	-28.85	13.99	2.85	-34.75	-22.94	-10.10	23	0.0000
	EP-A - CJ-A	-54.26	25.86	5.17	-64.94	-43.59	-10.49	24	0.0000
	CJ-B - CJ-A	-25.29	26.65	5.13	-35.83	-14.74	-4.93	26	0.0000
Outdoor	EP-B - EP-A	21.73	11.96	2.22	17.18	26.27	9.78	28	0.0000
	EP-B - CJ-B	-20.53	21.18	4.15	-29.09	-11.97	-4.94	25	0.0000
	EP-B - CJ-A	-50.71	20.51	3.95	-58.82	-42.60	-12.85	26	0.0000
	EP-A - CJ-B	-41.78	25.47	5.20	-52.54	-31.03	-8.04	23	0.0000
	EP-A - CJ-A	-71.63	27.15	5.43	-82.84	-60.42	-13.19	24	0.0000
	CJ-B - CJ-A	-28.34	14.32	2.76	-34.01	-22.67	-10.28	26	0.0000

**Table 3-11: Paired t-tests of 48-hr indoor and outdoor NO<sub>2</sub> concentrations between the four schools**

Microenvironment	School Pair	Paired Differences for NO <sub>2</sub>					t	df	t-test p-value
		Mean	Std. Dev	Std. Error	95% CI of the difference				
					Lower	Upper			
Indoor	EP-B - EP-A	4.18	2.63	0.66	2.78	5.58	6.36	15	0.0000
	EP-B -CJ-B	-106.75	99.48	24.87	-159.76	-53.74	-4.29	15	0.0006
	EP-B -CJ-A	-14.64	12.84	3.21	-21.48	-7.79	-4.56	15	0.0004
	EP-A -CJ-B	-110.93	97.90	24.47	-163.10	-58.76	-4.53	15	0.0004
	EP-A - CJ-A	-18.82	10.99	2.75	-24.68	-12.96	-6.85	15	0.0000
	CJ-B - CJ-A	92.11	90.74	22.68	43.76	140.46	4.06	15	0.0010
Outdoor	EP-B - EP-A	9.95	2.28	0.59	8.68	11.21	16.90	14	0.0000
	EP-B -CJ-B	-12.62	8.85	2.21	-17.34	-7.91	-5.71	15	0.0000
	EP-B -CJ-A	-4.54	4.06	1.01	-6.70	-2.38	-4.48	15	0.0004
	EP-A -CJ-B	-22.97	8.18	2.11	-27.50	-18.44	-10.88	14	0.0000
	EP-A - CJ-A	-14.33	3.32	0.86	-16.17	-12.49	-16.69	14	0.0000
	CJ-B - CJ-A	8.08	8.42	2.11	3.59	12.57	3.84	15	0.0016

**Table 3-12: Paired t-tests of 48-hr indoor and outdoor BC concentrations between the four schools**

Microenvironment	School Pair	Paired Differences for BC					t	df	t-test p-value
		Mean	Std. Dev	Std. Error	95% CI of the difference				
					Lower	Upper			
Indoor	EP-B - EP-A	0.42	0.29	0.05	0.32	0.53	8.06	29	0.0000
	EP-B -CJ-B	-1.53	0.86	0.17	-1.87	-1.19	-9.26	26	0.0000
	EP-B -CJ-A	-1.02	0.83	0.16	-1.34	-0.69	-6.45	27	0.0000
	EP-A -CJ-B	-2.02	1.01	0.20	-2.43	-1.61	-10.21	25	0.0000
	EP-A - CJ-A	-1.48	0.91	0.18	-1.84	-1.11	-8.40	26	0.0000
	CJ-B - CJ-A	0.51	0.57	0.11	0.29	0.74	4.75	27	0.0001
Outdoor	EP-B - EP-A	0.52	0.29	0.05	0.41	0.62	10.07	30	0.0000
	EP-B -CJ-B	-1.58	0.91	0.17	-1.94	-1.22	-9.02	26	0.0000
	EP-B -CJ-A	-0.89	0.59	0.11	-1.12	-0.66	-7.93	27	0.0000
	EP-A -CJ-B	-2.14	1.05	0.20	-2.55	-1.73	-10.61	26	0.0000
	EP-A - CJ-A	-1.44	0.67	0.13	-1.69	-1.18	-11.41	27	0.0000
	CJ-B - CJ-A	0.64	0.72	0.14	0.37	0.92	4.75	27	0.0001

### 3.2.7 Exhaled Nitric Oxide (eNO) Quality Assurance and Quality Control Procedures

Completeness, absolute precision, and relative precision of the eNO measurements were calculated using the same formulae as used for the pollutant measurements. These are presented in Table 3-13 through 3-15. Completeness was expressed as the percentage of the collected valid sample number to the target sample number over the study period. For the exhaled nitric oxide (eNO) measurements, two measurements were obtained per subject per sampling session. This resulted in the targeted 32 valid measurements for every child during the whole sampling period. The average completeness across all the subjects was 85% and a large majority of the subjects (50 subjects) met the 75% completeness target. Precision estimates were calculated for sets of paired duplicate samples, comparing the measurements for each subject with each sampling period. The mean subject-specific relative precision for eNO measurements across all subjects was 7.6 %, which met our target of less than 10%.



**Table 3-13: Completeness and precision estimates for health outcome measurements  
(subjectwise)**

City	School	Subject ID	RMSD	Absolute Precision	Relative Precision	Valid N	% Completeness
El Paso	EP-A	EP-A-01	1.4577	1.0308	0.0877	32	100
		EP-A-02	1.9526	1.3807	0.0728	32	100
		EP-A-03	2.7358	1.9345	0.3087	32	100
		EP-A-04	2.7172	1.9214	0.2155	30	94
		EP-A-05	2.6220	1.8540	0.2109	12	38
		EP-A-06	7.4017	5.2338	0.0793	28	88
		EP-A-07	3.6056	2.5495	0.0500	32	100
		EP-A-09	3.0542	2.1596	0.1572	32	100
		EP-A-10	3.7417	2.6458	0.0611	32	100
		EP-A-11	2.3604	1.6690	0.0771	28	88
		EP-A-12	3.3166	2.3452	0.0560	28	88
		EP-A-13	6.4587	4.5670	0.0788	28	88
		EP-A-14	2.4766	1.7512	0.0801	30	94
		EP-A-15	5.4528	3.8557	0.0987	30	94
		EP-A-16	2.8011	1.9807	0.1042	26	81
	EP-B	EP-B-01	4.3661	3.0873	0.0657	32	100
		EP-B-02	2.5949	1.8348	0.1135	30	94
		EP-B-03	1.4790	1.0458	0.0826	32	100
		EP-B-04	6.4087	4.5316	0.0540	28	88
		EP-B-05	2.9155	2.0616	0.0364	32	100
		EP-B-06	1.5706	1.1106	0.0955	30	94
		EP-B-07	4.8516	3.4306	0.0989	26	81
		EP-B-08	1.3628	0.9636	0.0775	28	88
		EP-B-09	1.7153	1.2129	0.1290	26	81
		EP-B-10	3.0923	2.1866	0.0245	32	100
		EP-B-11	3.4319	2.4267	0.0472	18	56
		EP-B-12	2.5704	1.8176	0.1542	28	88
		EP-B-13	3.6899	2.6092	0.0626	26	81
		EP-B-14	2.4202	1.7113	0.0624	28	88
Ciudad Juarez	CJ-A	CJ-A-01	2.3905	1.6903	0.0426	28	88
		CJ-A-02	1.5811	1.1180	0.0552	24	75
		CJ-A-04	2.0412	1.4434	0.0829	24	75
		CJ-A-05	1.3844	0.9789	0.0675	24	75
		CJ-A-06	2.2404	1.5842	0.1443	26	81
		CJ-A-07	3.1282	2.2120	0.1326	28	88
		CJ-A-08	2.5331	1.7912	0.0737	24	75
		CJ-A-09	2.6458	1.8708	0.1259	28	88
		CJ-A-10	2.1122	1.4936	0.0665	26	81
		CJ-A-11	1.8439	1.3038	0.1330	20	63
		CJ-A-12	1.4491	1.0247	0.0911	20	63
		CJ-A-13	3.0659	2.1679	0.0780	20	63
		CJ-A-14	1.4142	1.0000	0.0909	24	75
		CJ-A-31	2.0259	1.4325	0.0916	24	75
	CJ-B	CJ-B-16	2.6331	1.8619	0.0533	30	94
		CJ-B-17	2.0166	1.4259	0.0470	30	94
		CJ-B-18	4.8305	3.4157	0.0403	18	56
		CJ-B-19	2.4083	1.7029	0.0951	30	94
		CJ-B-20	1.9272	1.3628	0.0840	28	88

		CJ-B-21	3.7947	2.6833	0.0581	30	94
		CJ-B-22	2.7873	1.9709	0.0984	26	81
		CJ-B-23	2.5166	1.7795	0.0546	30	94
		CJ-B-24	2.5268	1.7867	0.0859	26	81
		CJ-B-25	1.9664	1.3904	0.0724	30	94
		CJ-B-26	1.4907	1.0541	0.0414	18	56
		CJ-B-27	1.4376	1.0165	0.0491	30	94
		CJ-B-28	1.9833	1.4024	0.0435	30	94
		CJ-B-29	2.1756	1.5384	0.0470	30	94
		CJ-B-30	2.1213	1.5000	0.1319	16	50

**Table 3-14: Completeness and precision estimates for health outcome measurements (schoolwise)**

City	School	RMSD	Abs.Precision	Relative Precision
El Paso	EP-A	3.8	2.7093	0.0930
	EP-B	3.3	2.3408	0.0646
Ciudad Juarez	CJ-A	2.2	1.5723	0.0847
	CJ-B	2.5	1.7872	0.0615

**Table 3-15: Completeness and precision estimates for health outcome measurements (Complete Cohort)**

Both the Cities	RMSD	Abs.Precision	Relative Precision
Complete Cohort	3.0838	2.1806	0.0762

### 3.2.8 Epidemiologic Analyses

Descriptive statistics of the health outcome data were calculated using SPSS for Windows, v. 15.0, 17.0 (SPSS, Inc., Chicago, IL), or Microsoft Excel 2007. Box plots and summary statistics were used to characterize the outcome measures by subject and school for both the cities. Scatter plots and Spearman Correlation Coefficients of subject-specific means and variances and histograms of the raw data were plotted to assess the overall distributions for the epidemiologic analyses. As part of the exploratory data analyses, “spaghetti” plots of the raw eNO outcome data were plotted as function of time for each subject. Time series of the raw eNO data for every school was plotted too.

Longitudinal associations between the various air pollution exposure metrics and exhaled nitric oxide measurements were examined using generalized linear mixed models. Linear mixed effect models (MIXED in SPSS version 17.0) were used with pollutants modeled as fixed effects and subjects modeled as random effects. Subject-specific eNO variance increased with the mean; therefore, log-transforming the eNO values were considered appropriate. School, ambient temperature and relative humidity were controlled as a *priori* covariates in all eNO models. Averaging times for the meteorological parameters were matched to the corresponding air pollutant variables of interest. The meteorological parameters were averaged for 48-hours and 96 hours (10:00 am Wednesday – 10: 00 am Friday or 10:00 am Monday – 10: 00 am Friday, respectively). Although the NIOX MINO is designed to remove NO from inhaled air, indoor NO levels were controlled as a modeled covariate in the models. This approach was based on previous research (Dorevitch et al., 2007). Subject-specific factors, including age, gender, race, obesity [defined as body mass index which was calculated using CDC’s BMI Percentile Calculator for Child and Teen (<http://apps.nccd.cdc.gov/dnpabmi/> )], hay fever status, cold

symptoms, and inhaled corticosteroid (ICS) and leukotriene blocker (LT) use were also considered as potential covariates. Inclusion of these factors did not change the interpretation of the results; therefore, they were omitted from the main models.

Separate models were executed for each pollutant variable of interest ( $PM_{2.5}$ ,  $PM_{10-2.5}$ ,  $PM_{10}$ ,  $NO_2$ , BC,  $O_3$ ). Exposure measures in different microenvironments (indoor, outdoor, and ambient) were used for each pollutant. A priori exposure windows of the previous 48-hrs (Wednesday – Friday) and 96-hrs (Monday – Friday) were selected to conduct the analyses. Due to the parallel study design, with subjects participating from four schools located in varying socioeconomic neighborhoods of two international cities sharing a common airshed, it was deemed necessary to examine whether the air pollution health associations differed by school using stratified analyses. To quantitatively examine significant interactions by school, an interaction term (expressed in the models as ‘pollutant\*school’) was incorporated with the main model. Additionally, t-tests and Fisher’s exacts tests were computed to examine these differences, by schools, baseline study population characteristics (including age, gender, ethnicity, BMI, caretaker’s education level), eNO outcome measures, and pollutant levels. A preliminary analysis of the study population characteristics as effect modifiers of the air pollutant health associations using stratified and interaction term approaches was also executed.

Effect estimates for the log-transformed eNO measurements were plotted as the % change in eNO per increase in pollutant concentrations (Fischer et al., 2002; Holguin et al., 2007; Liu et al., 2009). In order to compare the magnitude of effects across different metrics of the same pollutant, the effects were scaled to interquartile range (IQR) increases in concentrations, which differed across the different exposure metrics.

## **4.0 Results**

The environmental exposure and health assessment monitoring campaign resulted in 16 weeks of valid data from January 07- May 09, 2008. As mentioned before, sampling was not undertaken during the spring break, and TAKS testing schedules in El Paso. Similarly, monitoring was not possible during testing sessions at the Ciudad Juárez schools. The monitoring campaign generated 32 sessions of 48-hr PM (both PM<sub>2.5</sub> and PM<sub>10-2.5</sub>) indoor and outdoor samples, and 16 NO<sub>2</sub> samples. Concurrently, 16 sessions of weekly health outcome data including morbidity questionnaires, eNO measurements were collected from the 58 asthmatic subjects participating in this longitudinal repeated-measures design study.

### **4.1 Pollutant Concentrations**

Hourly PM and NO<sub>2</sub> concentrations measured at the TCEQ CAMS locations were averaged over the same 48-hr and 96-hr sampling period respectively for comparison. PM and BC concentrations are reported in µg/m<sup>3</sup>. NO<sub>2</sub> concentration is measured in ppb. PM<sub>10</sub> values were obtained by cumulating PM<sub>2.5</sub> and PM<sub>10-2.5</sub> values. Temporal variations of the indoor, outdoor, and ambient pollutant concentrations across the four schools and the TCEQ CAMS sites were plotted. The spatial contrast in the pollutant concentrations across the four schools and the TCEQ CAMS sites was examined through indoor and outdoor clustered box plots. The boxes are the inter-quartile ranges (75<sup>th</sup> & 25<sup>th</sup>), the whiskers show the minimum and maximum values, the outliers designated with circles are values between 1.5 and 3 box lengths from either end of the box, and extreme values, designated as asterisks, are values more than 3 box lengths from either end of the box. The median is indicated by the thick black line inside the boxes.

#### 4.1.1 48-hr PM<sub>2.5</sub> concentrations

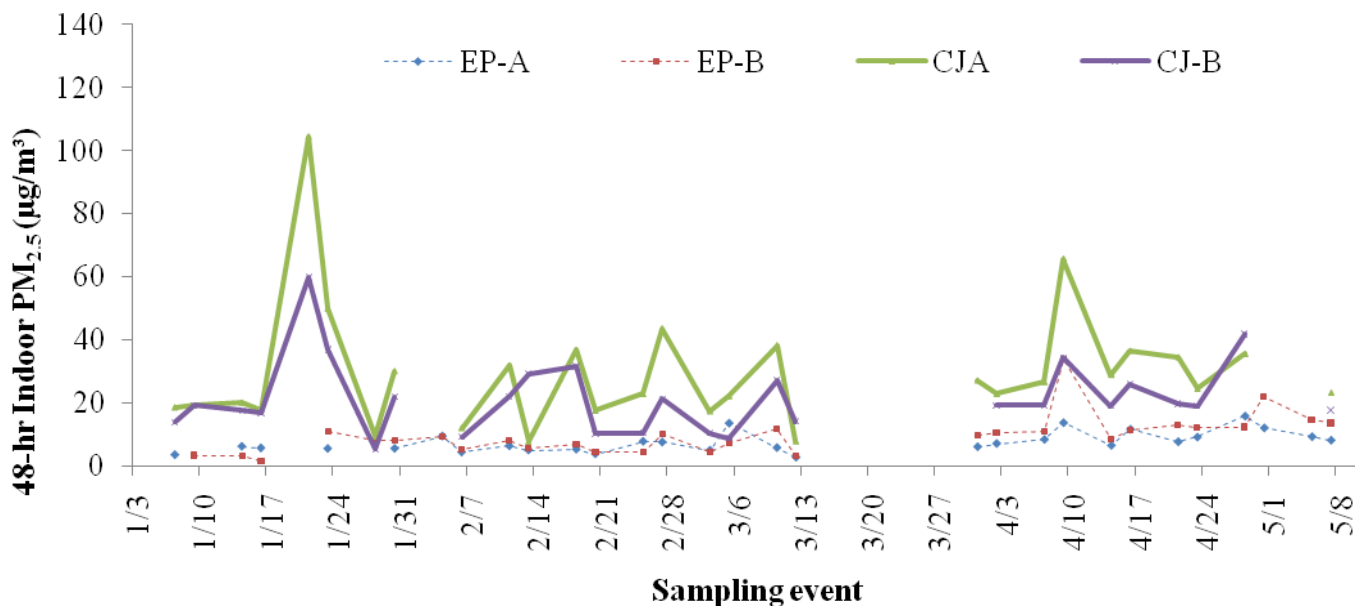
Table 4-1 shows the descriptive statistics for the 48-hr averaged PM<sub>2.5</sub> data. Figure 4-1 compares the concurrently measured indoor PM<sub>2.5</sub> concentrations and Figure 4-2 shows the outdoor and ambient PM<sub>2.5</sub> concentrations at the four schools and TCEQ CAMS sites, respectively. In El Paso, as expected, the indoor and outdoor concentrations for PM<sub>2.5</sub> at EP-A, 7.5(3.3) and 8.3(4.1), were lower than EP-B, 9.6(6.3) and 14.5(7.8)  $\mu\text{g}/\text{m}^3$ . The PM<sub>2.5</sub> results for the Ciudad Juárez schools were an aberration in the pattern. The outdoor PM<sub>2.5</sub> concentrations at CJ-A, the school located in the low exposure zone was higher, 34.6 (22.9)  $\mu\text{g}/\text{m}^3$ , than that measured in the high exposure zone school CJ-B, 26.2 (22.9)  $\mu\text{g}/\text{m}^3$ . Both schools relied on natural ventilation with no centralized heating or cooling. Fugitive dust emissions from unpaved roads and bare soil appear to dominate the outdoor PM (PM<sub>2.5</sub> as well as PM<sub>10-2.5</sub>).

**Table 4-1: Summary statistics for 48-hr PM<sub>2.5</sub> ( $\mu\text{g}/\text{m}^3$ )**

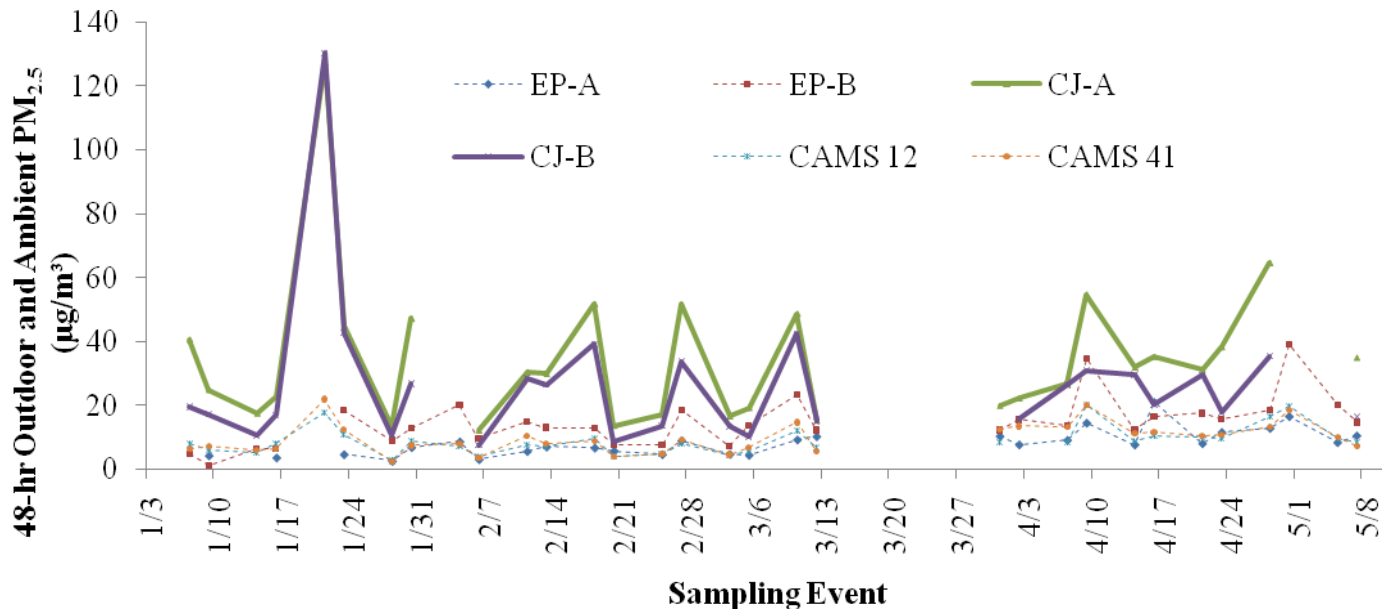
	<b>Indoor</b>				<b>Outdoor</b>				<b>Ambient</b>	
Location	EP A	EP - B	CJ- A	CJ - B	EP -A	EP - B	CJ -A	CJ - B	CAMS12	CAMS41
N	29	30	29	28	29	31	29	28	31	32
Mean	7.5	9.6	29.4	21.5	8.3	14.5	34.6	26.2	9.0	9.7
Median	6.4	8.8	24.5	19.2	7.7	13.7	30.4	19.8	8.2	9.0
SD	3.3	6.3	19.3	11.6	4.1	7.8	22.9	22.9	4.4	4.7
Minimum	2.6	1.5	7.7	5.4	2.6	1.2	12.1	7.5	2.6	2.4
Maximum	15.8	33.7	104.3	59.8	20.9	39.1	127.5	130.4	20.0	21.9
P <sub>10</sub>	4.2	3.3	11.5	9.8	4.2	6.5	14.9	10.4	4.2	4.6
P <sub>25</sub>	5.4	5.3	18.6	14.0	4.8	9.2	19.2	14.6	6.3	6.4
P <sub>75</sub>	9.1	11.6	35.5	26.3	10.2	18.0	44.9	29.9	9.9	12.5
P <sub>90</sub>	12.3	13.7	44.8	35.1	13.1	20.1	52.4	40.1	16.6	14.5
P <sub>98</sub>	14.6	26.8	82.7	50.1	18.4	36.4	92.3	83.0	19.7	20.8
P <sub>99</sub>	15.2	30.3	93.5	54.9	19.6	37.7	109.9	106.7	19.9	21.3

The trends in the indoor and outdoor temporal variations (Figure 4-1 and 4-2) indicate that CJ-A recorded higher concentrations, both outdoors and indoors, than CJ-B. The field staff noticed dust on the furniture and floor of the classroom throughout the study period at CJ-A. On

several occasions, windows were left open after class dismissal. At CJ-B, upkeep of the library, where indoor monitoring took place, was much better than the indoor microenvironment at CJ-A. Cleaning and other janitorial activities were not done on a regular basis in the Ciudad Juárez schools. In addition, enhanced resuspension of indoor  $PM_{2.5}$  at both the Ciudad Juárez schools (classroom at CJ-A and library at CJ-B) due to high daily foot traffic by students may explain high concentration values.



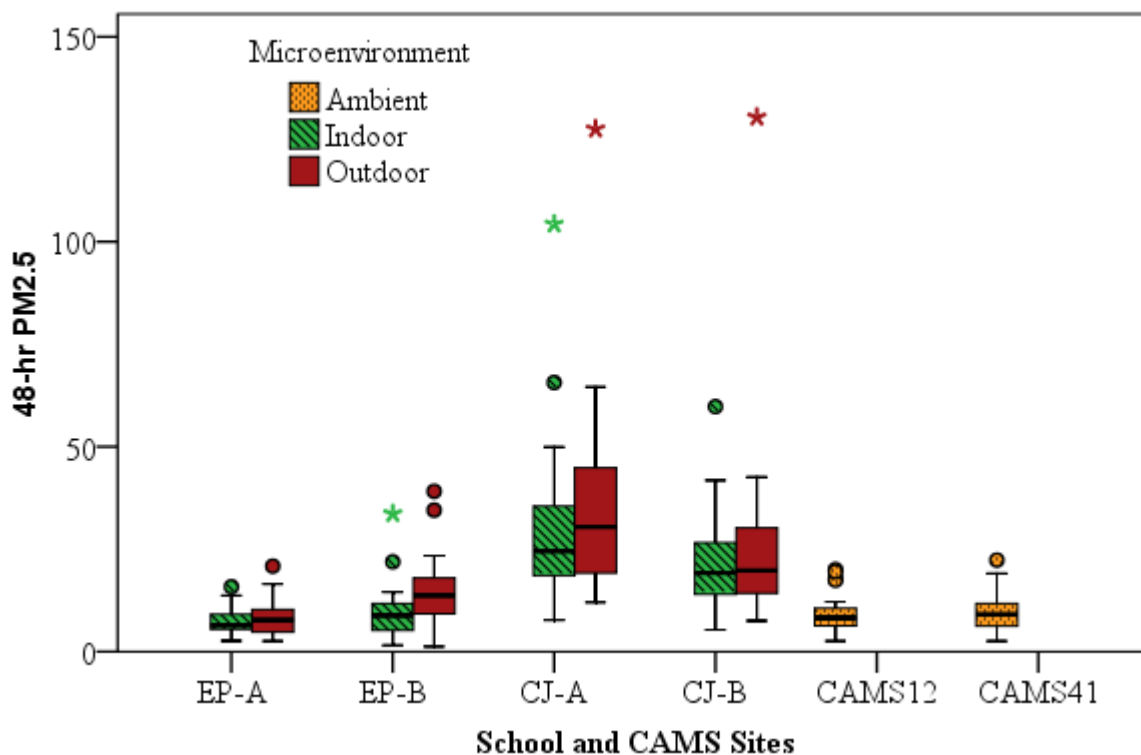
**Figure 4-1: Temporal variations of 48-hr indoor  $PM_{2.5}$  concentrations at the four schools**



**Figure 4-2: Temporal variations of 48-hr outdoor and ambient PM<sub>2.5</sub> at four schools and TCEQ CAMS sites**

In contrast, the indoor conditions at both the schools in El Paso were clean and salubrious. As previously indicated in Table 2-1, EP-A and EP-B were equipped with evaporative coolers for use in the classrooms during the warmer months. The rapid air change provided by the evaporative cooler tend to fill the indoor microenvironment with outdoor air quickly while the wetted filter (pad) of the cooler tends to reduce PM levels in the infiltrated air by approximately 40 to 50% for PM<sub>10</sub>, although it is less effective in removing PM<sub>2.5</sub> from the entering air (Paschold et al., 2003a, 2003b; Li et al., 2003). Although the indoor PM sampling was conducted at a computer room at EP-A, which also experienced high student traffic, the PM<sub>2.5</sub> concentration levels were the lowest in contrast to the other three schools. This could be attributed to regular cleaning activities by the school staff. A visual analysis of the clustered box plots in Figure 4-3 indicates that the indoor and outdoor PM<sub>2.5</sub> concentrations across the four schools varied considerably with CJ-B recording mean outdoor concentrations four times higher than EP-A.





**Figure 4-3: Box plots for the 48-hr indoor, outdoor and ambient PM<sub>2.5</sub> concentrations (µg/m³)**

The ambient PM<sub>2.5</sub> concentrations measured at TCEQ CAMS 12 and CAMS 41 stations are also shown in Table xx. CAMS 41 is located approximately 3 miles from school EP-B, and CAMS 12 is farther away from the two El Paso schools, but is less than 0.42 mile from Interstate Highway 10. The average PM<sub>2.5</sub> concentrations at TCEQ CAMS 12 and 41 were 9.0 (4.4) and 9.7(4.7) µg/m³ respectively, which were very similar to the mean concentrations at EP-A. The mean outdoor PM<sub>2.5</sub> concentrations at the El Paso high exposure school EP-B, 14.5 (7.8) µg/m³, was approximately 60% higher than that observed at both the TCEQ CAMS sites, thereby corroborating the existence of spatially consistent high PM pollution in the predefined high exposure study area.

A sandstorm occurred on April 09, 2008 (see Table 4-1), causing regional PM (both PM<sub>2.5</sub> and PM<sub>10-2.5</sub>) to reach elevated levels both indoors and outdoors, as is obvious from the temporal variations in Figures 4-1 and 4-2. The Paso del Norte PM pollution is atypical of any

other urban area due to the significant amount of uncontrolled geologic emission sources, dust emanating from unpaved roads, fugitive emissions from less-regulated aged vehicles, biomass emissions from residential cooking and waste burning, emissions from brick kilns and house heating, and other unidentified anthropogenic sources (Li et al., 2003). Resuspension of urban dust from roadways dominates the fine fraction of PM. In addition, frequently occurring temperature inversions tend to trap PM in this high altitude region. The extremely high PM<sub>2.5</sub> indoor and outdoor concentrations at CJ-A and CJ-B during the January 21-23, 2008 sampling event can be attributed to traffic or unknown fugitive emissions in the near vicinities of both the schools as the average wind speed during this sampling period was not high enough to generate a dust storm in the region.

#### **4.1.2 48-hr PM<sub>10-2.5</sub> concentrations**

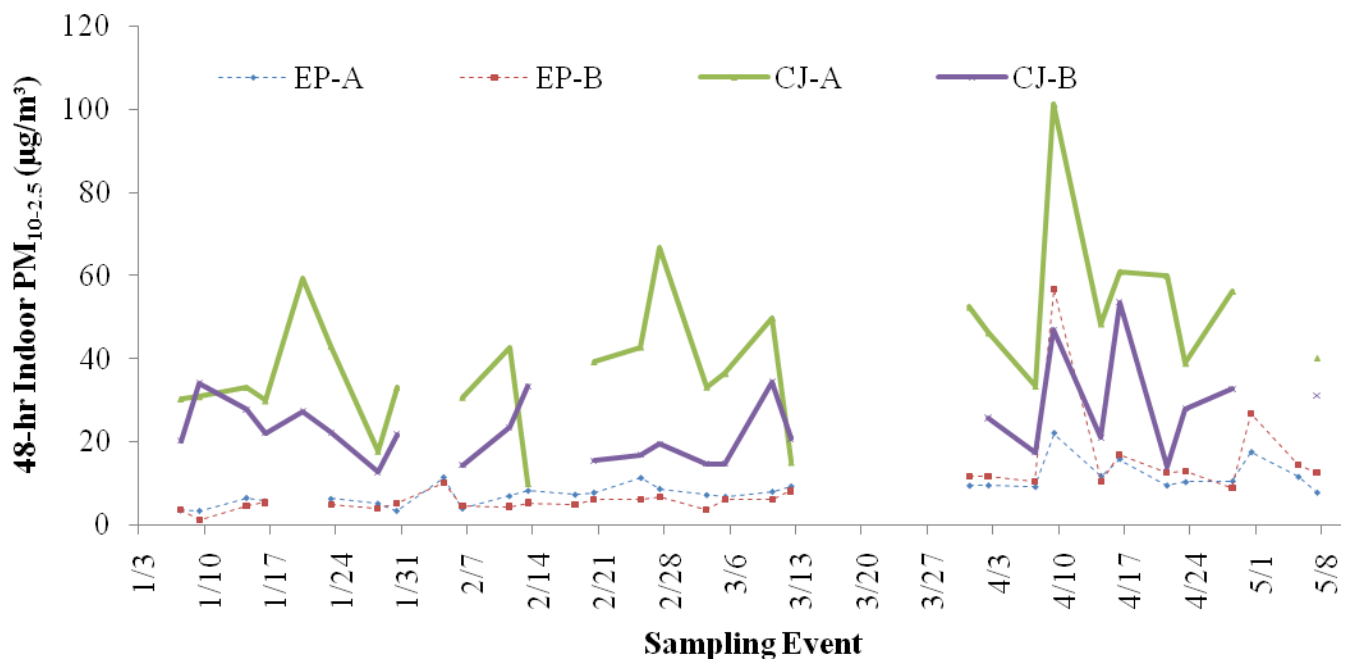
The descriptive statistics for the 48-hr averaged PM<sub>10-2.5</sub> data are shown in Table 4-2. Figures 4-4 and 4-5 compare the concurrently measured indoor and outdoor PM<sub>10-2.5</sub> concentrations at the four schools and TCEQ CAMS sites respectively. The box plots indicate the spatial contrast in the concentrations observed at the various microenvironments across the sampling sites (Figure 4-6).

The indoor and outdoor PM<sub>10-2.5</sub> concentrations ranged from 8.9(4.0) and 9.9(5.1) at EP-A to 42.2(18.0) and 57.9(21.6)  $\mu\text{g}/\text{m}^3$  at CJ-A, respectively. In El Paso, the mean PM<sub>10-2.5</sub> concentrations were more than two-fold higher at EP-B than at EP-A. A maximum of 66.0  $\mu\text{g}/\text{m}^3$  was observed at EP-B due to a dust storm experienced in the region on April 09, 2008. For the same averaging period, TCEQ CAMS 12 and 41 recorded a high of 104.2 and 94.3  $\mu\text{g}/\text{m}^3$ , respectively. The mean outdoor concentrations at EP-B were similar to the ambient concentrations at CAMS12 and CAMS 41 which were 26.3(19.6) and 24.9(16.8)  $\mu\text{g}/\text{m}^3$

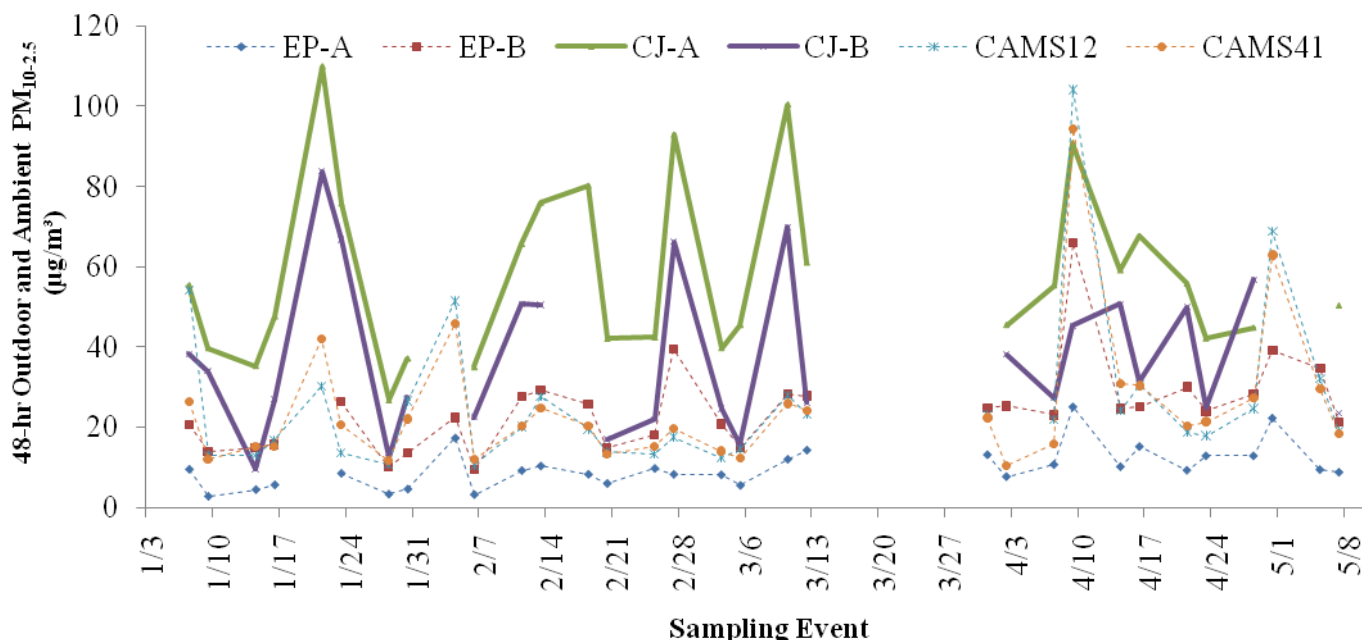
respectively – calculated as the difference between concurrent data measured by two collocated continuous PM<sub>10</sub> and PM<sub>2.5</sub> TEOM monitors at the two CAMS sites. The close proximity of CAMS 41 to school EP-B may explain some of the agreement in PM<sub>10-2.5</sub> levels between these two sites.

**Table 4-2: Summary statistics for 48-hr PM<sub>10-2.5</sub> (µg/m<sup>3</sup>)**

	<b>Indoor</b>				<b>Outdoor</b>				<b>Ambient</b>	
Location	EP A	EP - B	CJ- A	CJ - B	EP -A	EP - B	CJ -A	CJ - B	CAMS12	CAMS41
N	31	31	28	27	31	31	28	27	31	32
Mean	8.9	9.9	42.2	24.7	9.9	24.5	57.9	37.5	26.3	24.9
Median	8.2	6.1	39.8	22.1	9.3	24.6	52.9	31.5	20.1	20.5
SD	4	10.1	18	10	5.1	10.8	21.6	19.4	19.6	16.8
Minimum	3.5	1.2	10	12.6	2.8	9.5	26.7	9.6	10.6	10.4
Maximum	22	56.8	101.2	53.6	25	66	109.9	83.8	104.2	94.3
P <sub>10</sub>	4.0	3.9	26.2	14.5	4.4	13.9	36.6	16.4	13.0	12.0
P <sub>25</sub>	6.7	4.8	32.5	17.1	6.8	16.9	42.2	24.1	14.1	15.1
P <sub>75</sub>	10.4	11.7	50.4	29.6	12.4	28.0	69.7	50.6	27.8	26.6
P <sub>90</sub>	11.7	14.4	60.2	34.2	15.2	34.6	91.4	66.4	51.5	40.9
P <sub>98</sub>	19.2	38.8	82.6	50.1	23.4	50.1	104.8	76.6	83.0	74.9
P <sub>99</sub>	20.6	47.8	91.9	51.8	24.2	58.0	107.4	80.2	93.6	84.6



**Figure 4-4: Temporal variations of 48-hr indoor PM<sub>10-2.5</sub> concentrations at the four schools**

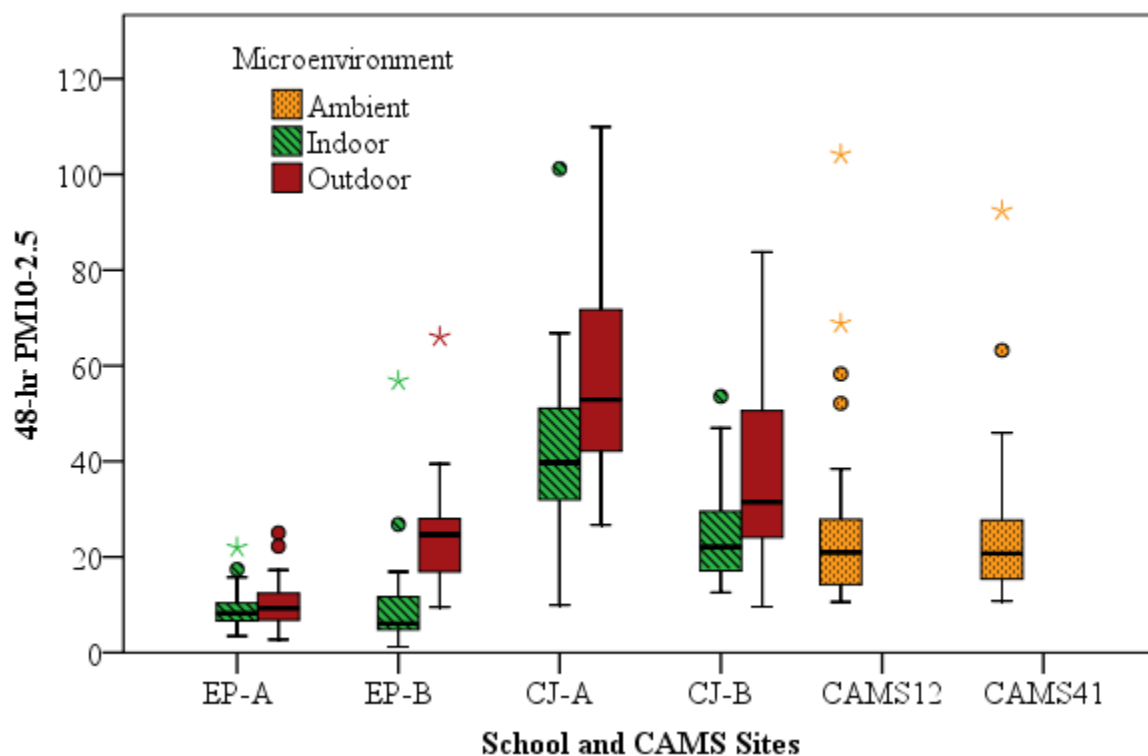


**Figure 4-5: Temporal variations of 48-hr outdoor  $PM_{10-2.5}$  at four schools and TCEQ CAMS sites**

Coarse particles are predominantly composed of geologic materials, which are strongly associated with wind-blown dust, pollen, disintegration of tires, and breaklinings from vehicles, or by dust generated from mechanical disturbance such as emissions from construction, quarrying activities, and vehicular movement/mechanical disturbance of granular surfaces by vehicles traveling on paved or unpaved surfaces (Li et al., 2001). Coarse particles are more spatially non-uniform than fine particles with a shorter residence time (Monn, 2001). It is obvious that the low exposure school, EP-A is less influenced by the coarse PM pollution than the other three schools.

The  $PM_{10-2.5}$  concentration trends at both the Ciudad Juárez schools were similar to the trend observed for  $PM_{2.5}$  concentrations. High  $PM_{10-2.5}$  concentrations, both indoors and outdoors, were observed at CJ-A throughout the study period. Similar to the observed indoor  $PM_{2.5}$  concentration at CJ-A, the indoor  $PM_{10-2.5}$  recorded an elevated level of 42.2 (18.0)  $\mu\text{g}/\text{m}^3$ ,

again possibly due to heavy foot traffic in this classroom and lack of janitorial activities on a daily basis. Judging from the high outdoor  $PM_{10-2.5}$  concentrations observed at CJ-A, 57.9 (21.6)  $\mu g/m^3$ , and CJ-B, 37.5 (19.4)  $\mu g/m^3$ , and the prevailing westerly winds during the study period (Figure 2-22), it is likely that the high PM observed during the study was largely caused by fugitive dust emissions from unpaved roads and/or unvegetated surfaces in Ciudad Juárez. The PM results for Ciudad Juárez from this study negate the differences between the low and high exposure zones, thereby having possible repercussions for children's exposure to these pollutants. The April 09, 2008 sandstorm led to extremely pronounced  $PM_{10-2.5}$  concentrations in the region – similar to what was observed for  $PM_{2.5}$ .



**Figure 4-6: Box plots for the 48-hr indoor, outdoor and ambient  $PM_{10-2.5}$  ( $\mu g/m^3$ )**

Schools EP-A and EP-B were equipped with evaporative coolers facilitating rapid air changes for thermal comforts in contrast to natural ventilation at the two Ciudad Juárez schools.

For buildings equipped with evaporative coolers where the indoor air is constantly replenished with outside air, Li and colleagues (Li et al., 2003; Paschold et.al., 2003a, 2003b) have demonstrated in laboratory settings and in select El Paso homes that evaporative coolers reduce indoor  $PM_{10}$  by approximately 40 % and have a less effective reduction of approximately 10% on  $PM_{2.5}$ . Because the majority of the PM mass for  $PM_{10}$  is in the coarse fraction mode, the removal efficiency for evaporative cooler on  $PM_{10-2.5}$  is estimated to be approximately 40%. The removal efficiency, as is obvious from Table 4-2, is around 11% and 60% at EP-A and EP-B, respectively. The lower removal efficiency at EP-A could be explained by resuspension of PM due to high student traffic. The library reference room, which served as the indoor microenvironment at EP-B, experienced minimal human traffic because it was used infrequently by teachers to prepare the course material for their pedagogical tasks.

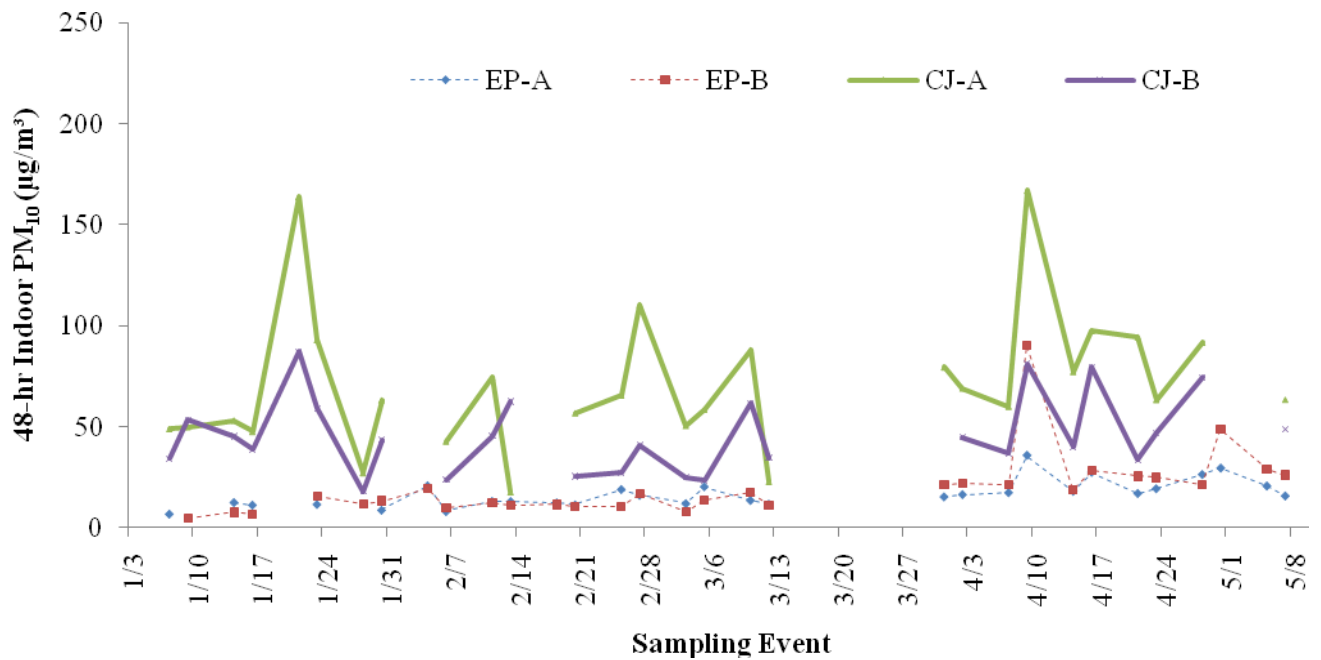
#### **4.1.3 48-hr $PM_{10}$ concentrations**

Similar to  $PM_{10-2.5}$ , indoor and outdoor  $PM_{10}$  (as the sum of  $PM_{2.5}$  and  $PM_{10-2.5}$ ) concentrations exhibited distinct spatial variation between the low and high exposure zones, across both cities, confirming that the  $PM_{10}$  mass in the PdN region is dominated by coarse particles at approximately 60 % (Li, et al 2001; U.S. EPA, 2005). The descriptive statistics are shown in Table 4-3, for indoor, outdoor, and ambient  $PM_{10}$  concentrations. The indoor and outdoor temporal variations are shown in Figures 4-7 and 4-8, respectively.

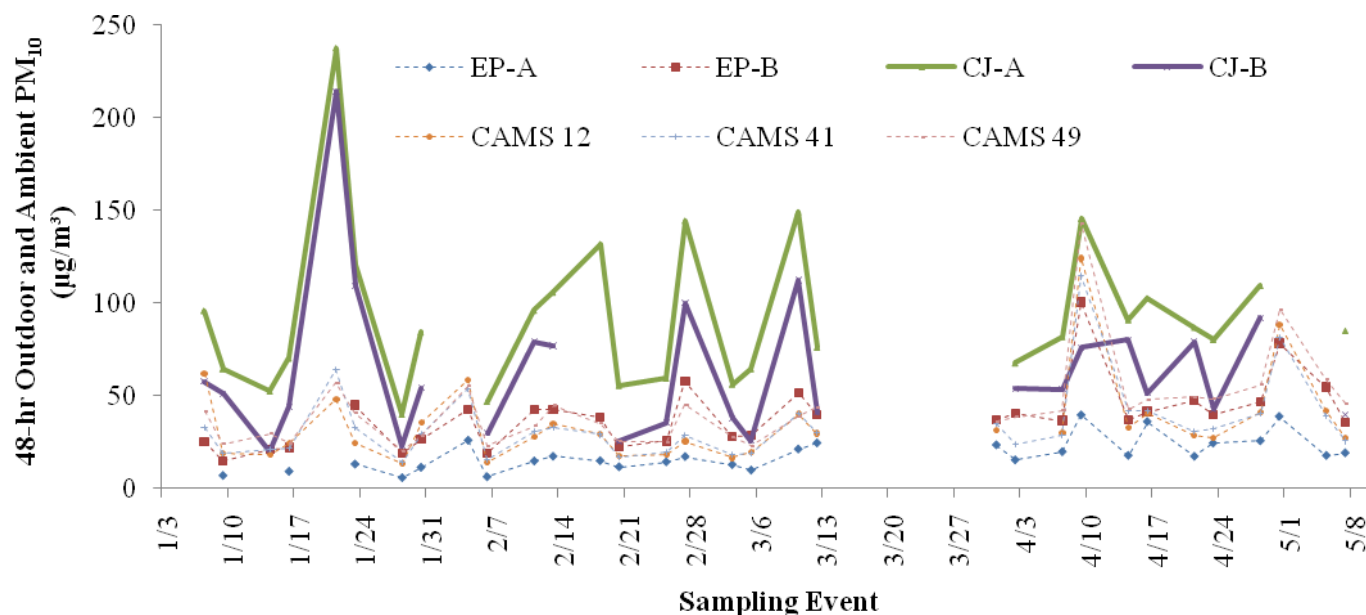
In El Paso, the outdoor concentrations at EP-B averaged 39.0 (17.6)  $\mu\text{g}/\text{m}^3$ , which is more than twice the mean 18.4 (8.8)  $\mu\text{g}/\text{m}^3$  at EP-A. Ambient  $PM_{10}$  concentrations along the border (as recorded at EP-A and TCEQ CAMS stations 12 and 41) agreed closely among themselves spatially and temporally and increased slightly towards the south in the rural area of the PdN (as recorded at CAMS 49).

**Table 4-3: Summary statistics for 48-hr PM<sub>10</sub> (µg/m<sup>3</sup>)**

	Indoor				Outdoor				Ambient		
Location	EP A	EP - B	CJ- A	CJ - B	EP -A	EP - B	CJ -A	CJ - B	CAMS12	CAMS41	CAMS49
N	29	30	28	27	29	31	28	27	31	32	32
Mean	16.7	19.7	71.4	45.8	18.4	39	93	63.2	35.2	34.6	43.6
Median	15.9	16.3	63.4	43.7	17.3	38.5	84.8	53.7	29.2	30.3	41.3
SD	6.6	16.1	34.8	18.9	8.8	17.6	41.3	40.1	22.8	20.3	23.6
Minimum	7	4.6	17.7	17.9	5.9	15.1	40.1	20	13.3	14.1	20.4
Maximum	35.7	90.5	166.9	87.1	39.5	100.5	237.4	214.2	124.2	114.5	142.9
P <sub>10</sub>	10.9	8.0	38.1	24.5	8.8	21.2	54.8	25.6	17.9	18.7	24.0
P <sub>25</sub>	12.1	11.0	50.4	33.9	12.9	26.1	64.6	38.9	22.3	21.5	28.5
P <sub>75</sub>	19.4	21.9	89.0	56.2	23.5	43.8	106.7	79.3	40.5	39.7	48.0
P <sub>90</sub>	26.5	28.3	101.3	76.5	28.0	54.7	144.8	103.7	58.6	52.8	57.1
P <sub>98</sub>	32.2	66.3	165.1	84.0	39.1	87.2	189.7	161.2	102.7	94.0	114.2
P <sub>99</sub>	33.9	78.4	166.0	85.6	39.3	93.9	213.6	187.7	113.4	104.2	128.6



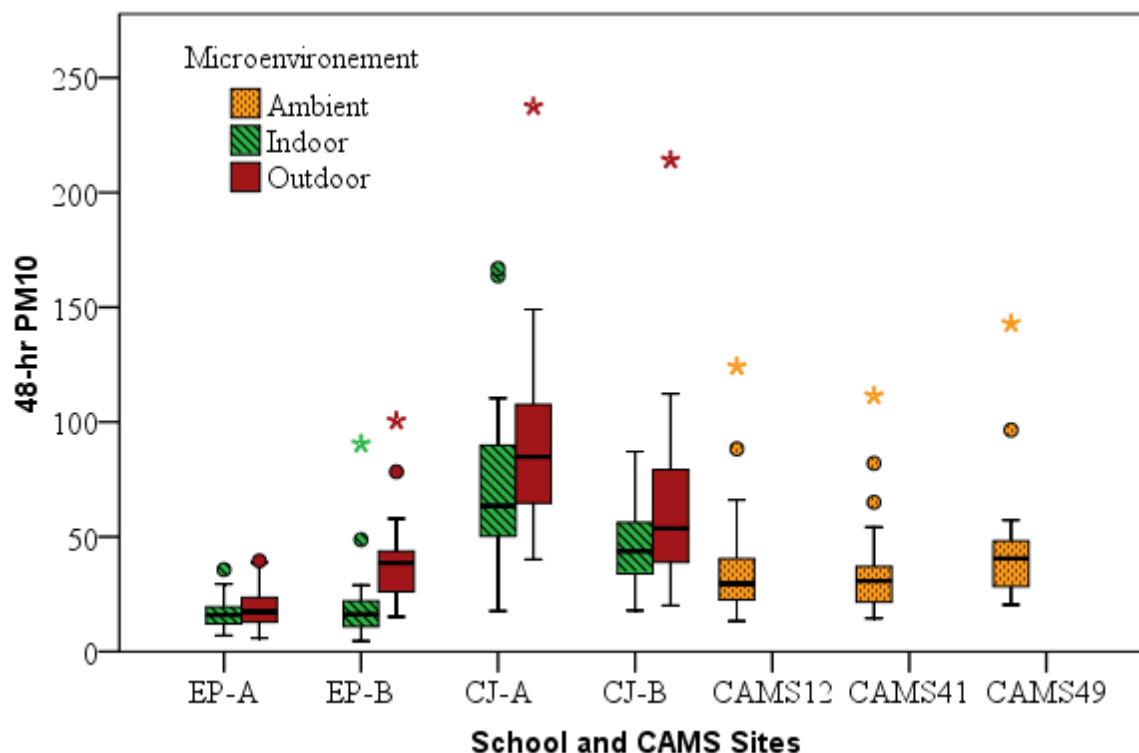
**Figure 4-7: Temporal variations of 48-hr indoor PM<sub>10</sub> concentrations at the four schools**



**Figure 4-8: Temporal variations of 48-hr outdoor and ambient PM<sub>10</sub> at four schools and TCEQ CAMS sites**

Based on the PM<sub>10</sub> levels observed at EP-B, 39.0 (17.6) µg/m<sup>3</sup>, and CAMS stations 12 and 41, 34.6 (20.3) – 43.6 (23.6) µg/m<sup>3</sup>, it is clear that PM pollution was ubiquitous in the corridor bounded by I-10 and the border highway (Route 375) along the U.S. Mexico border. Furthermore, high mean outdoor PM<sub>10</sub> concentrations observed at CJ-A, 93.0 (41.3) µg/m<sup>3</sup>, were approximately one - and - a half times higher than CJ-B, 63.2 (40.1) µg/m<sup>3</sup>, for the complete sampling period. Indoor median PM<sub>10</sub> concentrations at EP-A (15.9) µg/m<sup>3</sup> and EP-B (16.3) µg/m<sup>3</sup> were almost similar, in strong contrast to those measured in Ciudad Juarez - 63.4 µg/m<sup>3</sup> for CJ-A, and 43.7µg/m<sup>3</sup> for CJ-B – as is evident from the clustered box plots shown in Figure 4-9. Differences in the use of ventilation system, building insulation, and ambient outdoor concentration are contributors to this contrast in indoor PM.





**Figure 4-9: Box plots for the 48-hr indoor, outdoor and ambient PM<sub>10</sub> concentrations (µg/m³)**

#### 4.1.4 96-hr NO<sub>2</sub> concentrations

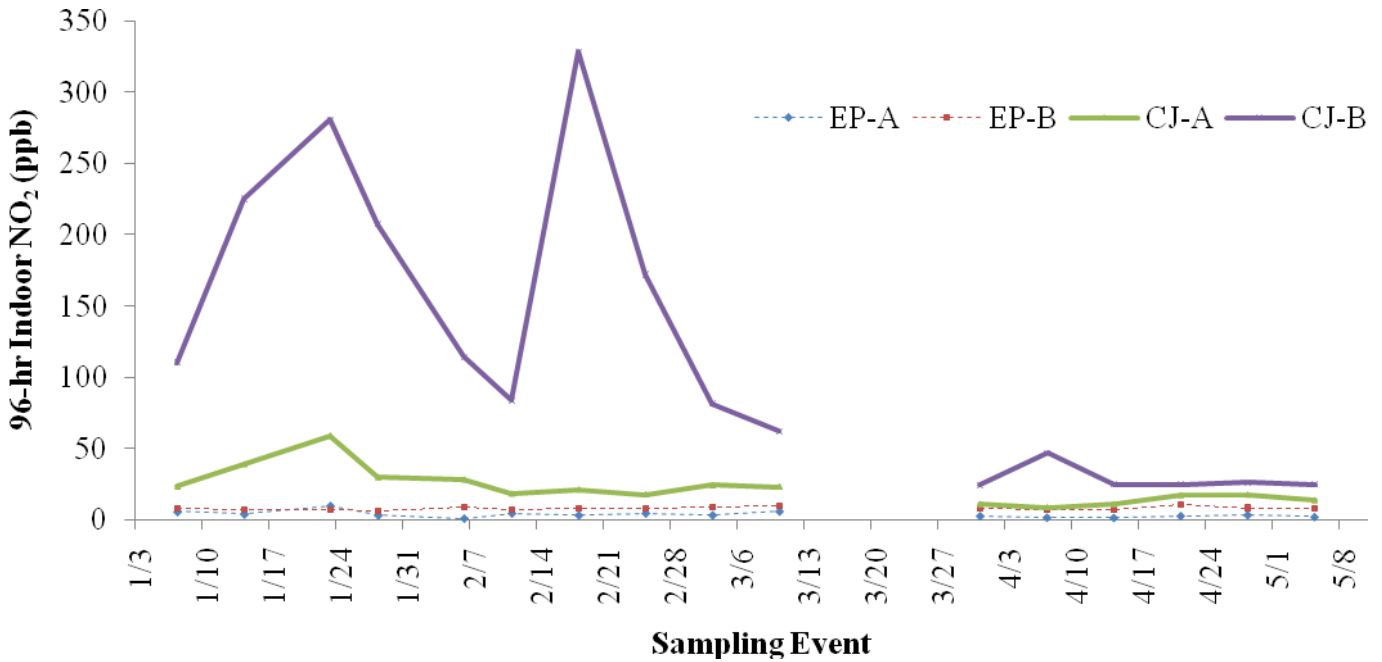
Nitrogen dioxide concentrations for indoor, outdoor, and ambient microenvironments are plotted in Figures 4-10 and 4-11 respectively. All values are reported as part per billion in volume of air (ppb). Table 4-4 and Figure 4-12 summarize the statistical parameters at the different microenvironments for the various sites.

The indoor and outdoor NO<sub>2</sub> concentrations ranged from a low of 4.0 (2.2) and 4.5 (3.5) ppb at EP-A to a high of 114.9 (98.9) and 26.8 (10.2) ppb at CJ-B, respectively. Within El Paso, the mean indoor concentrations were two-fold higher at the high exposure school EP-B than at the low traffic school EP-A. Extremely high concentrations were observed at CJ-B indoors (library in this case) throughout the study period. At this school, gas and kerosene heaters were used during the winter months. Unventilated gas and kerosene heaters and cooking stoves are major indoor sources for NO<sub>2</sub> (Dimitroulopoulou et. al., 2001).

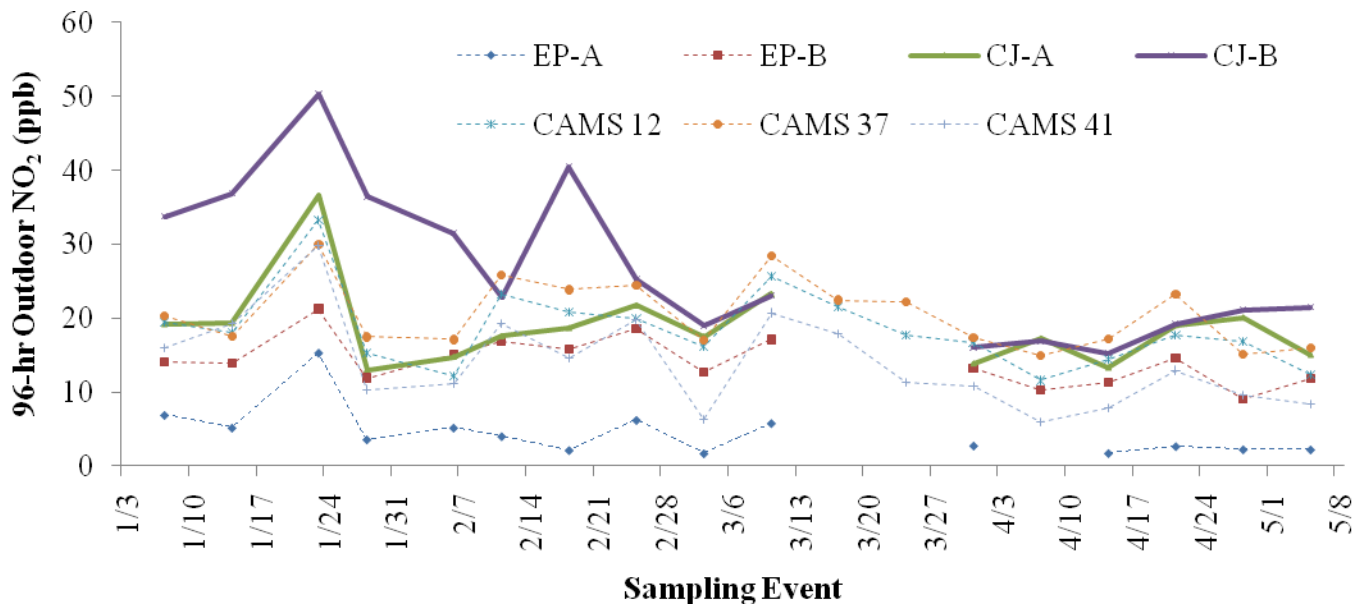
On many occasions, staff meetings were conducted while food was prepared and/or heated on cooking stoves in the same microenvironment. At other times, eggs were being boiled and popcorn popped in preparation for staff afterschool meetings. The combination of the gas heaters and gas stoves during the sampling period resulted in high NO<sub>2</sub> concentrations indoors. The highest concentration observed at this school was 328 ppb and the lowest was 24 ppb, compared to the 1-hr average NAAQS standard for NO<sub>2</sub>, 100 ppb. This suggests that the high concentrations observed at this indoor environment would have been much higher since the data was averaged over a 96-hr period. It appears that children were frequently and unnecessarily exposed to the excessive levels of NO<sub>2</sub> at this school since most children took their reading sessions in the library, where NO<sub>2</sub> could have lingered in the room for a long time.

**Table 4-4: Summary statistics for 96 -hr NO<sub>2</sub> (ppb)**

	<b>Indoor</b>				<b>Outdoor</b>				<b>Ambient</b>		
Location	EP A	EP - B	CJ- A	CJ - B	EP -A	EP - B	CJ -A	CJ - B	CAMS12	CAMS37	CAMS41
N	16	16	16	16	15	16	16	16	16	16	16
Mean	4	8.1	22.8	114.9	4.5	14.2	18.8	26.8	18.4	20.4	13.9
Median	3.5	7.9	19.8	82.8	3.6	14	18.1	23	17.3	17.5	12
SD	2.2	1.1	12.5	98.9	3.5	3.2	5.6	10.2	5.6	4.9	6.5
Minimum	1.2	6.4	8.8	24.3	1.7	9	13	15.2	11.6	15	6
Maximum	10.2	10.4	59.2	328.3	15.3	21.2	36.6	50.4	33.3	30	29.8
P <sub>10</sub>	1.75	6.99	10.99	24.91	1.92	10.79	13.57	16.43	12.31	15.70	7.38
P <sub>25</sub>	2.74	7.51	16.34	25.96	2.26	11.91	14.97	19.15	15.52	17.15	9.80
P <sub>75</sub>	4.87	8.54	25.32	180.91	5.51	16.07	19.54	34.42	20.62	23.70	18.88
P <sub>90</sub>	6.10	9.72	34.49	252.86	6.64	17.85	22.48	38.70	23.98	26.59	20.06
P <sub>98</sub>	9.00	10.33	53.14	313.95	12.98	20.45	32.58	47.42	30.71	29.48	26.72
P <sub>99</sub>	9.59	10.37	56.15	321.10	14.16	20.84	34.58	48.89	32.00	29.77	28.26

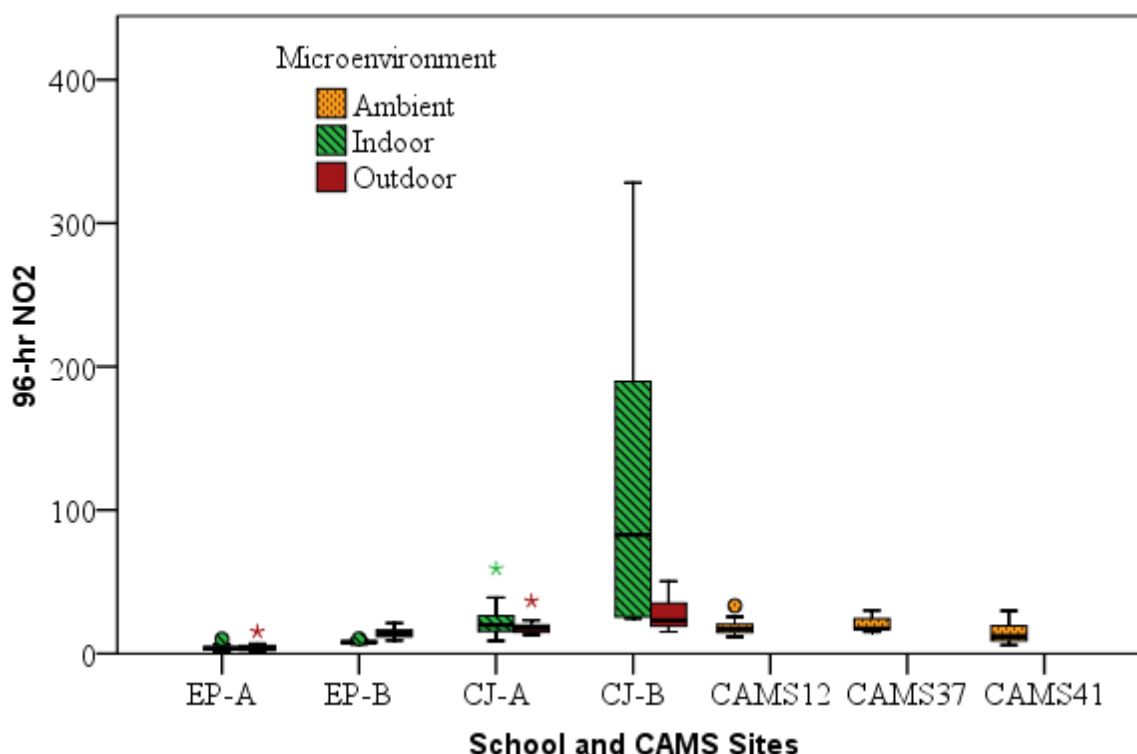


**Figure 4-10: Temporal variations of 96-hr indoor NO<sub>2</sub> concentrations at the four schools**



**Figure 4-11: Temporal variations of 96-hr outdoor and ambient NO<sub>2</sub> concentrations at four schools and TCEQ CAMS sites**

The outdoor concentrations for NO<sub>2</sub> were low in the low traffic zones at EP-A and CJ-A, as compared to the relatively high concentrations in the high traffic zones at EP-B and CJ-B. In Ciudad Juarez, the outdoor median concentration at the school CJ-A and CJ-B were 18.11 and 22.96 ppb respectively. On the US side, the median concentrations at schools EP-A and EP-B were 3.61 and 14.02 ppb respectively. EP-B recorded mean outdoor concentrations more than three times higher than EP-A. The spatial variation of the outdoor NO<sub>2</sub> data across the four schools suggests that the low and high traffic density criterion was well represented by the zoning procedure.



**Figure 4-12: Box plots for the 96-hr indoor, outdoor and ambient NO<sub>2</sub> concentrations (ppb)**

Hourly NO<sub>2</sub> data was available from three TCEQ CAMS sites: CAMS 12, 37, and 41. This set of data was processed and included in the data analysis. CAMS 37 is located within 1 mile from the El Paso high exposure school (EP-B). The ambient concentrations ranged between

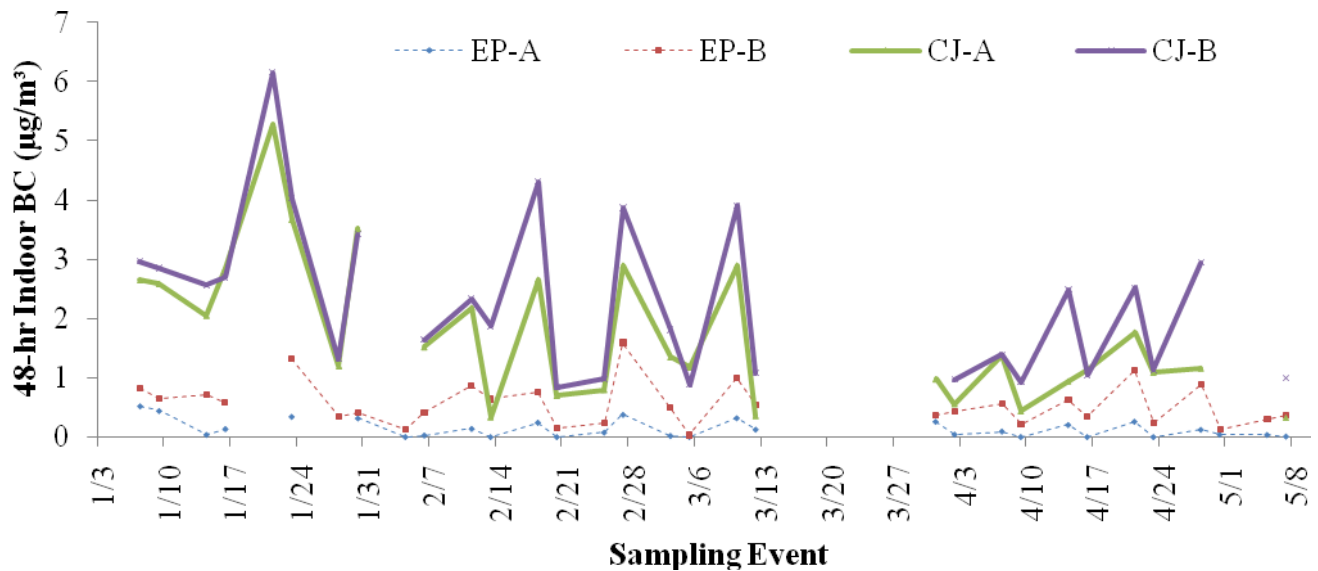
13.9 (6.5) and 20.4 (4.9) ppb for CAMS 12, 37, and 41 throughout the sampling period. NO<sub>2</sub> levels along the border, as observed at EP-B, CAMS 12, 37, and 41, appeared to be similar and elevated due to the close proximity to major arterial roadways.

#### 4.1.5 48-hr Black Carbon concentrations

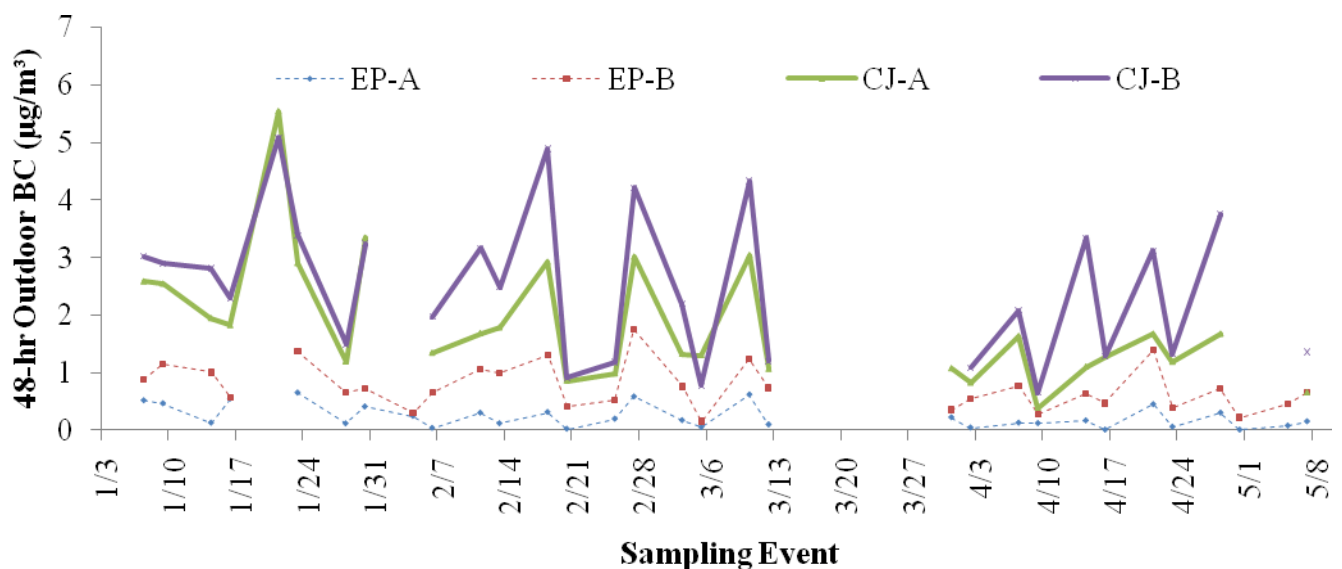
Black carbon (BC) may serve as a surrogate of diesel traffic (Gotschi 2002). The blackness of the filters can be attributed to high number of particles from diesel combustion that caused high black carbon concentrations. In the case of diesel exhaust, filter reflectance measurements are good surrogates of diesel exhaust particles (Kinney et.al, 2000). BC concentrations were computed from the 48-hr PM<sub>2.5</sub> substrates (37-mm Teflon filters). Temporal variations for the 48-hr averages are shown in Figures 4-13 and 4-14 while the descriptive statistics and clustered box plots are shown in Table 4-5 and Figure 4-15.

**Table 4-5: Summary statistics for 48-hr BC (µg/m<sup>3</sup>)**

	<b>Indoor</b>				<b>Outdoor</b>			
Location	EP A	EP - B	CJ- A	CJ - B	EP -A	EP - B	CJ -A	CJ - B
N	30	31	29	28	31	31	29	28
Mean	0.14	0.56	1.74	2.28	0.23	0.75	1.81	2.48
Median	0.09	0.5	1.35	2.1	0.16	0.67	1.63	2.39
SD	0.15	0.36	1.2	1.33	0.2	0.39	1.07	1.27
Minimum	0	0.03	0.33	0.84	0	0.15	0.38	0.65
Maximum	0.53	1.59	5.27	6.15	0.65	1.74	5.54	5.08
P <sub>10</sub>	0.00	0.16	0.42	0.96	0.03	0.31	0.85	1.04
P <sub>25</sub>	0.01	0.32	0.94	1.07	0.08	0.46	1.10	1.31
P <sub>75</sub>	0.26	0.74	2.65	2.95	0.36	1.00	2.54	3.27
P <sub>90</sub>	0.35	1.00	3.02	3.95	0.55	1.30	3.02	4.25
P <sub>98</sub>	0.48	1.43	4.37	5.16	0.63	1.54	4.31	4.98
P <sub>99</sub>	0.51	1.51	4.82	5.65	0.64	1.64	4.92	5.03



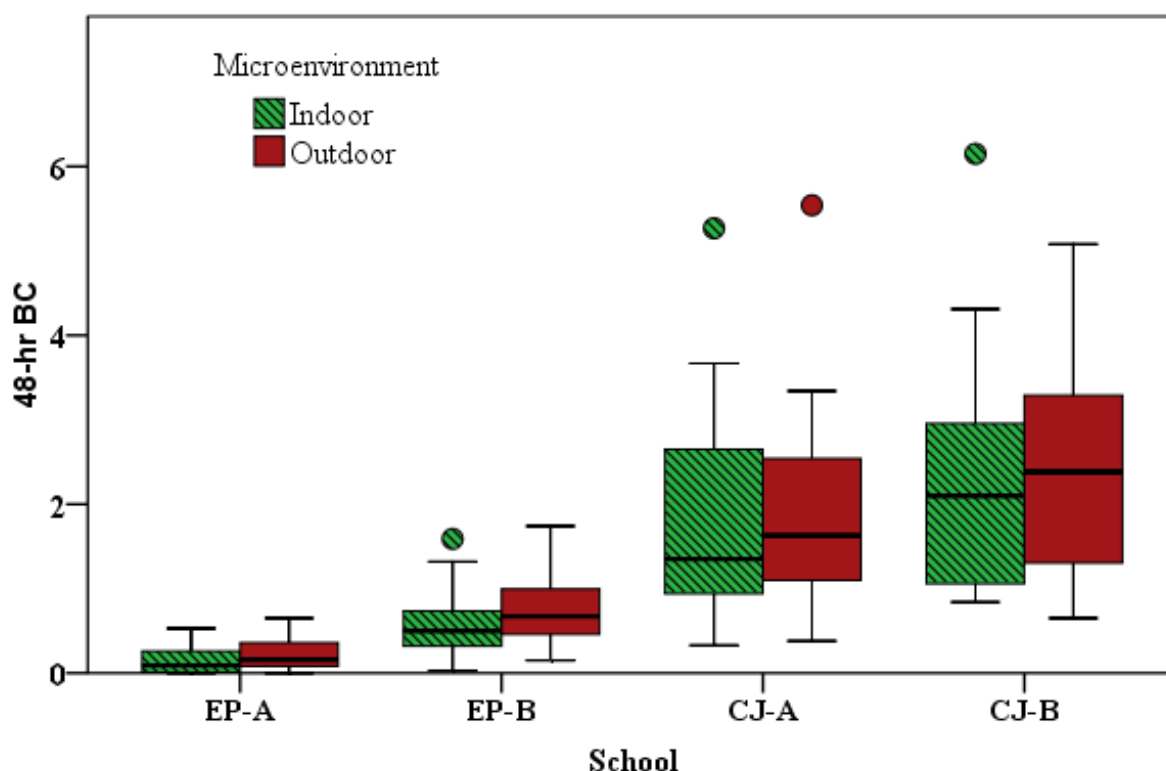
**Figure 4-13: Temporal variations of 48-hr indoor BC concentrations at the four schools**



**Figure 4-14: Temporal variations of 48-hr outdoor BC concentrations at four schools**

EP-A was shown again to have the lowest measured pollutant concentrations, either indoors or outdoors among the four tested schools. The 48-hr indoor BC concentrations ranged from 0.14 (0.15) at EP-A to 2.28 (1.33) at CJ-B, and from 0.23(0.2) at EP-A to 2.48(1.27)  $\mu\text{g}/\text{m}^3$  at CJ-B for the outdoor microenvironment. Outdoor BC levels exhibited high spatial variability

across the four schools, ranging from means of  $0.23 \mu\text{g}/\text{m}^3$  at EP-A to  $2.48 \mu\text{g}/\text{m}^3$  at CJ-B. In contrast to total PM levels, the within city concentration differences for BC corresponded to the traffic zones, with higher mean BC levels recorded at EP-B and CJ-B in contrast to EP-A and CJ-A, respectively, as is evident from the visual analysis of the clustered box plots in Figure 4-15. Whereas mobile source emissions were likely the primary contributor to the observed BC concentration in El Paso, cooking, waste burning, wood burning and primitive brick manufacturing may have contributed to the high outdoor BC concentrations observed in Ciudad Juárez.



**Figure 4-15: Box plots for the 48-hr indoor and outdoor BC concentrations ( $\mu\text{g}/\text{m}^3$ )**

## 4.2 Study Population Characteristics

The study population included 15 subjects from school EP-A, 14 subjects from school EP-B, 14 subjects from school CJ-A, and 15 subjects from school EP-B. The health

characteristics of the subjects are shown in Table 4-6. The summary data of these subject characteristics by school along with p-values of t-tests and Fisher's exact tests examining differences between the four schools is shown in Table 4-7. Children lived in close vicinity of their schools ( around two miles) except for one subject from school CJ-B who resided nearer school CJ-A. The remaining four cohorts did not overlap geographically. The overall median age of the children was 8 (range: 6-12) years old. Although age and gender distributions were similar across the cities and the respective school-based cohorts, significant differences were observed for other subject characteristics.

All subjects at schools EP-B, CJ-A, and CJ-B were Hispanic. At school EP-A, four students were Black, three were White, and the remaining eight students were Hispanic. Out of the complete cohort of 58 students, 38 were male. The Body Mass Index (BMI) was calculated using CDC's BMI Percentile Calculator for Child and Teen. The calculator provides BMI results from height and weight data. The calculator also provides the BMI-for-age percentile values, which indicates how the subject's weight compares to that of other children of the same age and gender. The calculator categories the BMI-for-age percentiles according to the following cut points:

- Underweight =  $< 5^{\text{th}}$  percentile;
- Healthy weight =  $5^{\text{th}}$ - $85^{\text{th}}$  percentile;
- Overweight =  $85^{\text{th}}$ - $95^{\text{th}}$  percentile;
- Obese =  $\geq 95^{\text{th}}$  percentile.

The BMI-for-age percentile is more appropriate for between subject and school comparisons than the raw BMI result. The mean BMI percentiles for the two El Paso schools were 55.6 compared to 74.4 for the Ciudad Juárez schools. Within El Paso, BMI percentile was



lower at EP-A (50.6) than EP-B (61.0). The BMI percentiles at CJ-A and CJ-B were 83.9 and 66.8, respectively. Table 4-8 is the summary of the cohort BMI for the four schools based on gender. Figures 4-17 and 4-18 are the bar charts showing the prevalence of overweight and obese students at EP-A and EP-B, and CJ-A and CJ-B, respectively.

Caretaker's education levels also differed across the four schools. The number of subjects whose caretakers has less than a high school education was significantly greater in Ciudad Juárez (63%) than in El Paso (17%). This may indicate the overall lower socioeconomic conditions for the Ciudad Juárez subjects as compared to their counterparts in El Paso. School lunch rates at the El Paso schools indicated lower socioeconomic conditions at EP-B, where 99% of the total student population received free lunch compared to school EP-A, where 53% of total student population received free lunch. However, public schools in Ciudad Juárez do not provide any meals to their students. The students at CJ-A and CJ-B either brought their lunches from home or purchased snacks from a convenience store located in close proximity to the schools.

A significantly greater number of subjects experienced hay fever or seasonal allergies in El Paso (55%) than in Ciudad Juárez (28%). On the same lines, a significantly greater number of subjects in El Paso (34%) used Inhaled Corticosteroid (ICS) Medicine than in the two Ciudad Juárez schools (3%). The lower usage of medicines in the Ciudad Juárez schools could be attributed to less access to health care and lower socioeconomic status of these subjects.

**Table 4-6: Subject wise health characteristics of the cohort for the four schools**

School	Subject ID	Gender	Age	Weight (lb)	Height (in)	BMI (lb/in <sup>2</sup> )	BMI for age and gender (pctl)	Weight Category	Race	Caretaker's Education
EP-A	EP-A-01	F	10	64.00	52.50	16.3	32.6	Healthy	White	Undergrad
	EP-A-02	M	8	76.00	51.50	20.1	93.0	Overweight	Hispanic	< High School
	EP-A-03	M	9	66.00	52.50	16.8	59.1	Healthy	White	Graduate
	EP-A-04	M	9	60.00	52.00	15.6	34.1	Healthy	Hispanic	Unknown
	EP-A-05	M	8	64.00	51.50	17.0	63.8	Healthy	Black	Unknown
	EP-A-06	F	9	105.00	55.50	24.0	96.9	Obese	Hispanic	2 yr college
	EP-A-07	M	9	64.00	52.00	16.6	54.1	Healthy	Hispanic	2 yr college
	EP-A-09	M	7	50.00	47.00	15.9	53.4	Healthy	Hispanic	2 yr college
	EP-A-10	M	8	58.00	51.00	15.7	40.9	Healthy	Hispanic	< High School
	EP-A-11	F	6	51.00	48.50	15.2	46.6	Healthy	White	2 yr college
	EP-A-12	F	9	54.00	50.00	15.2	27.7	Healthy	Hispanic	Unknown
	EP-A-13	M	9	60.00	53.00	15.0	15.3	Healthy	Black	Graduate
	EP-A-14	F	8	204.00	64.00	35.0	99.7	Obese	Black	Unknown
	EP-A-15	M	10	65.00	55.00	15.1	11.3	Healthy	Black	Undergrad
	EP-A-16	M	10	63.00	53.00	15.8	30.0	Healthy	Hispanic	Unknown
EP-B	EP-B-01	M	9	80.00	56.00	17.9	74.4	Healthy	Hispanic	High School
	EP-B-02	F	6	40.00	45.00	13.9	12.7	Healthy	Hispanic	Undergrad
	EP-B-03	F	7	45.00	48.00	13.7	8.1	Healthy	Hispanic	High School
	EP-B-04	M	8	67.00	53.00	16.8	61.3	Healthy	Hispanic	Undergrad
	EP-B-05	F	9	55.00	51.00	14.9	18.8	Healthy	Hispanic	High School
	EP-B-06	M	8	88.00	50.00	24.7	98.7	Obese	Hispanic	High School
	EP-B-07	M	11	150.00	58.00	31.3	99.0	Obese	Hispanic	High School
	EP-B-08	M	12	140.00	60.00	27.3	97.5	Obese	Hispanic	High School
	EP-B-09	M	12	80.00	58.00	16.7	25.5	Healthy	Hispanic	< High School
	EP-B-10	M	8	60.00	50.00	16.9	63.2	Healthy	Hispanic	2 yr college
	EP-B-11	M	8	58.00	53.00	14.5	15.4	Healthy	Hispanic	< High School
	EP-B-12	M	11	110.00	58.00	23.0	92.4	Overweight	Hispanic	Unknown
	EP-B-13	M	10	135.00	60.00	26.4	97.9	Obese	Hispanic	Undergrad
	EP-B-14	M	8	80.00	54.00	19.3	88.7	Overweight	Hispanic	Undergrad
CJ-A	CJ-A-01	F	10	106.7	58.86	21.7	90.7	Overweight	Hispanic	Unknown
	CJ-A-02	F	12	92.4	57.28	19.8	69.1	Healthy	Hispanic	< High School
	CJ-A-04	M	7	60.5	48.23	18.3	89.7	Overweight	Hispanic	Undergrad
	CJ-A-05	F	8	83.6	50.98	22.6	97.7	Obese	Hispanic	High School
	CJ-A-06	F	7	55	48.03	16.8	74.4	Healthy	Hispanic	2 yr college
	CJ-A-07	M	8	100.1	50.79	27.3	99.3	Obese	Hispanic	< High School
	CJ-A-08	F	6	52.8	48.43	15.8	63.2	Healthy	Hispanic	< High School
	CJ-A-09	M	7	.	45.50				Hispanic	< High School
	CJ-A-10	M	7	63.8	50.00	17.9	86.4	Overweight	Hispanic	High School
	CJ-A-11	M	7	52.8	47.83	16.2	68.0	Healthy	Hispanic	< High School
	CJ-A-12	M	8	.	41.00				Hispanic	< High School
	CJ-A-13	M	7	66.55	50.59	18.3	90.6	Overweight	Hispanic	< High School
	CJ-A-14	F	11	101.2	58.86	20.5	82.9	Healthy	Hispanic	< High School
	CJ-A-31	F	10	107.8	56.89	23.4	94.4	Overweight	Hispanic	< High School
CJ-B	CJ-B-16	M	10	77	54.72	18.1	69.9	Healthy	Hispanic	Graduate
	CJ-B-17	M	9	59.4	52.76	15.0	21.8	Healthy	Hispanic	Graduate

	CJ-B-18	M	12	125.4	66.14	20.2	73.2	Healthy	Hispanic	< High School
	CJ-B-19	F	7	97.9	50.79	26.7	99.5	Obese	Hispanic	< High School
	CJ-B-20	F	10	119.9	58.46	24.7	96.6	Obese	Hispanic	< High School
	CJ-B-21	M	9	74.8	52.36	19.2	88.2	Overweight	Hispanic	High School
	CJ-B-22	M	12	95.7	59.84	18.8	63.3	Healthy	Hispanic	Undergrad
	CJ-B-23	M	10	117.7	58.86	23.9	97.2	Obese	Hispanic	Unknown
	CJ-B-24	M	7	57.2	52.56	14.6	20.7	Healthy	Hispanic	High School
	CJ-B-25	F	6	66	51.57	17.4	84.6	Healthy	Hispanic	< High School
	CJ-B-26	M	6	50.6	47.24	15.9	64.9	Healthy	Hispanic	< High School
	CJ-B-27	F	9	62.7	54.53	14.8	17.5	Healthy	Hispanic	< High School
	CJ-B-28	M	11	89.1	57.87	18.7	70.0	Healthy	Hispanic	< High School
	CJ-B-29	M	8	96.8	51.77	25.4	98.9	Obese	Hispanic	Graduate
	CJ-B-30	F	8	60.5	52.76	15.3	35.4	Healthy	Hispanic	< High School

**Table 4-7: Study population characteristics by each school**

Characteristic	Level	All Subjects	City		P-value <sup>c</sup>	School				P-value <sup>c</sup>
			Ciudad Juarez	El Paso		CJ-A	CJ-B	EP-A	EP-B	
# of Subjects		58	29	29		14	15	15	14	
Age [yrs]	Mean (Range)	8.7 (6-12)	8.6 (6-12)	8.8 (6-12)	0.592	8.2 (6-12)	8.9 (6-12)	8.6 (6-10)	9.1 (6-12)	0.552
Gender [N (%)]	Male	38 (66%)	17 (59%)	21 (72%)	0.269	7 (50%)	10 (67%)	10 (67%)	11 (79%)	0.464
Race [N (%)]	Black	4 (7%)	0 (0%)	4 (14%)	<b>0.010</b>	0 (0%)	0 (0%)	4 (27%)	0 (0%)	< <b>0.001</b>
	Hispanic	51 (88%)	29 (100%)	22 (76%)		14 (100%)	15 (100%)	8 (53%)	14 (100%)	
	White	3 (5%)	0 (0%)	3 (10%)		0 (0%)	0 (0%)	3 (20%)	0 (0%)	
BMI [lbs/in <sup>2</sup> ] <sup>a</sup>	Mean (Range)	19.2 (13.7-35.0)	19.5 (14.6-27.3)	18.8 (13.7-35.0)	0.592	19.9 (15.8-27.3)	19.2 (14.6-26.7)	18.0 (15.0-35.0)	19.8 (13.7-31.3)	0.682
BMI for Age and Gender [pctl] <sup>a,b</sup>	Mean (Range)	64.6 (8.1-99.7)	74.4 (17.5-99.5)	55.6 (8.1-99.7)	<b>0.019</b>	83.9 (63.2-99.3)	66.8 (17.5-99.5)	50.6 (11.3-99.7)	61.0 (8.1-99.0)	<b>0.034</b>
BMI Category [N (%)] <sup>a,b</sup>	Normal	35 (63%)	15 (56%)	20 (69%)	0.409	5 (42%)	10 (67%)	12 (80%)	8 (57%)	0.243
	Overweight	9 (16%)	6 (22%)	3 (10%)		5 (42%)	1 (6%)	1 (7%)	2 (29%)	
	Obese	12 (21%)	6 (22%)	6 (21%)		2 (16%)	4 (27%)	2 (13%)	4 (14%)	
Hay Fever [N (%)]		24 (41%)	8 (28%)	16 (55%)	<b>0.033</b>	4 (29%)	4 (27%)	8 (53%)	8 (57%)	0.221
Medications Use [N (%)] <sup>a</sup>	ICS Use	11 (19%)	1 (3%)	10 (34%)	<b>0.005</b>	1 (7%)	0 (0%)	7 (47%)	3 (21%)	<b>0.004</b>
	ICS + LT Use	8 (14%)	1 (3%)	7 (24%)	<b>0.026</b>	1 (7%)	0 (0%)	5 (33%)	2 (14%)	<b>0.045</b>
Caretaker Education [N (%)] <sup>a</sup>	<High School	21 (42%)	17 (63%)	4 (17%)	<b>0.002</b>	9 (69%)	8 (57%)	2 (20%)	2 (15%)	<b>0.012</b>

**Abbreviations:**

**BMI**=body mass index; **pctl**=percentile; **ICS**=inhaled corticosteroids; **LT**=leukotriene blockers; **SABA**=short-acting bronchodilators.

<sup>a</sup>Missing information for BMI (2 subjects) and for caretaker education (8 subjects) - (5 at EP-A and 1 at each of the other schools)

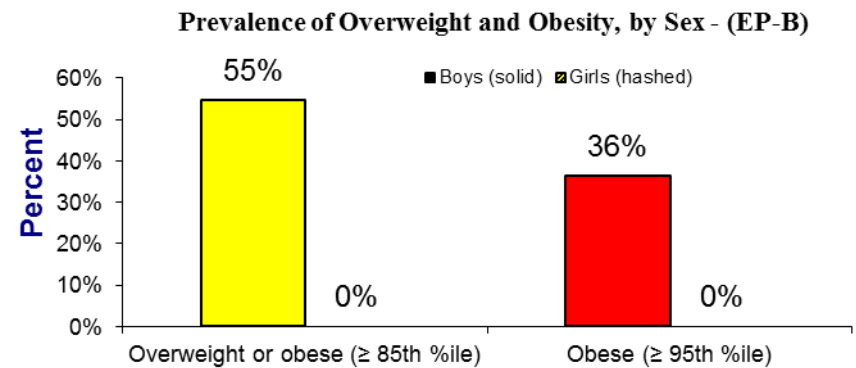
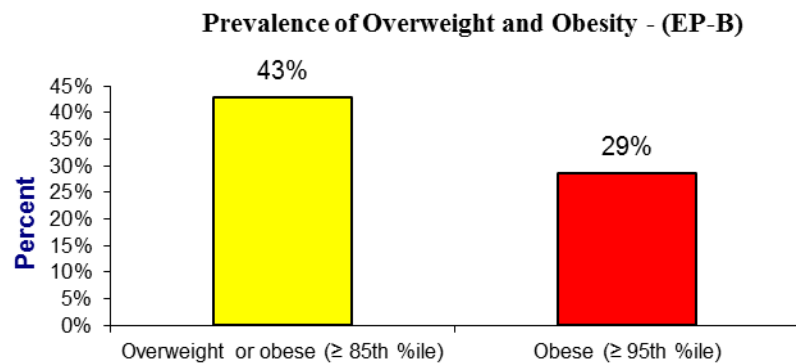
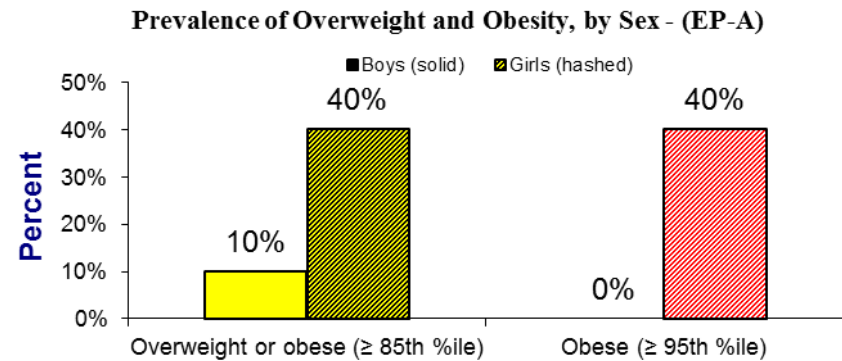
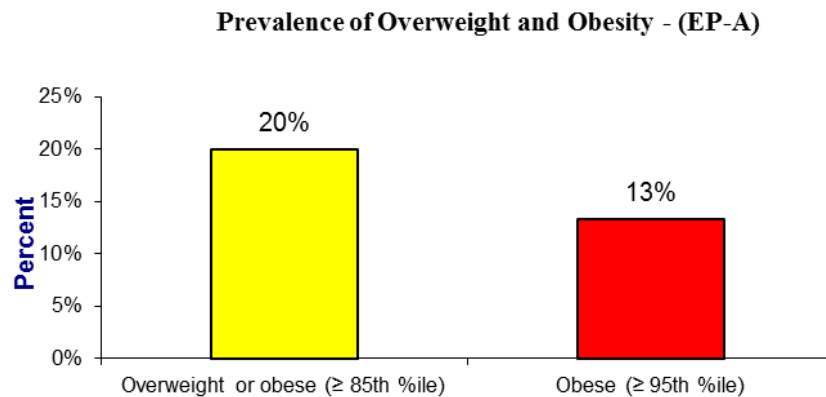
<sup>b</sup>BMI for Age and Gender percentile values (CDC 2011) assigned to the following BMI categories: normal=5<sup>th</sup>-85<sup>th</sup> pctl; overweight=85<sup>th</sup>-95<sup>th</sup> pctl; obese= $\geq$ 95<sup>th</sup> pctl

<sup>c</sup>p-values for t-tests or analyses of variance for continuous variables and Chi-square tests (when all cell values > 5); otherwise Fisher's Exact Test for categorical variables

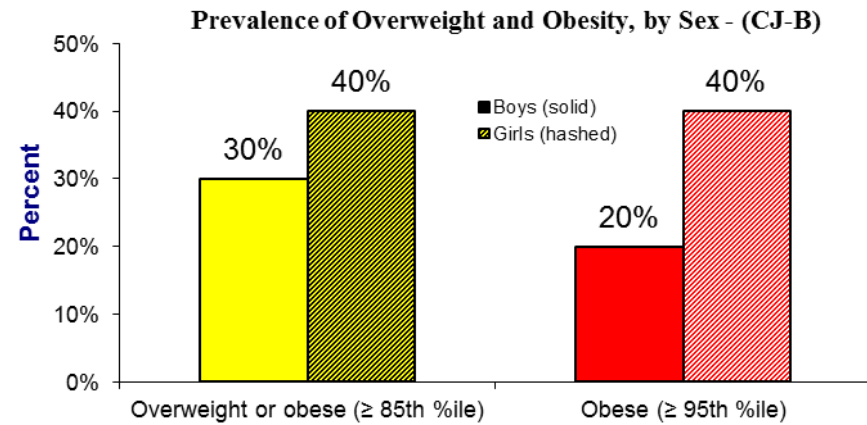
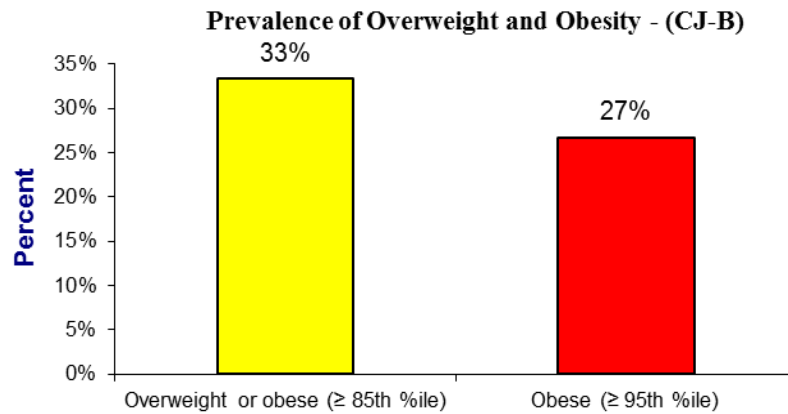
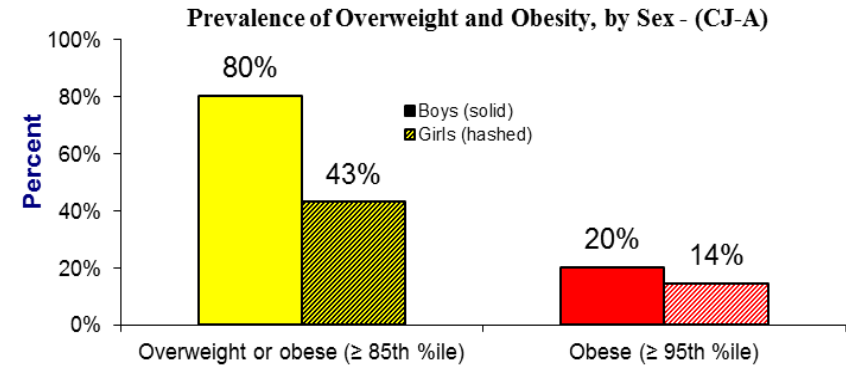
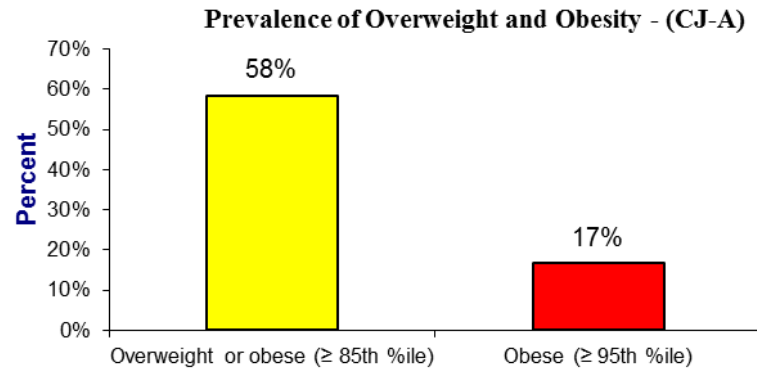
**Table 4-8: Summary of Cohort BMI at the four schools based on gender**

	EP-A			EP-B			CJ-A			CJ-B		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
<b>Number of subjects assessed</b>	10	5	15	11	3	14	5	7	12	10	5	15
<b>Underweight (&lt; 5<sup>th</sup> % ile)</b>	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
<b>Normal BMI (5<sup>th</sup>-85<sup>th</sup> % ile)</b>	90%	60%	80%	45%	100%	57%	20%	57%	42%	70%	60%	67%
<b>Overweight or obese (≥85<sup>th</sup> % ile)</b>	10%	40%	20%	55%	0%	43%	80%	43%	58%	30%	40%	33%
<b>Obese (≥95<sup>th</sup> % ile)</b>	0%	40%	13%	36%	0%	29%	20%	14%	17%	20%	40%	27%

\*Terminology based on: Barlow SE and the Expert Committee. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. Pediatrics. 2007; 120 (suppl 4):164-92.



**Figure 4-17: Prevalence of overweight and obese students at schools EP- A and EP-B in El Paso, Texas**



**Figure 4-18: Prevalence of overweight and obese students at schools CJ- A and CJ-B in Ciudad Juárez, Chihuahua**

### 4.3 Health Outcomes Characterization

Over the course of the study period, 787 exhaled nitric oxide (eNO) measurements were administered, with an average of 14 (range: 6-16) repeated measures per subject. Table 4-9 presents the summary statistics for the eNO measurements for each subject at the four schools. This data is also presented graphically in box plots by subject for each school. The box plots for the subject-wise eNO measurements at schools EP-A, EP-B, CJ-A, and CJ-B are shown in Figures 4-19, 4-20, 4-21, 4-22, respectively. Figure 4-23 is the box plot for the schoolwise eNO measurements. The overall median eNO levels were 20.0 ppb (range: 2.5-135.0 ppb). These levels were in line with those found in other panel based studies of asthmatic children (Barraza-Villarreal et al., 2008; Delfino et al., 2006; Koenig et al., 2003; Liu et al., 2009). However, a wide variation in subject-specific median eNO levels (range: 6.8-89.3 ppb) was observed. Eleven children reported Environmental Tobacco Smoke (ETS) exposure several times per month or more. However, the median eNO levels remained the same when these subjects were excluded from the analyses. These observations are presented in Table 4-10. The time series for the eNO measurements at the four schools are shown from Figure 4-24 to Figure 4-28. The overall spaghetti plots of the raw eNO data as a function of time for each subject at the four schools were plotted. Figures 4-29, 4-30, 4-31, and 4-32 are these plots for school EP-A, EP-B, CJ-A, and CJ-B, respectively.

878 symptoms diaries were collected over the study period. These diaries each had the recording for seven days of subject's health data as recorded by the respective caretakers. Overall, the weekly reporting of cough, difficulty breathing, cold symptoms, and school absenteeism was greater in Ciudad Juárez than in El Paso schools. However, Short-Acting Bronchodilator (SABA) usage was greater in El Paso than in Ciudad Juárez. These trends,



together with ICS medication usage patterns, may be partly attributed to differences in socioeconomic status and health care access across both the cities.

**Table 4-9: Summary statistics by subject for exhaled nitric oxide measurements**

Subject ID	N	Mean	Median	Std. Dev	Variance	MAX	MIN	Q1 (0.25)	Q3 (0.75)	90th percentile	99th percentile
<b>EP-A (El Paso)</b>											
EP-A-01	16	11.8	11.3	3.6	13.2	21.0	7.5	9.4	12.8	16.0	20.4
EP-A-02	16	19.0	19.5	5.5	30.6	29.5	9.5	14.5	23.3	24.3	28.8
EP-A-03	16	6.3	6.8	2.0	4.2	9.0	2.5	5.0	7.5	8.8	9.0
EP-A-04	15	8.9	7.5	3.9	15.2	15.0	3.8	6.3	12.3	13.7	14.9
EP-A-05	6	8.8	9.0	2.8	7.9	12.5	5.3	6.6	10.6	11.8	12.4
EP-A-06	14	66.0	60.3	18.7	349.7	118.5	45.0	57.5	70.5	84.4	114.7
EP-A-07	16	51.0	47.8	13.2	175.3	80.0	28.0	42.4	55.9	69.0	79.1
EP-A-09	16	13.7	11.0	9.6	91.3	41.0	4.3	9.3	14.1	24.8	39.6
EP-A-10	16	43.3	43.3	13.3	176.8	61.5	12.5	36.5	52.9	59.0	61.2
EP-A-11	14	21.6	14.0	16.0	254.5	46.5	5.0	10.0	37.4	45.6	46.4
EP-A-12	14	41.9	41.8	15.5	238.9	74.5	19.0	35.6	45.9	60.0	72.6
EP-A-13	14	57.9	55.0	23.2	538.1	119.5	27.0	44.4	62.6	81.3	115.1
EP-A-14	15	21.9	20.5	8.2	67.8	37.0	9.5	17.3	28.3	33.1	36.7
EP-A-15	15	39.1	30.5	20.6	424.0	71.0	15.5	21.0	58.8	65.5	70.5
EP-A-16	13	19.0	19.0	4.7	22.0	25.5	12.5	14.0	23.0	24.2	25.4
<b>EP-B (El Paso)</b>											
EP-B-01	16	47.0	46.3	8.3	69.6	63.0	28.0	43.8	52.8	56.3	62.1
EP-B-02	15	16.2	14.5	6.4	41.5	30.0	7.0	11.5	20.5	23.9	29.2
EP-B-03	16	12.7	12.0	2.6	6.6	20.5	9.5	11.0	13.6	14.8	19.8
EP-B-04	14	83.9	86.8	30.6	936.8	135.0	32.5	61.5	107.6	111.9	132.0
EP-B-05	16	56.7	57.3	12.6	159.0	77.5	35.0	47.9	63.4	73.3	77.1
EP-B-06	15	11.6	11.5	3.4	11.4	17.0	6.0	8.8	14.0	15.9	16.9
EP-B-07	14	33.1	29.5	13.6	185.5	63.0	12.0	26.4	33.4	52.9	61.9
EP-B-08	14	12.4	12.8	2.5	6.4	16.0	6.5	11.6	14.0	14.5	15.8
EP-B-09	13	9.4	8.5	3.6	12.9	16.0	4.3	7.5	10.0	14.9	15.9
EP-B-10	16	89.1	89.3	17.2	296.5	116.5	61.5	78.4	98.3	115.5	116.5
EP-B-11	9	51.4	56.5	17.3	299.6	69.0	22.5	48.5	64.5	67.8	68.9
EP-B-12	14	11.8	10.8	7.1	50.0	32.0	3.8	8.5	14.6	16.6	30.1
EP-B-13	14	43.3	44.0	15.4	237.8	65.5	15.0	35.1	54.1	62.9	65.4
EP-B-14	14	27.4	25.3	11.0	121.1	59.0	14.5	21.0	29.9	35.6	56.1
<b>CJ-A (Juarez)</b>											
CJ-A-01	14	39.6	27.8	25.3	638.4	85.0	12.5	22.0	61.5	75.0	84.1
CJ-A-02	12	20.3	17.5	9.3	86.2	40.5	10.5	13.3	25.8	30.9	39.5
CJ-A-04	12	17.4	13.8	12.0	144.1	44.5	6.0	11.6	16.9	36.9	43.9
CJ-A-05	12	14.5	13.8	7.6	57.4	30.0	2.5	10.4	18.1	22.3	29.2
CJ-A-06	13	11.0	9.0	6.5	42.6	30.0	5.0	7.5	12.5	15.5	28.3
CJ-A-07	14	16.7	16.0	6.2	38.5	27.5	10.0	10.8	21.6	25.3	27.4
CJ-A-08	12	24.3	26.0	5.2	27.4	33.0	16.0	20.6	27.1	29.0	32.6
CJ-A-09	14	14.9	13.0	6.5	42.3	27.0	6.0	10.6	19.1	24.3	26.7
CJ-A-10	13	22.5	17.0	14.5	211.6	54.5	7.5	11.5	33.5	37.3	52.5
CJ-A-11	10	9.8	9.0	3.6	13.2	14.5	5.0	7.0	13.6	14.1	14.5
CJ-A-12	10	11.3	10.5	6.1	37.0	26.0	5.0	7.3	13.3	15.7	25.0
CJ-A-13	10	27.8	22.5	14.9	223.1	59.5	11.5	18.4	36.0	44.7	58.0
CJ-A-14	12	11.0	11.0	2.8	7.7	17.5	7.0	9.6	12.1	12.5	17.0
CJ-A-31	12	15.6	9.5	20.2	408.0	77.5	5.3	6.4	12.5	23.8	71.7
<b>CJ-B (Juarez)</b>											
CJ-B-16	15	34.9	34.0	14.7	216.4	58.0	12.5	24.3	47.5	51.8	57.4
CJ-B-17	15	30.4	20.5	21.2	448.7	73.0	9.0	15.3	43.5	63.5	72.8

CJ-B-18	9	84.8	79.0	21.2	449.4	125.0	63.0	67.0	101.0	107.4	123.2
CJ-B-19	15	17.9	18.0	5.5	30.0	30.5	9.0	14.5	19.5	24.9	29.8
CJ-B-20	14	16.2	15.3	7.4	54.6	35.5	5.0	12.3	18.0	23.5	34.1
CJ-B-21	15	46.2	33.5	29.9	896.0	109.0	11.0	26.0	63.0	89.1	106.7
CJ-B-22	13	20.0	21.0	6.2	39.0	33.5	10.0	16.5	23.5	25.0	32.5
CJ-B-23	15	32.6	24.0	20.0	400.4	77.5	10.0	18.8	44.5	60.3	75.5
CJ-B-24	13	20.8	19.0	8.5	71.7	39.0	7.0	16.0	26.5	27.5	37.6
CJ-B-25	15	19.2	19.5	4.5	20.6	27.5	11.0	16.0	22.5	23.6	27.0
CJ-B-26	9	25.4	21.5	14.3	205.8	53.0	10.5	18.5	26.0	46.6	52.4
CJ-B-27	15	20.7	20.5	5.4	28.7	33.0	10.0	17.8	22.8	26.1	32.2
CJ-B-28	15	32.2	24.0	19.7	388.7	71.0	11.5	18.5	41.8	62.7	70.0
CJ-B-29	15	32.7	28.0	15.6	242.0	64.5	9.5	21.8	39.8	55.1	63.2
CJ-B-30	8	11.4	10.0	6.3	39.7	25.0	5.0	7.9	12.6	17.7	24.3

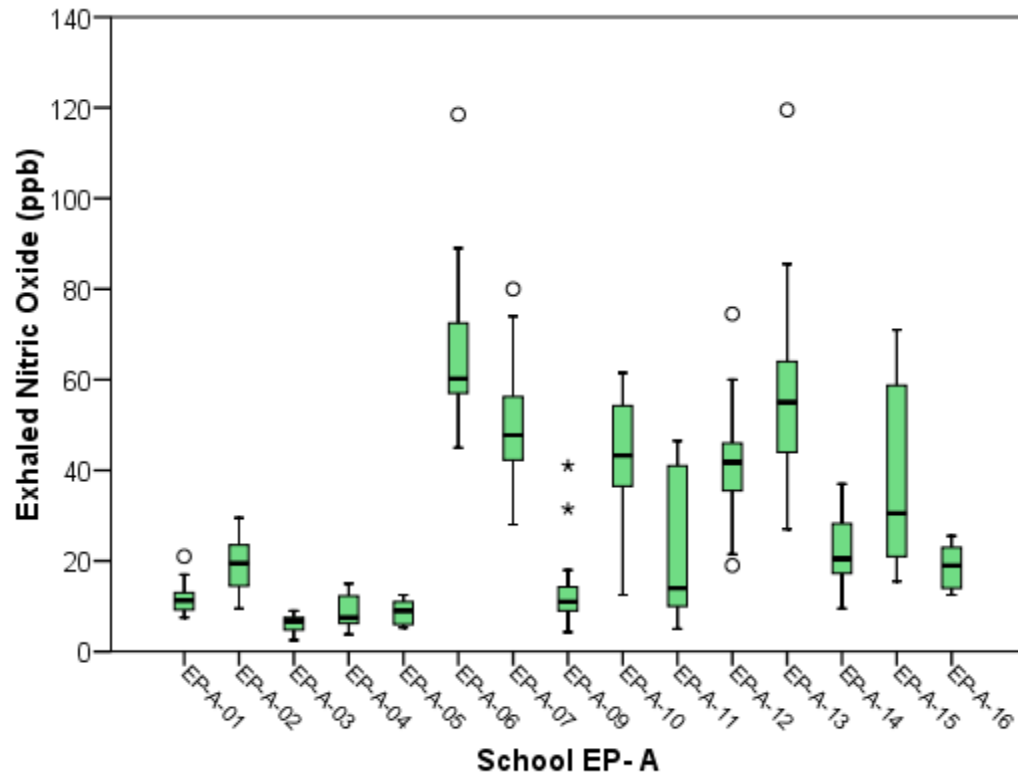


Figure 4-19: Box plots of exhaled nitric oxide measurements by subjects for EP-A

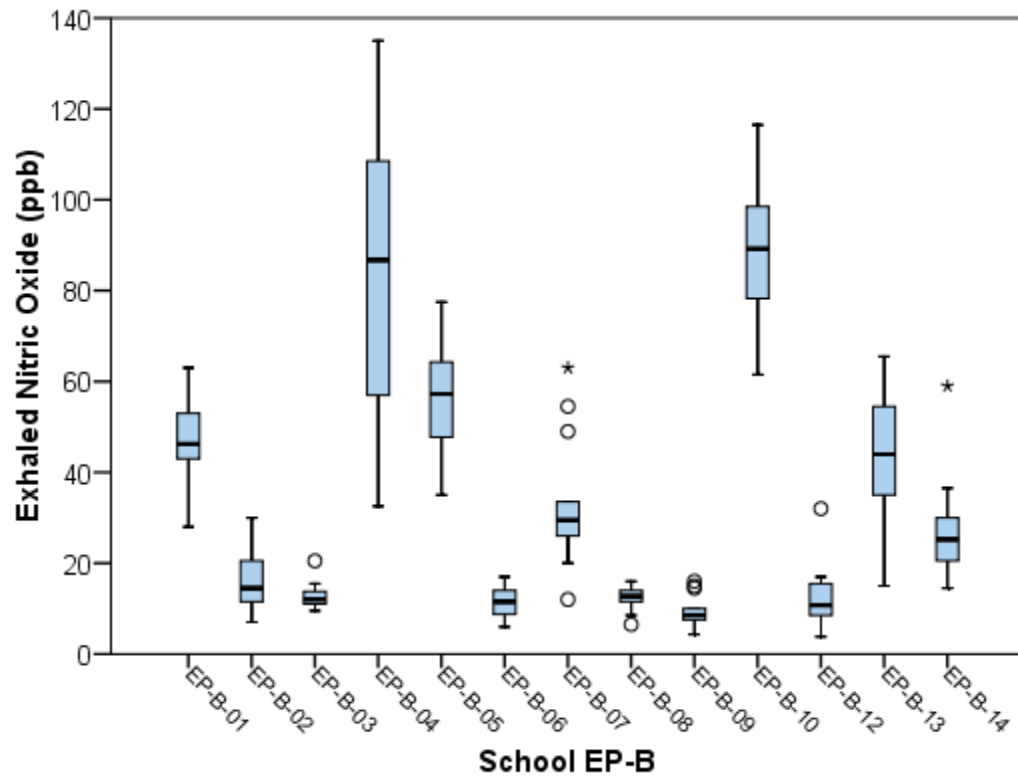


Figure 4-20: Box plots of exhaled nitric oxide measurements by subjects for EP-B

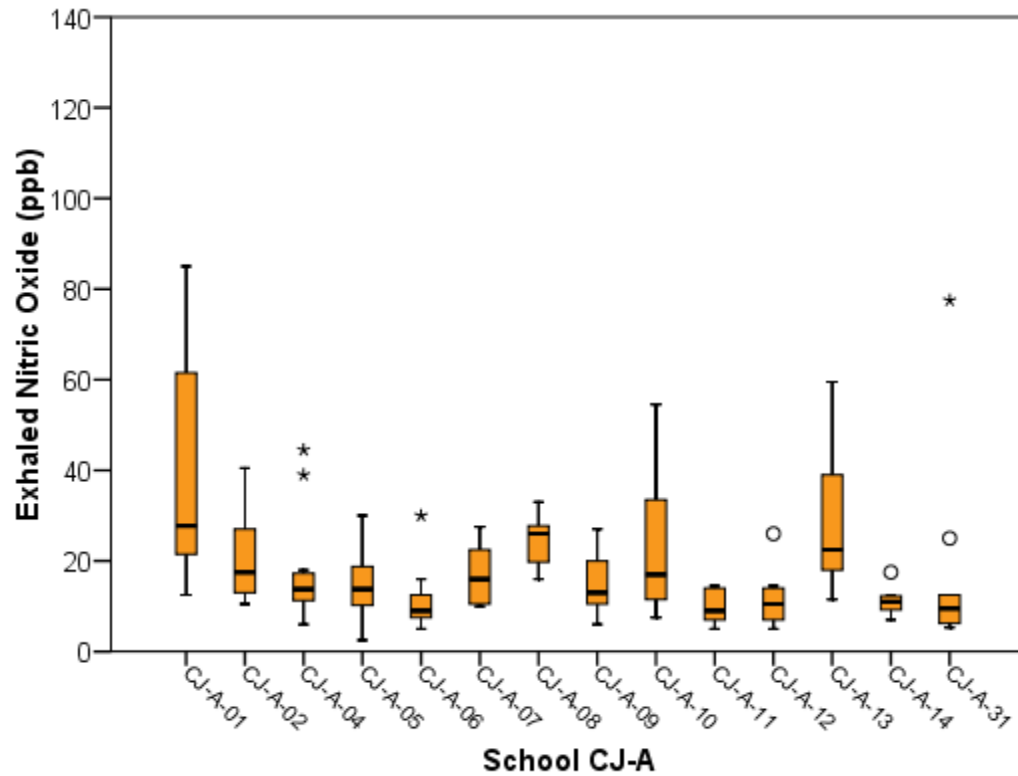


Figure 4-21: Box plots of exhaled nitric oxide measurements by subjects for CJ-A

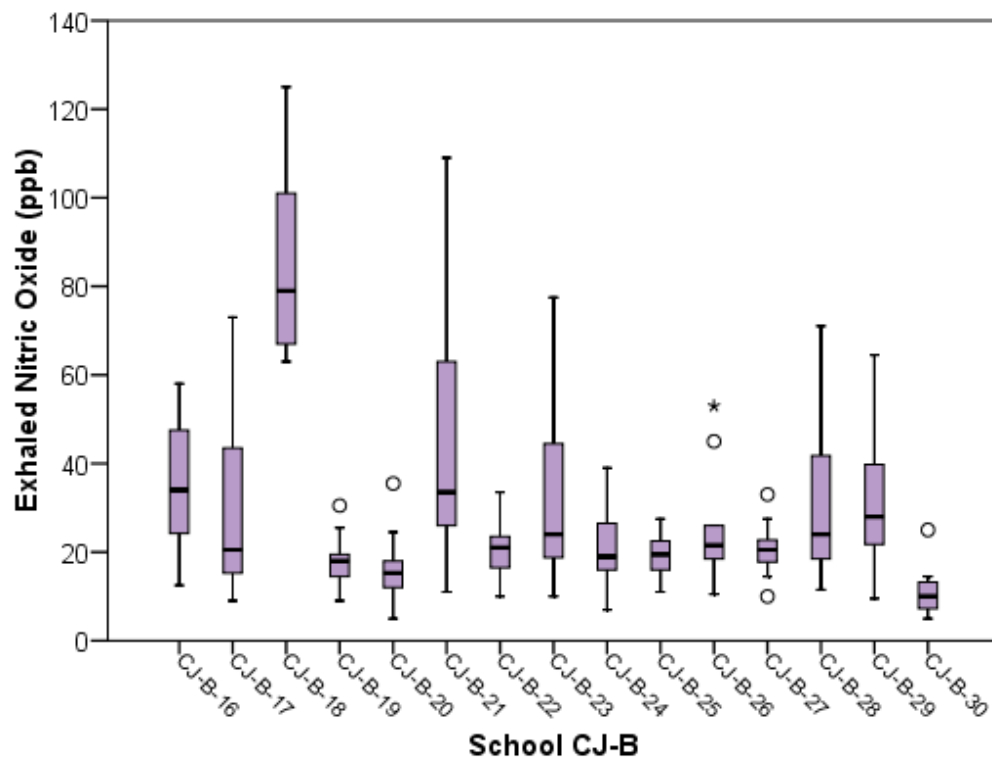


Figure 4-22: Box plots of exhaled nitric oxide measurements by subjects for CJ-B

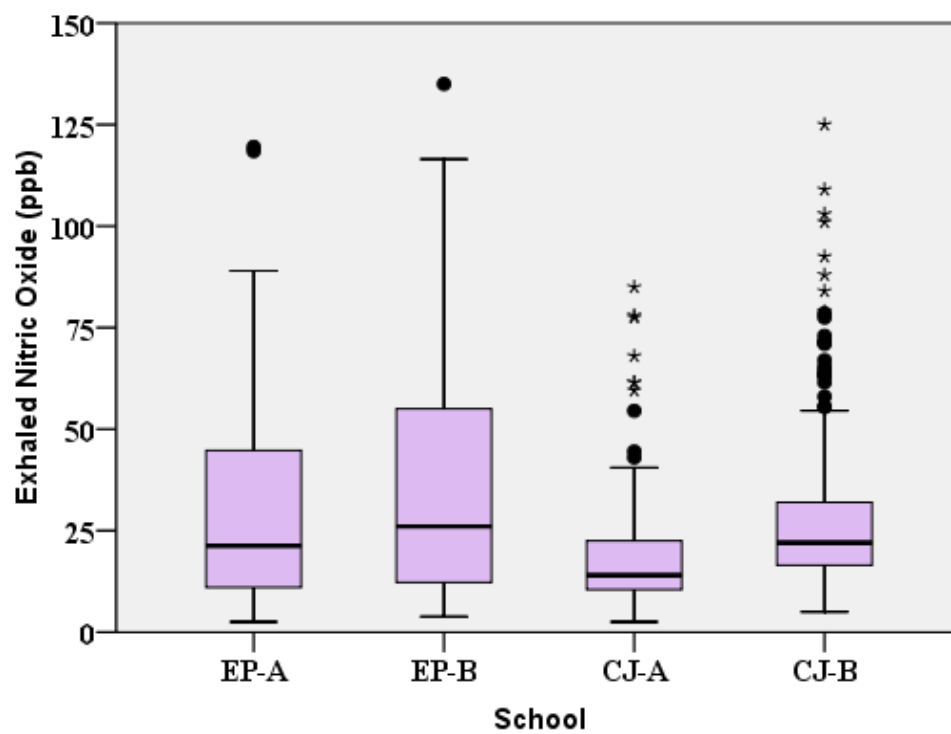


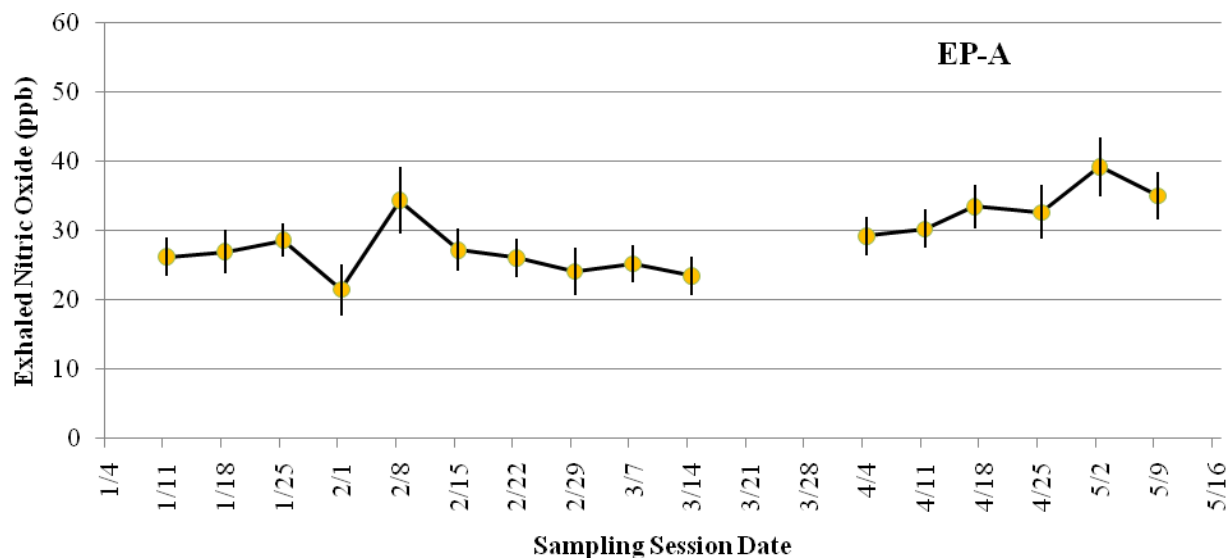
Figure 4-23: Box plots of exhaled nitric oxide (ppb) by school

**Table 4-10: Subject health outcome observations by each school**

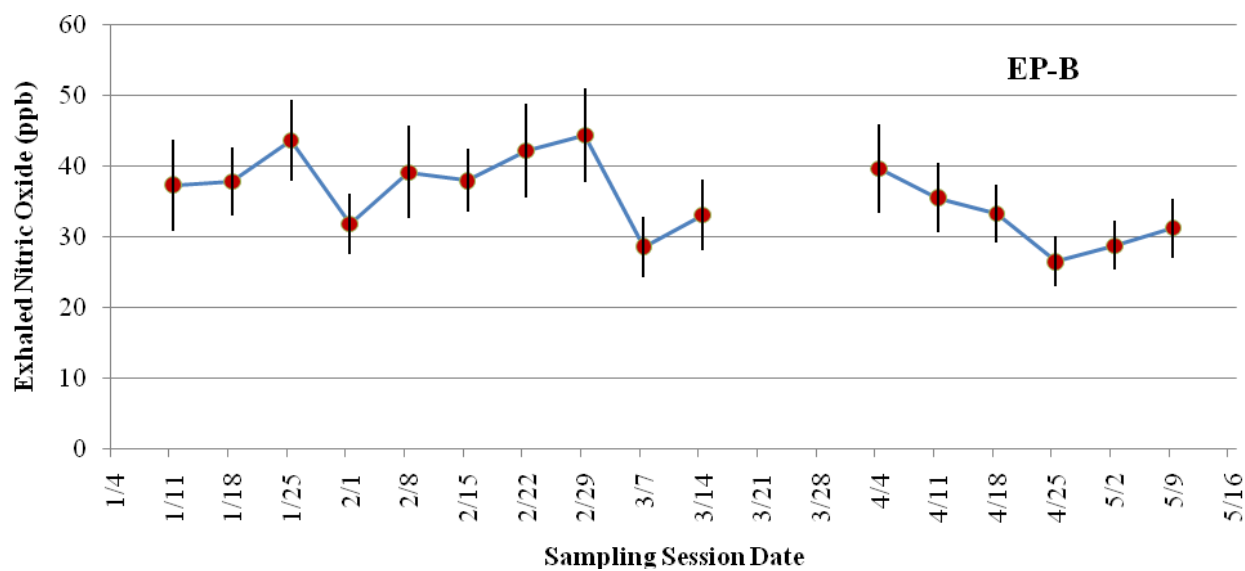
Characteristic	Level	All Subjects	City		P-value <sup>b</sup>	School				P-value <sup>b</sup>
			Ciudad Juarez	El Paso		CJ-A	CJ-B	EP-A	EP-B	
# of Subjects		58	29	29		14	15	15	14	
Exhaled NO [ppb]	n <sup>a</sup> Median (Range)	787 20.0 (2.5-135.0)	371 18.5 (2.5-125.0)	416 23.0 (18.5-135.0)	<0.001	170 14.0 (2.5-85.0)	201 22.0 (5.0-125.0)	216 21.3 (2.5-119.5)	200 26.0 (3.8-135.0)	<0.001
Exhaled NO in non-ETS exposed subjects [ppb]	N (# subjects) Median (Range)	637 (47) 20.0 (2.5-135.0)	310 (24) 17.5 (2.5-109.0)	327 (23) 28.0 (2.5-135.0)	<0.001	148 (12) 12.5 (2.5-85.0)	162 (12) 21.0 (5.0-109.0)	184 (13) 25.8 (2.5-119.5)	143 (10) 33.0 (4.3-135.0)	<0.001
Symptoms occurrence in last week [N (%)]	n <sup>a</sup>	878	475	403		228	247	207	196	
	Cough	274 (31%)	203 (43%)	71 (18%)	<0.001	137 (60%)	66 (27%)	30 (14%)	41 (21%)	<0.001
	Wheeze	92 (10%)	41 (9%)	50 (12%)	0.067	24 (11%)	17 (7%)	11 (5%)	39 (20%)	<0.001
	Difficulty Breathing	105 (12%)	74 (16%)	31 (8%)	<0.001	34 (15%)	40 (16%)	3 (1%)	28 (14%)	<0.001
	Cold Symptoms	155 (18%)	115 (24%)	40 (10%)	<0.001	73 (32%)	42 (17%)	26 (13%)	14 (7%)	<0.001
	Missed School	90 (10%)	79 (17%)	11 (3%)	<0.001	38 (17%)	41 (17%)	5 (2%)	6 (3%)	<0.001
	SABA Use	125 (14%)	50 (11%)	75 (19%)	<0.001	23 (10%)	27 (11%)	19 (9%)	56 (29%)	<0.001

<sup>a</sup>n refers to the number of weekly exhaled NO samples or symptoms diaries completed over the study period

<sup>b</sup>p-values for t-tests or analyses of variance for continuous variables and Chi-square tests (when all cell values > 5); otherwise Fisher's Exact Test for categorical variables

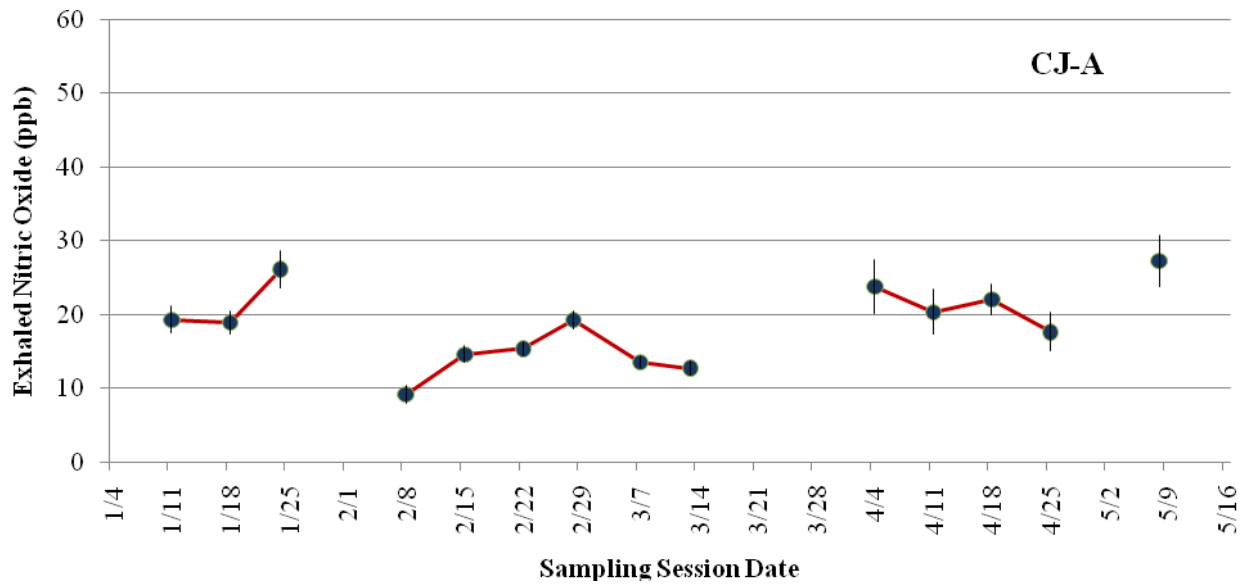


**Figure 4-24: Time series of exhaled nitric oxide at EP-A. Error bar represent the 95% confidence interval for the mean**

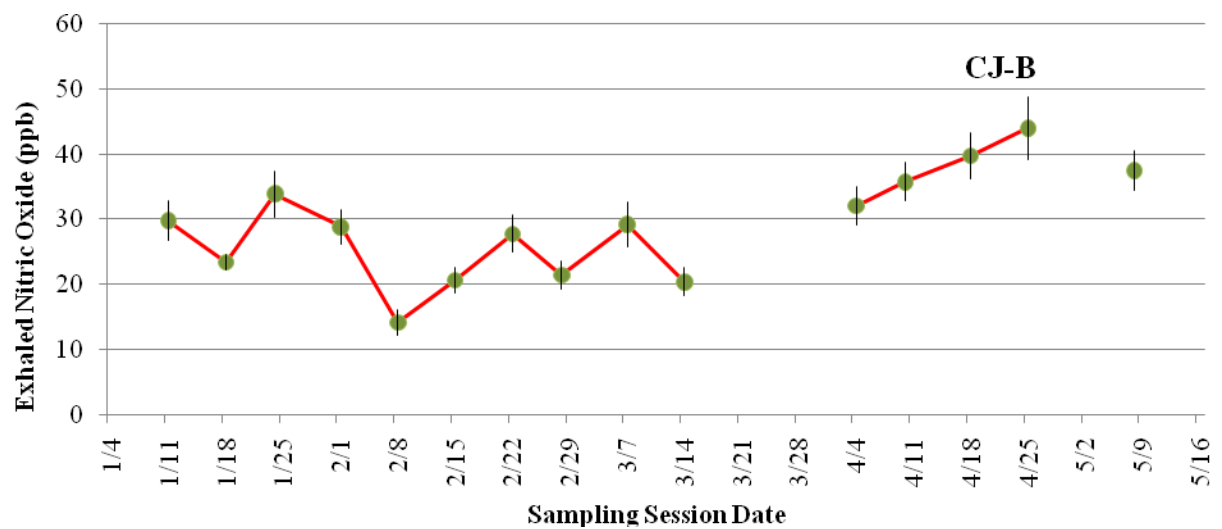


**Figure 4-25: Time series of exhaled nitric oxide at EP-B. Error bar represent the 95% confidence interval for the mean**

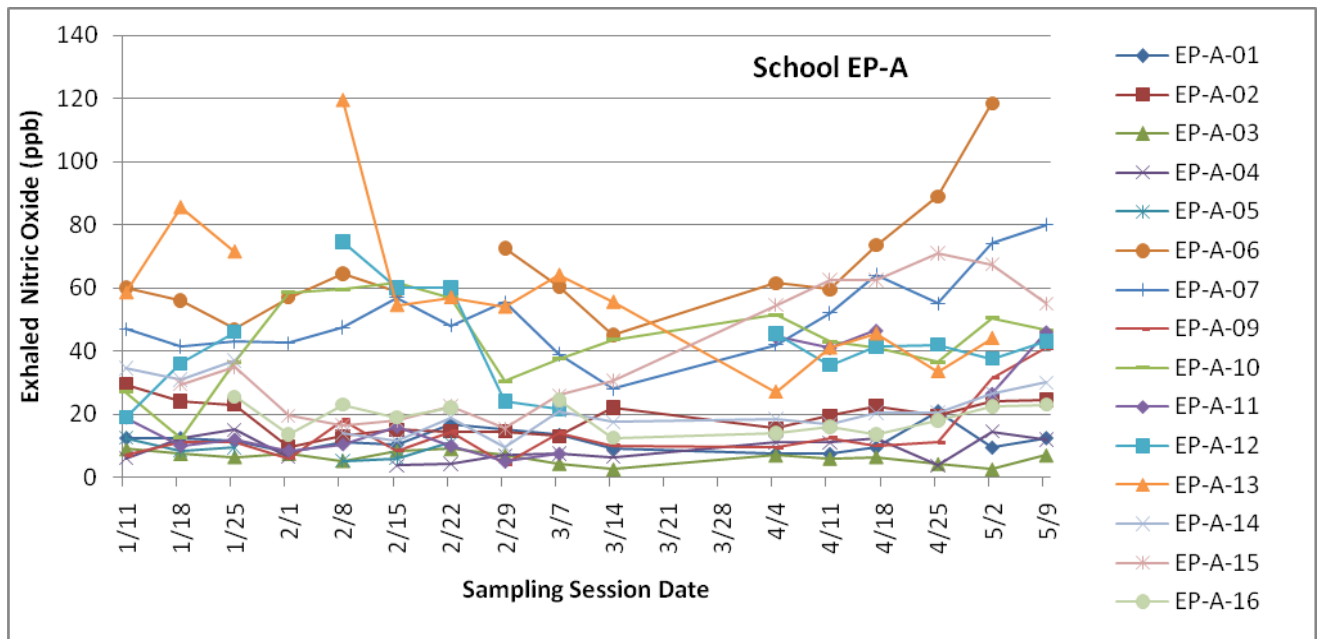




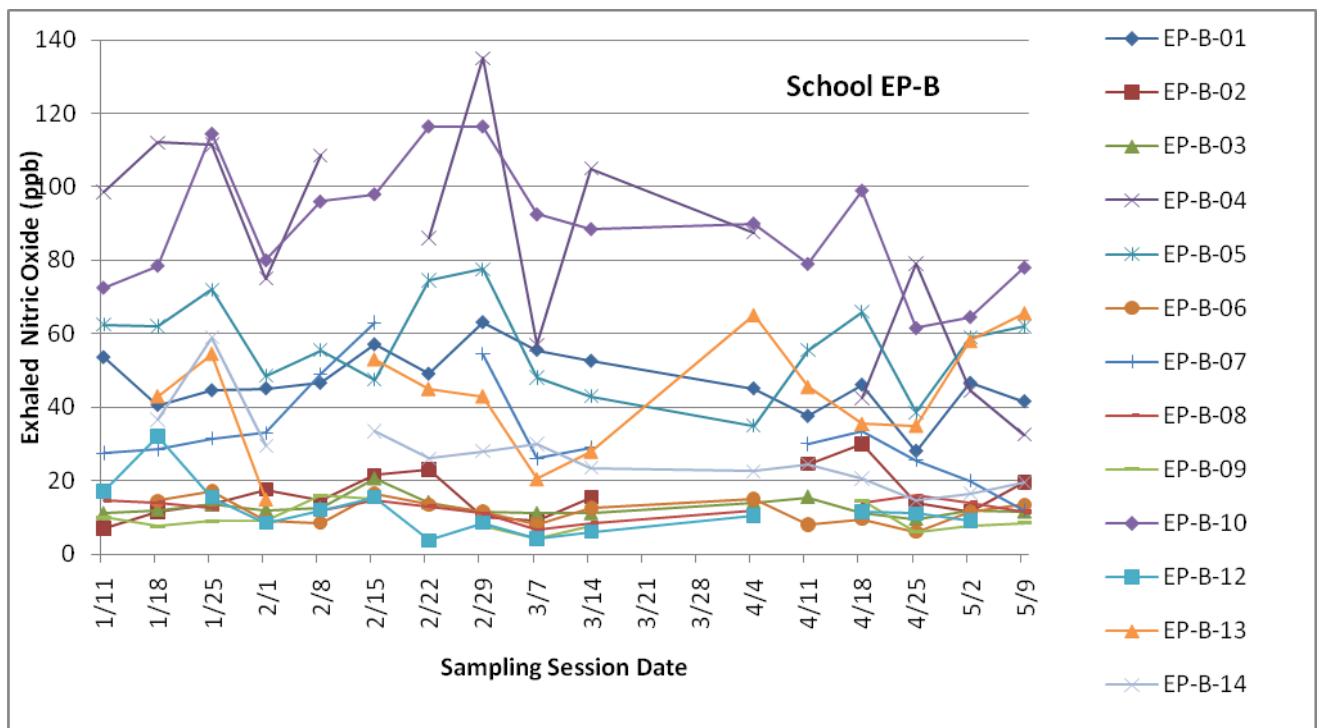
**Figure 4-26: Time series of exhaled nitric oxide at CJ-A. Error bar represent the 95% confidence interval for the mean**



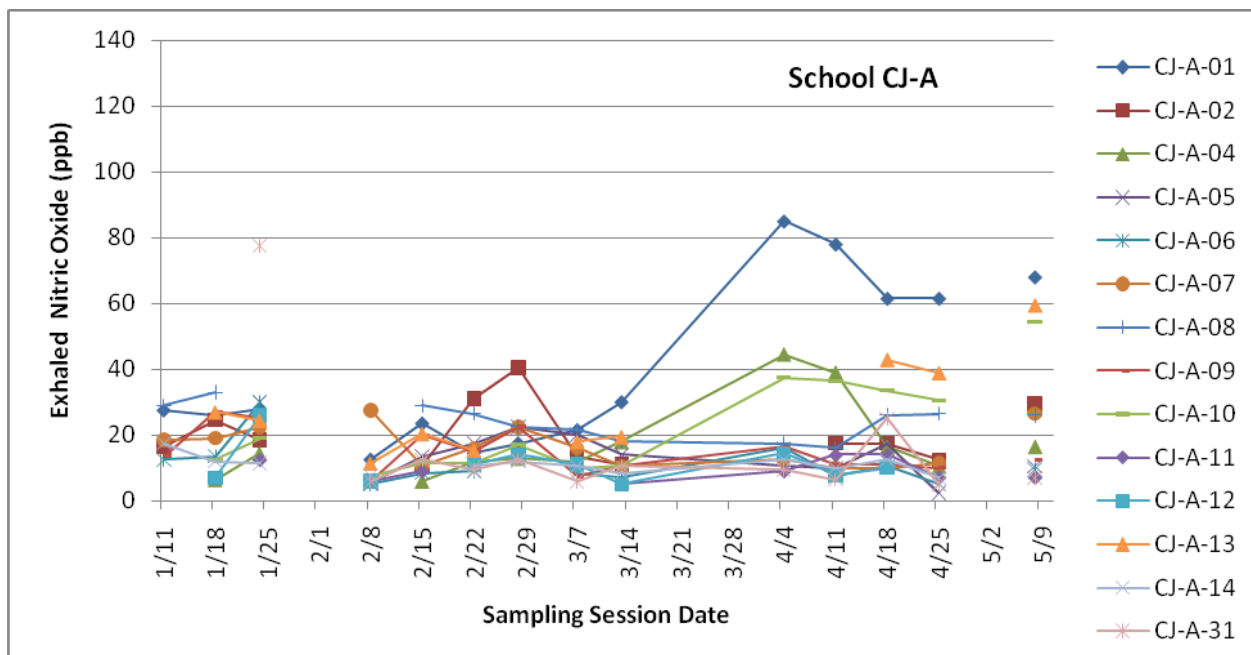
**Figure 4-27: Time series of exhaled nitric oxide at CJ-B. Error bar represent the 95% confidence interval for the mean**



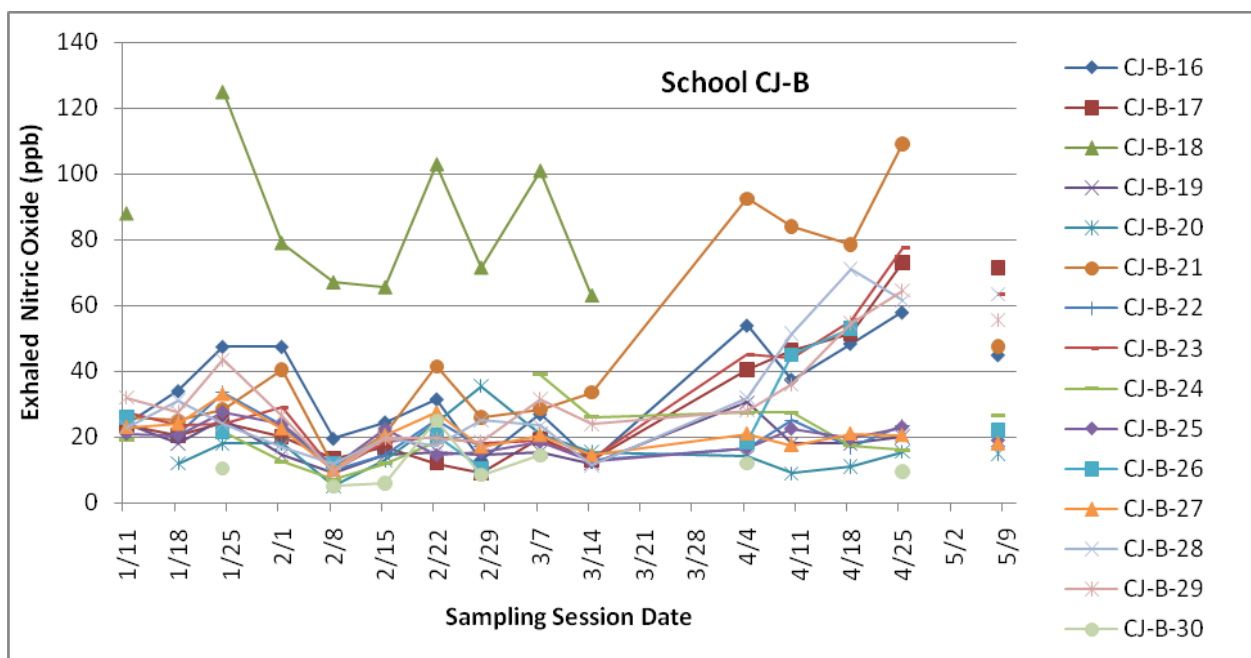
**Figure 4-28: Time series plots of exhaled nitric oxide measurements by subject for EP-A**



**Figure 4-29: Time series plots of exhaled nitric oxide measurements by subject for EP-B**



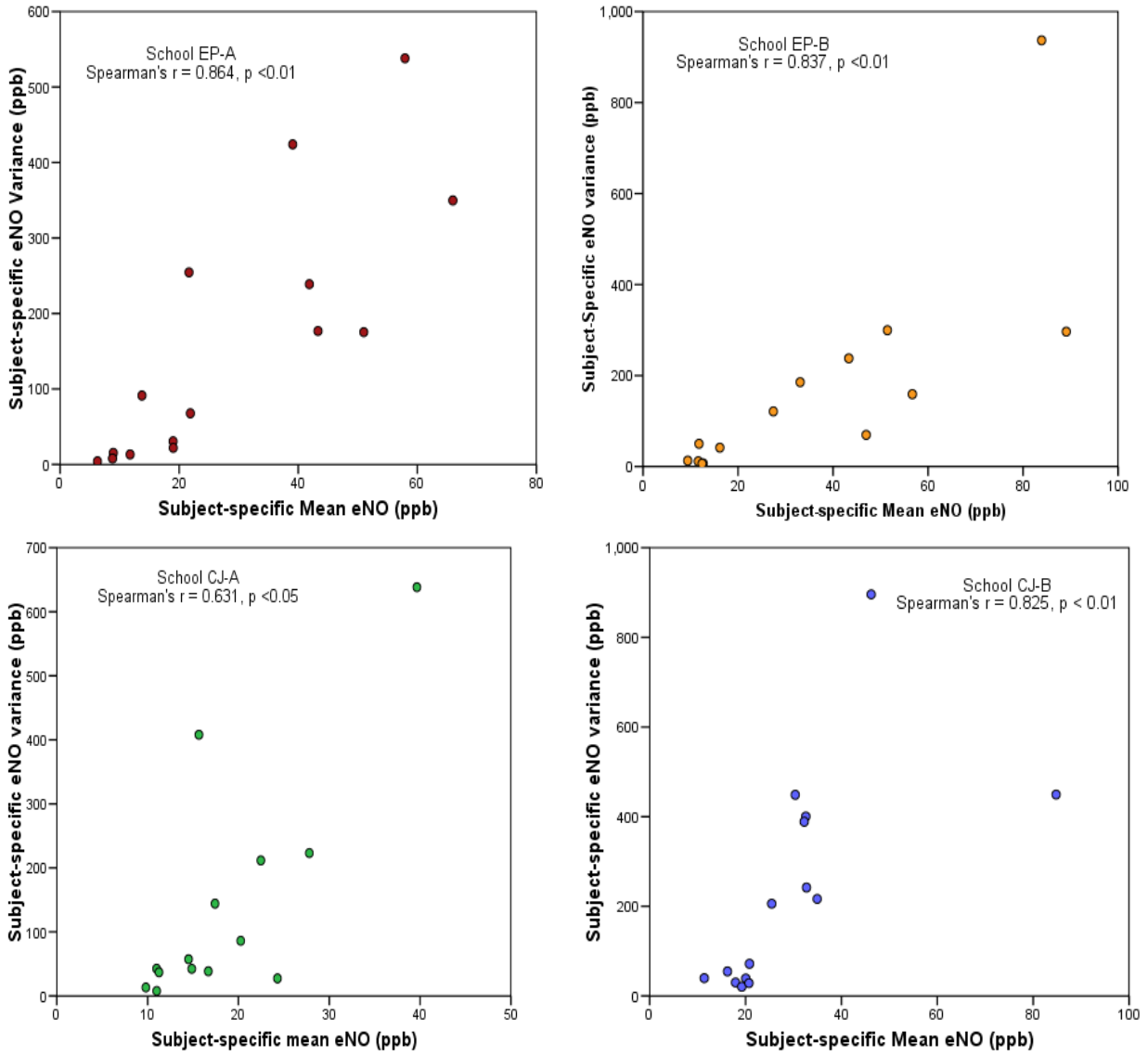
**Figure 4-30: Time series plots of exhaled nitric oxide measurements by subjects for CJ-A**



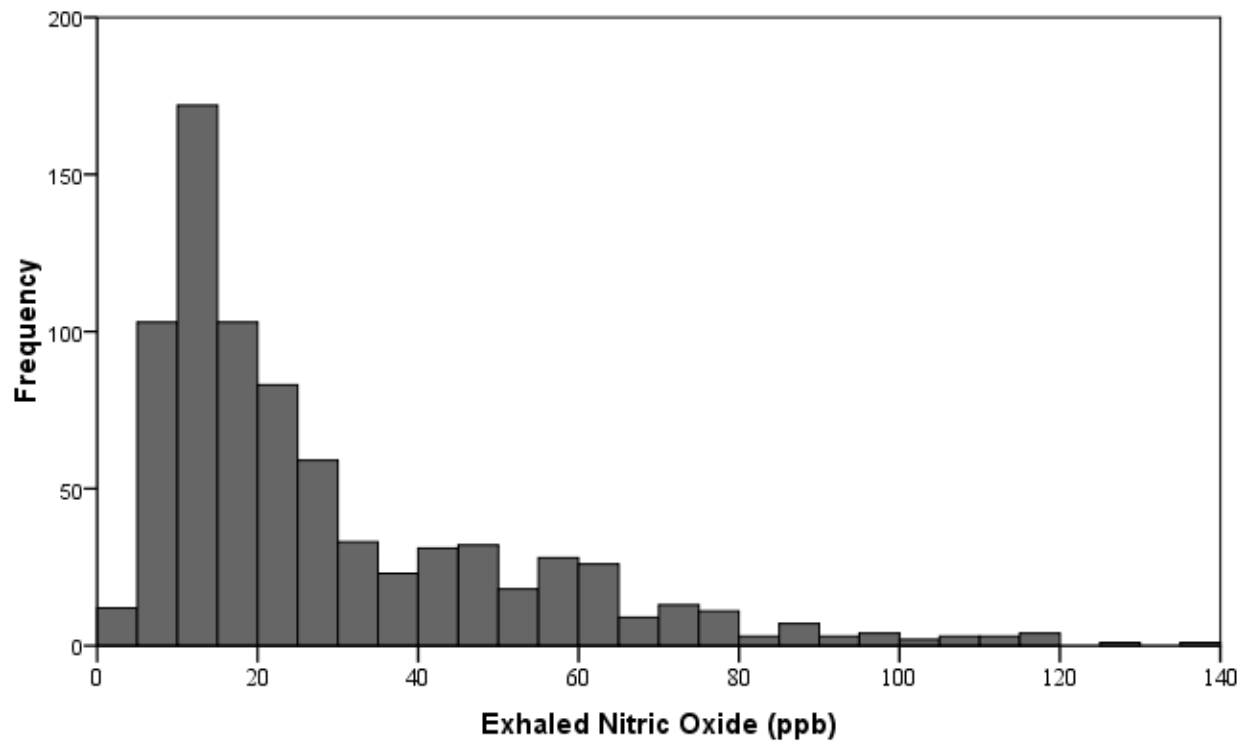
**Figure 4-31: Time series plots of exhaled nitric oxide measurements by subjects for CJ-B**

#### **4.4 Assessment of Exhaled Nitric Oxide (eNO) measurement distributions**

The distribution of the eNO measurements across the four schools was assessed for epidemiologic analyses. Scatter plots of subject-specific means and variances of the eNO measurements are presented in Figure 4-32. The corresponding Spearman's Correlations are shown in the graphs too. The subject-specific variance increased with the means; therefore, the log-transformation of the eNO values was appropriate. Histograms of the outcome distributions, overall and by school, also illustrated the log-normal distribution of eNO. These are presented in Figures 4-33 and 4-34.



**Figure 4-32: Scatter plots of subject-specific eNO measurements means and variances at the four schools**



**Figure 4-33: Histogram of overall eNO distribution at the four schools**

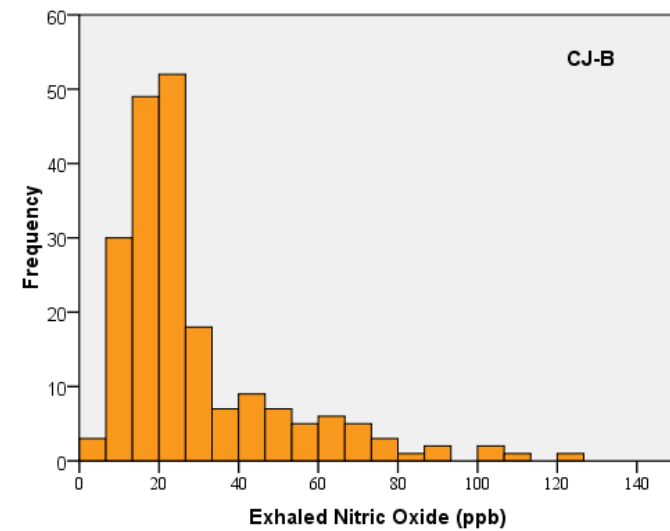
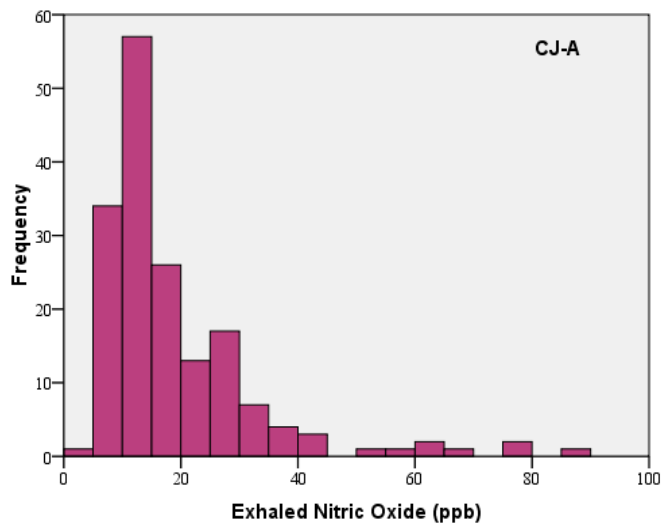
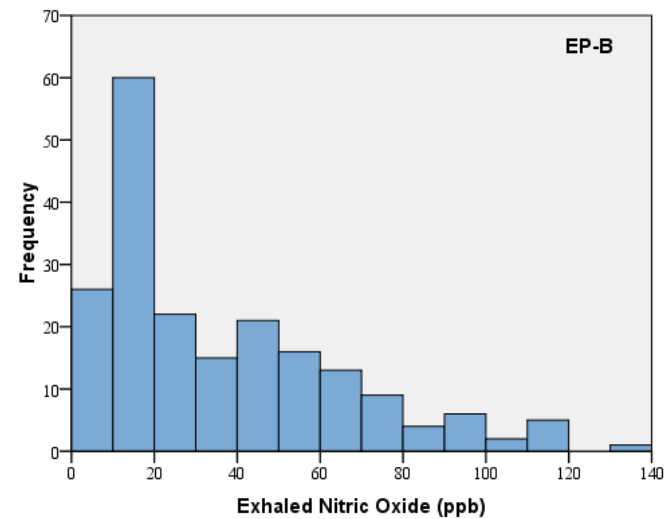
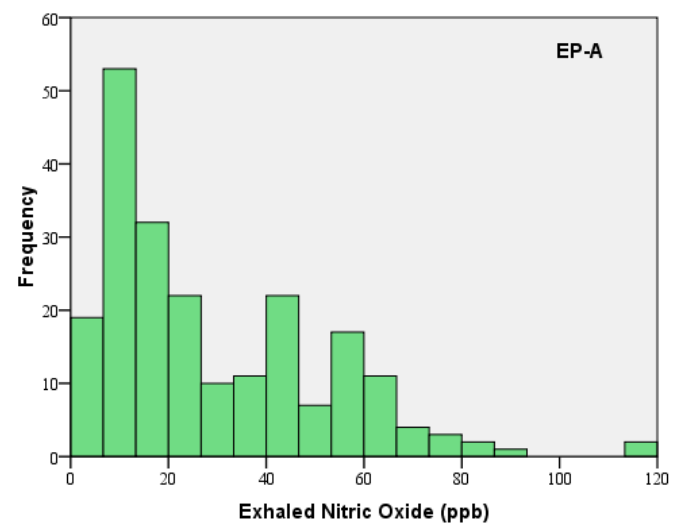


Figure 4-34: Histogram of eNO distribution at the four schools

## **5.0 Indoor-Outdoor Pollutant Concentration Ratios**

Indoor/outdoor (I/O) ratios for pollutants like PM and NO<sub>2</sub> are some of the salient features in understanding the realistic exposure of school-going asthmatic children to these pollutants. The US population spends a majority of their time indoors (Klepeis et al., 2001). These ratios for pollutant concentrations may be affected by various parameters. Differences in building envelope tightness (Goyal and Khare, 2009; Luoma and Batterman, 2001; Poupard et al., 2005), building design (Ashmore and Dimitroulopoulou, 2009), pollutant differential penetration efficiency (Sarnat et al., 2006), building air exchange rates (Rojas-Bracho et al., 2000; Singer et al., 2004) are some of the crucial parameters that influence these ratios. In addition, presence of central air conditioning (Li et al., 2003), types of HVAC systems (Parker et al., 2008; Weschler, 2009), other indoor air pollution sources (Wadden and Scheff, 1983), and human presence, occupancy rates and patterns (Blondeau et al., 2005; Branis et al., 2005, Diapouli et al., 2008; Guo et al., 2008; Monn et al., 1997) are other important factors determining indoor/outdoor pollution ratios. These ratios also vary on a diurnal and seasonal basis (Singer et al., 2004). Indoor air pollution can be attributed to both indoor and outdoor sources. Pollutants can migrate from outdoors to indoors and indoor air sources could exacerbate indoor air pollution. Indeed, indoor air pollution concentrations can exceed outdoor air concentrations (Diette et al., 2007).

The results, for all the monitored pollutants, clearly demonstrated a myriad range of ratios of indoor to outdoor concentrations. During the sampling period, several unique characteristics and conditions including levels of indoor activity in the monitored locations, infiltration levels etc. were noted. This may limit the generalization of the indoor-outdoor results



to other periods and seasons of the year or schools in other parts of the nation. Some of these characteristics are as follows:

- The El Paso schools were relatively old and ventilation systems were aged, possibly deteriorated, and not documented;
- The Ciudad Juárez schools were naturally ventilated and the windows were inadvertently always left open after school hours at CJ-A. In contrast, evaporative coolers were employed at schools EP-A and EP-B and the doors and windows were closed after school hours at these two schools.
- Both the El Paso schools switched from heating to cooling around April 12, 2008.
- EP- A and EP-B turned off their respective cooling systems at 4:30 PM during weekdays after April 12 and on weekends throughout the year.

In spite of the abovementioned observations, the indoor-outdoor analysis in the following paragraphs should nevertheless be still viewed as suggestive of the relationships between indoor and outdoor pollutant concentrations for exposure assessment usage in the Paso del Norte region.

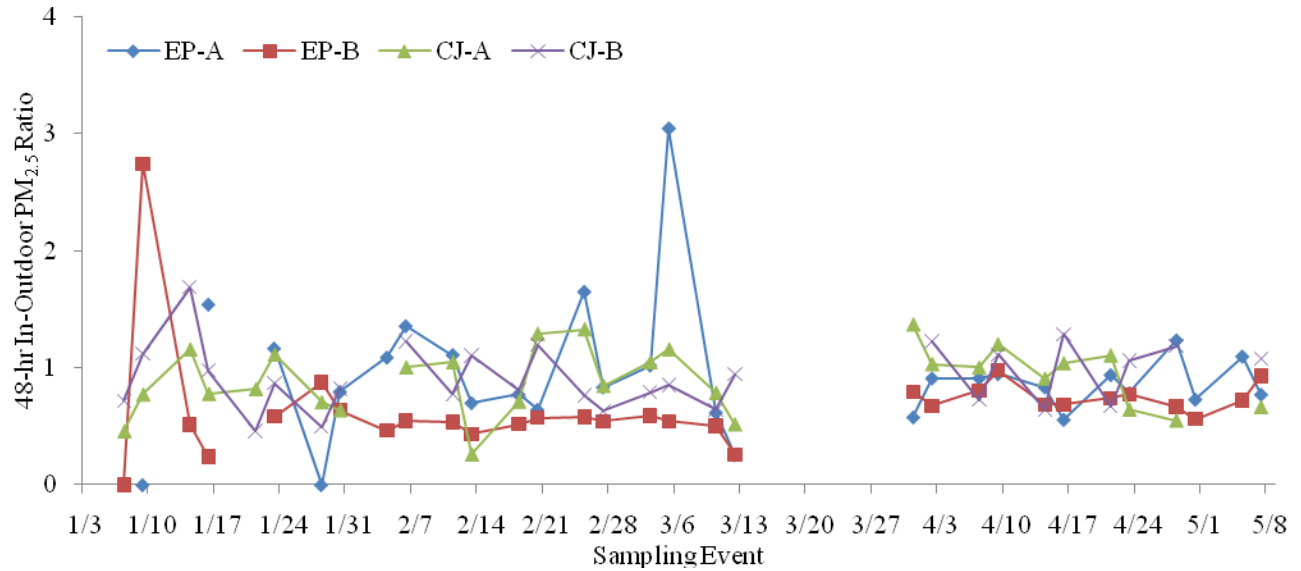
### 5.1 48-hr PM<sub>2.5</sub> Indoor-Outdoor Ratios

The time series for 48-hr PM<sub>2.5</sub> I/O concentration ratios is plotted in Figure 5-1. The summary statistics and the I/O ratios box plots for the four schools are shown in Table 5-1 and Figure 5-2.

**Table 5-1: Summary statistics for I/O ratios for PM<sub>2.5</sub>**

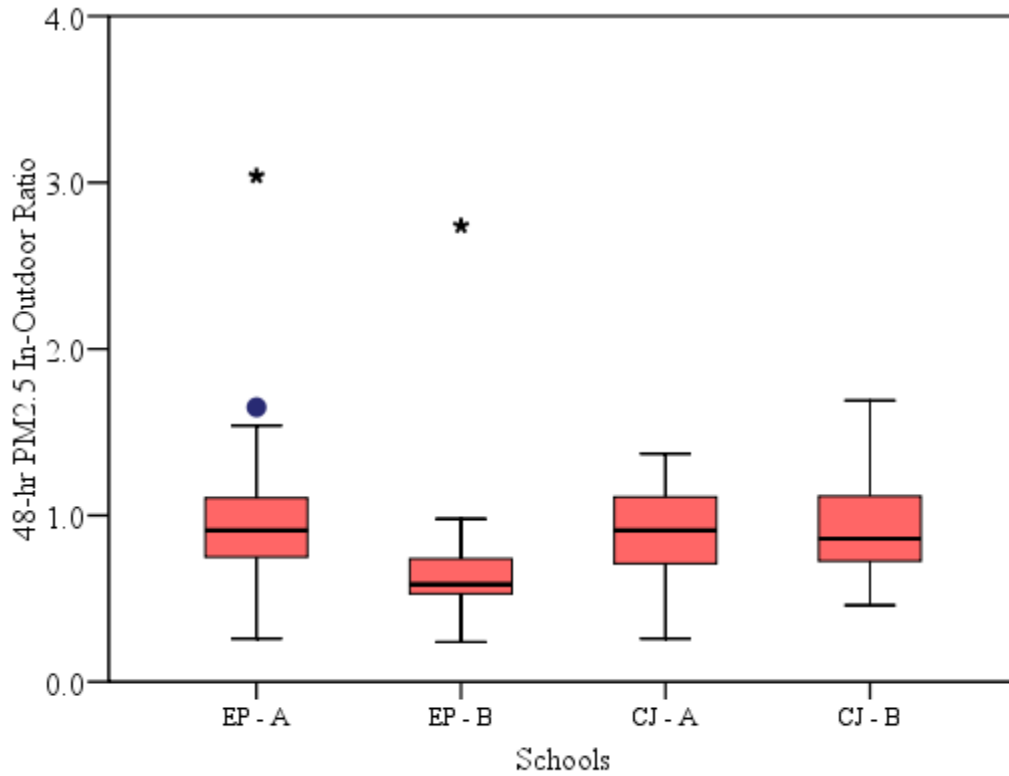
Location	EP -A	EP - B	CJ - A	CJ - B
N	27	30	29	28
Mean	1.00	0.69	0.89	0.92
Median	0.91	0.59	0.91	0.86
Std. Dev	0.51	0.42	0.28	0.28
Maximum	3.04	2.74	1.37	1.69
Minimum	0.26	0.24	0.26	0.46
IQR	0.35	0.20	0.40	0.39

The mean I/O ratios for PM<sub>2.5</sub> were: 1.00 (0.51) at EP-A, 0.69 (0.42) at EP-B, 0.89 (0.28) at CJ-A, and 0.92 (0.28), respectively. The ventilation systems between the El Paso and Ciudad Juárez schools also varied. EP-A and EP-B were heated through a closed-loop radiant heater with minimum fresh air from outdoors during the winter months, and with individual evaporative coolers throughout the school premises for summer thermal comfort. At EP-A, the PM sampling set up was placed in the computer room. The door of this room was usually kept open during school hours. The sampling room saw high movement of children. Albeit, this room was centrally heated during the winter months and had air-conditioning on once April had set in, it still saw elevated levels of indoor PM<sub>2.5</sub> indicating substantial amount of particle infiltration and particle generation due to student activities. At school EP-B, the indoor sampler was placed in the library reference room, which was kept closed and experienced minimal human traffic. The mean PM<sub>2.5</sub> I/O ratio of 0.69(0.42), at this school substantiates this logic. Ciudad Juarez schools were not equipped with any forced ventilation systems and natural ventilation was the primary mechanism for indoor-outdoor air exchange. As a result, the schools in Ciudad Juárez likely experienced greater outdoor pollutant infiltration than schools in El Paso, which corresponds to the high I/O ratios of 0.89 (0.28) and 0.92 (0.28) at CJ-A and CJ-B, respectively.



**Figure 5-1: Time series for 48-hr PM<sub>2.5</sub> indoor-outdoor concentration ratios**

High I/O ratios, especially at EP-A, CJ-A, and CJ-B suggests that building envelope may not prevent the infiltration of particles indoor (Blondeau et al., 2005) and indoor concentrations may be influenced by outdoor sources of PM<sub>2.5</sub>, which is similar to the observations made in other studies (Hazenkamp-von Arx et al., 2004; Long et al., 2001; Janssen et al., 2000). Sawant et.al (2004) documented a median I/O PM<sub>2.5</sub> ratio of 0.38 and a range of 0.05-2.02 for a study conducted at seven schools in Mira Loma, CA. In our study, the median I/O ratios for the four schools are higher than the Mira Loma study.



**Figure 5-2: Box plot for 48-hr PM<sub>2.5</sub> I/O ratios at the four schools**

## 5.2 48-hr Indoor-Outdoor PM<sub>10-2.5</sub>

Summary statistics and time series for 48-hr PM<sub>10-2.5</sub> I/O ratios are shown in Table 5-2 and Figure 5-3, respectively. The box plots for 48-hr PM<sub>10-2.5</sub> I/O ratios are shown in Figure 5-4.

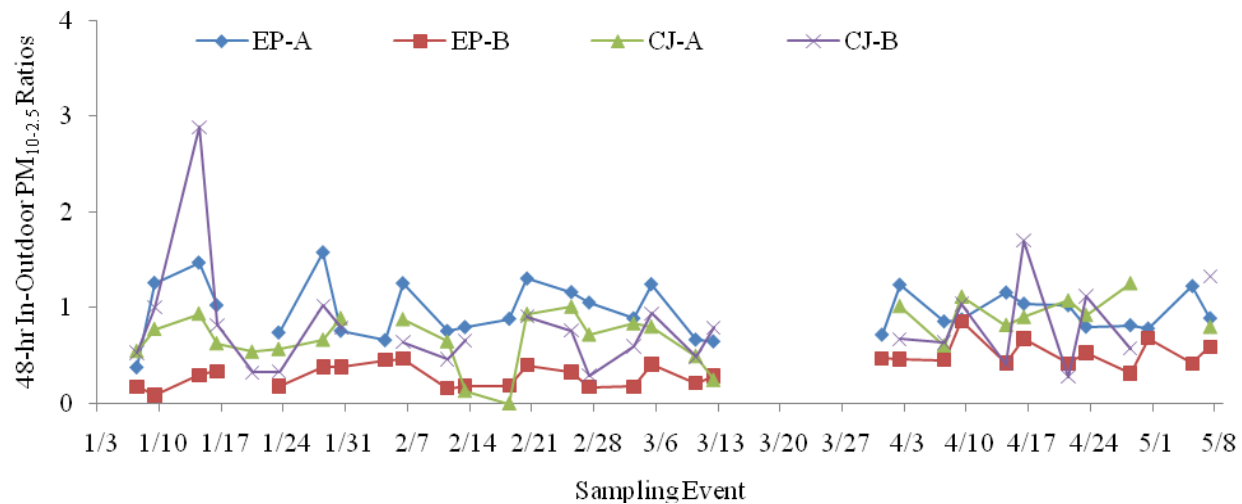
**Table 5-2: Summary statistics for I/O ratios for PM<sub>10-2.5</sub>**

Location	EP - A	EP - B	CJ - A	CJ - B
N	31	31	27	27
Mean	0.97	0.37	0.77	0.82
Median	0.89	0.39	0.80	0.67
Std. Dev	0.27	0.18	0.25	0.53
Maximum	1.57	0.86	1.25	2.88
Minimum	0.38	0.09	0.13	0.28
IQR	0.42	0.26	0.31	0.46

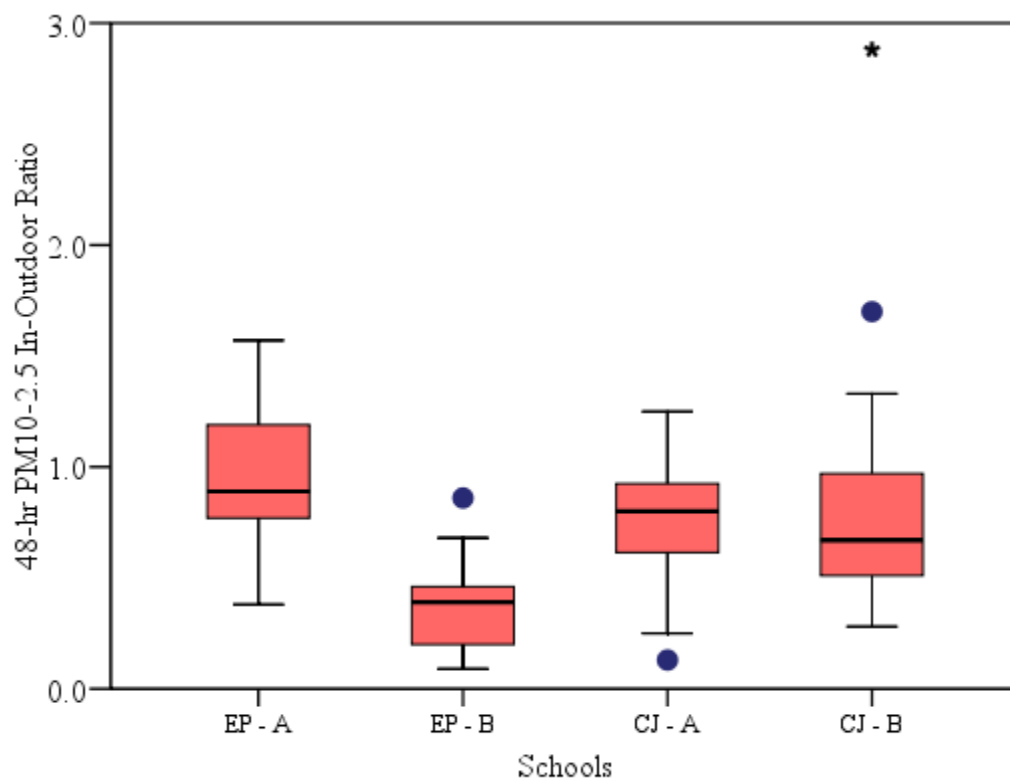
Generally, coarse particles have lower penetration efficiency and are removed by means of gravitational settling (Tippayawong et al., 2009). The spatial distribution of ambient PM<sub>10-2.5</sub>

is highly variable within an urban area because the largest particles that support this size fraction settle by gravity rapidly as they move away from the source (Hinds 1999). Without the presence of indoor sources, the indoor  $PM_{10-2.5}$  is mainly the results of outdoor air infiltrating into the indoor environment and is highly correlated to the level of outdoor  $PM_{10-2.5}$ . For the same indoor sources described for  $PM_{2.5}$  earlier and the fact that evaporative coolers are more effective in removing outdoor  $PM_{10-2.5}$  indoors (Li et al., 2003), the high average I/O ratio for  $PM_{10-2.5}$  at EP-A, 0.97(0.27), could be attributed to resuspension of particles due to children's activities indoors. These ratios are in sharp contrast to EP-B, 0.37(0.18), which saw minimal human traffic in the indoor microenvironment. The median ratio was the lowest (0.39) for EP-B and the highest (0.89) for EP-A. The median ratio of 0.89 at school EP-A indicates that indoor concentrations were influenced by the infiltration of ambient air inside the monitoring room. Also, the median ratios at the CJ-A and CJ-B were 0.80 and 0.67, respectively, indicating that the infiltration of air inside CJ-A was higher than CJ-B. School EP-A recorded the greatest variation in the minimum and maximum I/O ratios.

High I/O ratios at CJ-A, 0.77(0.25) and CJ-B, 0.82(0.53) can be imputed to insufficient ventilation during the winter months. Also, the infrequent cleaning (at CJ-A) may have led to high indoor particles. There were more students in this school in relation to room dimensions, and the constant movement of children may have caused particle resuspensions in the classroom. In addition, cooking activities and heating devices during winter months at CJ-B may have led to particle generation indoors, as has been demonstrated by Diapouli et al (2008).



**Figure 5-3: Time series for 48-hr  $PM_{10-2.5}$  I/O concentration ratios**



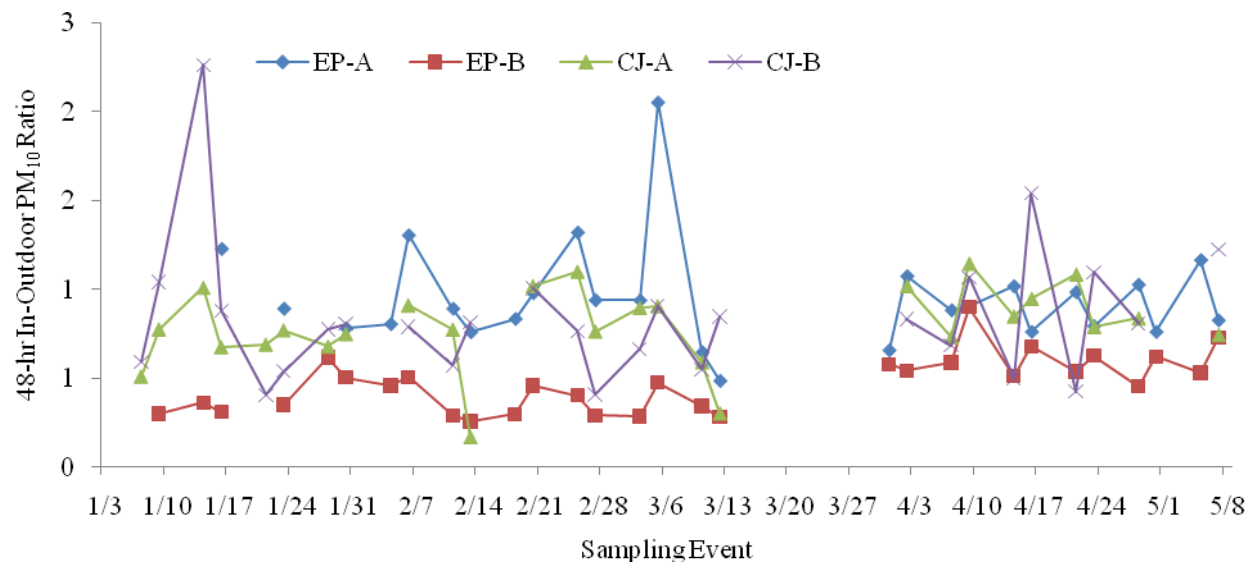
**Figure 5-4: Box plot for 48-hr  $PM_{10-2.5}$  I/O ratios at the four schools**

### 5.3 48-hr PM<sub>10</sub> Indoor-Outdoor Ratios

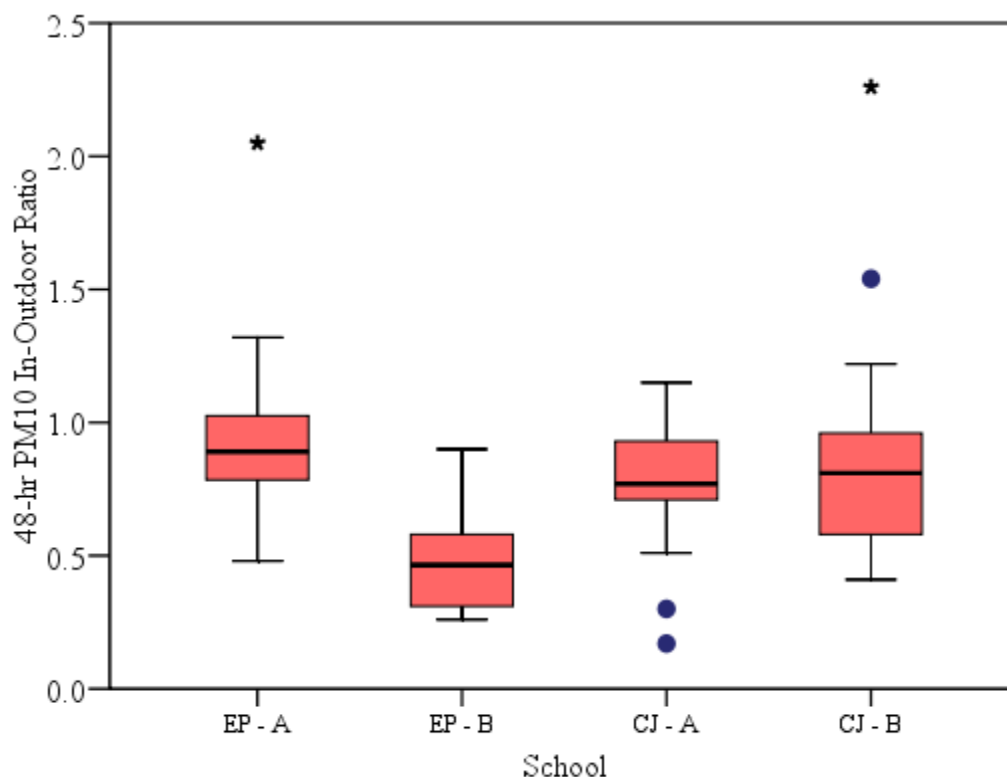
The 48-hr PM<sub>10</sub> concentrations were dominated by the coarse PM<sub>10-2.5</sub> mass in line with previous studies conducted in this region (Li et al., 2011). The time series and summary statistics for the PM<sub>10</sub> indoor-outdoor ratios are similar to that of PM<sub>10-2.5</sub>. Therefore, the discussion for PM<sub>10</sub> I/O ratios is omitted here to avoid redundancy. Summary statistics, time series and box plots are shown in Table 5-3, Figure 5-5, and Figure 5-6, respectively. High I/O ratios (approaching unity) were observed for PM<sub>10</sub> mass at schools in Athens, Greece (Diapouli et al., 2007) and are in line with the observations from this study

**Table 5-3: Descriptive statistics for I/O ratios for PM<sub>10</sub>**

Location	EP -A	EP - B	CJ - A	CJ - B
N	27	30	27	27
Mean	0.95	0.47	0.79	0.84
Median	0.89	0.47	0.77	0.81
Std. Dev	0.29	0.16	0.23	0.39
Maximum	2.05	0.90	1.15	2.26
Minimum	0.48	0.26	0.17	0.41
IQR	0.23	0.25	0.22	0.37



**Figure 5-5: Time series for 48-hr PM<sub>10</sub> I/O concentration ratios**



**Figure 5-6: Box plot for 48-hr PM<sub>10</sub> I/O ratios at the four schools**

#### 5.4 96-hr NO<sub>2</sub> Indoor-Outdoor Ratios

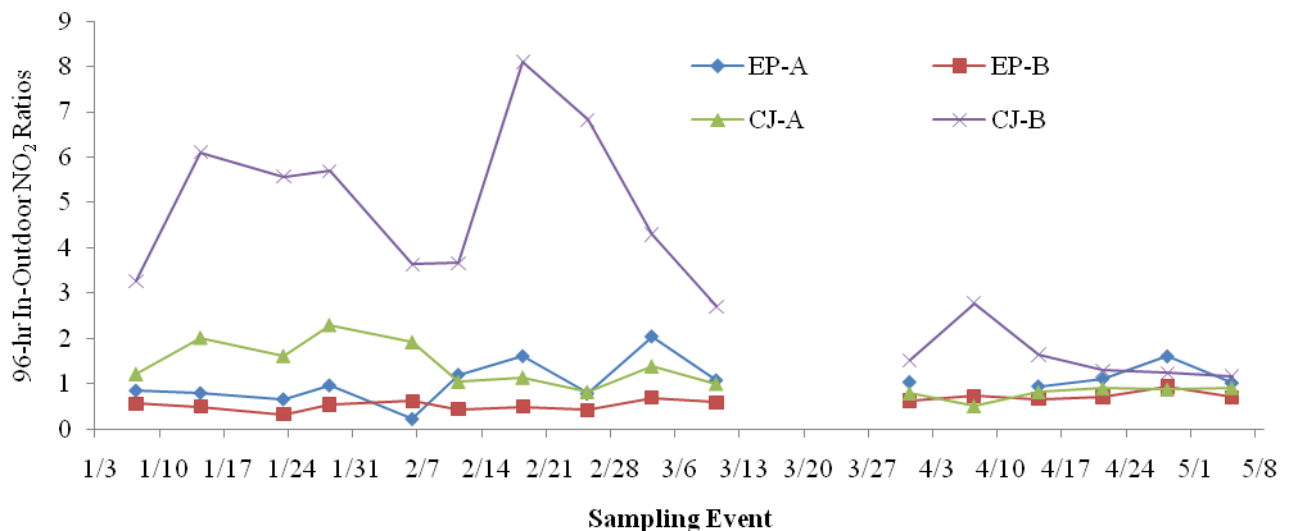
The time series for 96-hr I/O NO<sub>2</sub> is plotted in Figure 5-7. Summary statistics are shown in Table 5-4 and Figure 5-8, respectively.

**Table 5-4: Descriptive statistics for I/O ratios for NO<sub>2</sub>**

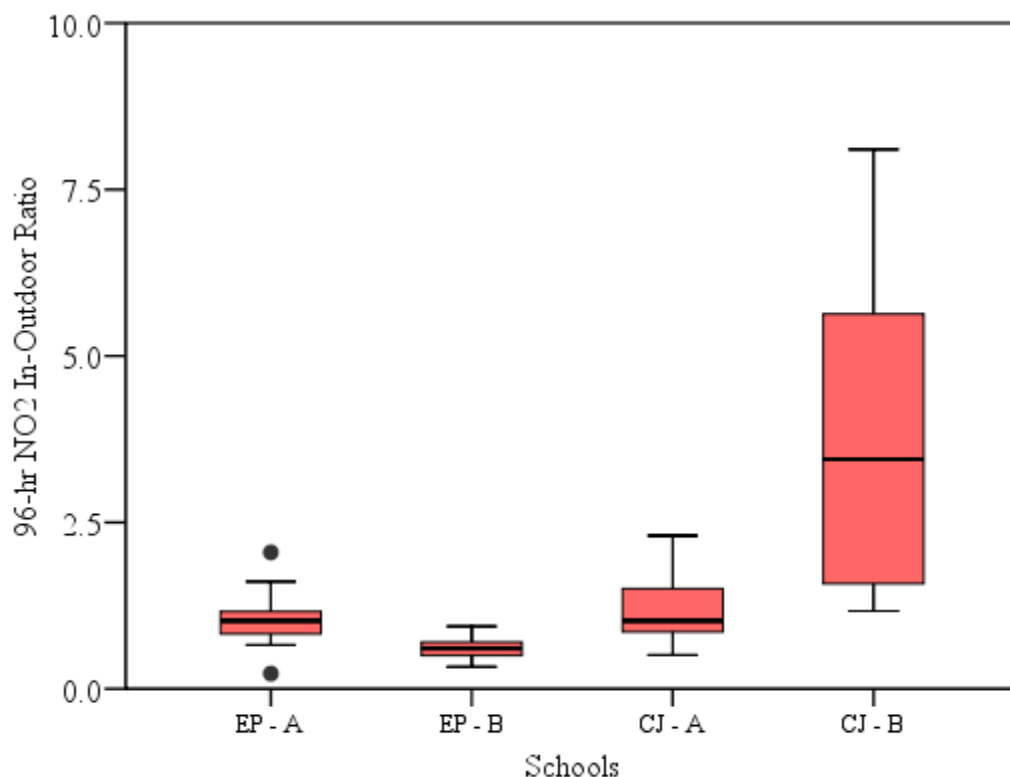
Location	EP - A	EP - B	CJ - A	CJ - B
N	15	16	16	16
Mean	1.07	0.60	1.21	3.72
Median	1.02	0.61	1.02	3.45
Std. Dev	0.44	0.15	0.51	2.19
Maximum	2.05	0.94	2.30	8.10
Minimum	0.23	0.33	0.51	1.17
IQR	0.33	0.20	0.58	3.99



Ambient gaseous pollutants such as NO<sub>2</sub> may infiltrate into indoor environments easily unless a positive pressure exists in the indoor environments. The high I/O ratios at EP-A [1.07(0.44)], and CJ-A [1.21(0.51)], were the consequence of open exchange of air between indoors and outdoors, as also reported in French classrooms of I/O ratios ranging between 0.9 and 1.0 with either natural or mechanical ventilation and no known indoor sources of NO<sub>2</sub> (Blondeau et al., 2005). The mean I/O ratio at EP-B, 0.60 (0.15), was the least of all four schools. The usage of gas heaters and cooking stoves inside the library at CJ-B resulted in a high I/O ratio of 3.72 (2.19). Unventilated gas or kerosene heaters and cooking stoves are major indoor sources of NO<sub>2</sub> (Dimitroulopoulou et. al., 2001; Melia et.al., 1990), and may contribute to high indoor exposures for children and teachers at CJ-B. Linaker et al. (1996, 2000) suggested the relevance of indoor sources of NO<sub>2</sub> to children's personal exposure and indoor concentrations of NO<sub>2</sub> are more related to personal exposures than outdoor concentrations (Levy et al. 1998).



**Figure 5-7: Time series for 96-hr NO<sub>2</sub> I/O concentration ratios**



**Figure 5-8: Box plot for 96-hr NO<sub>2</sub> I/O ratios at the four schools**

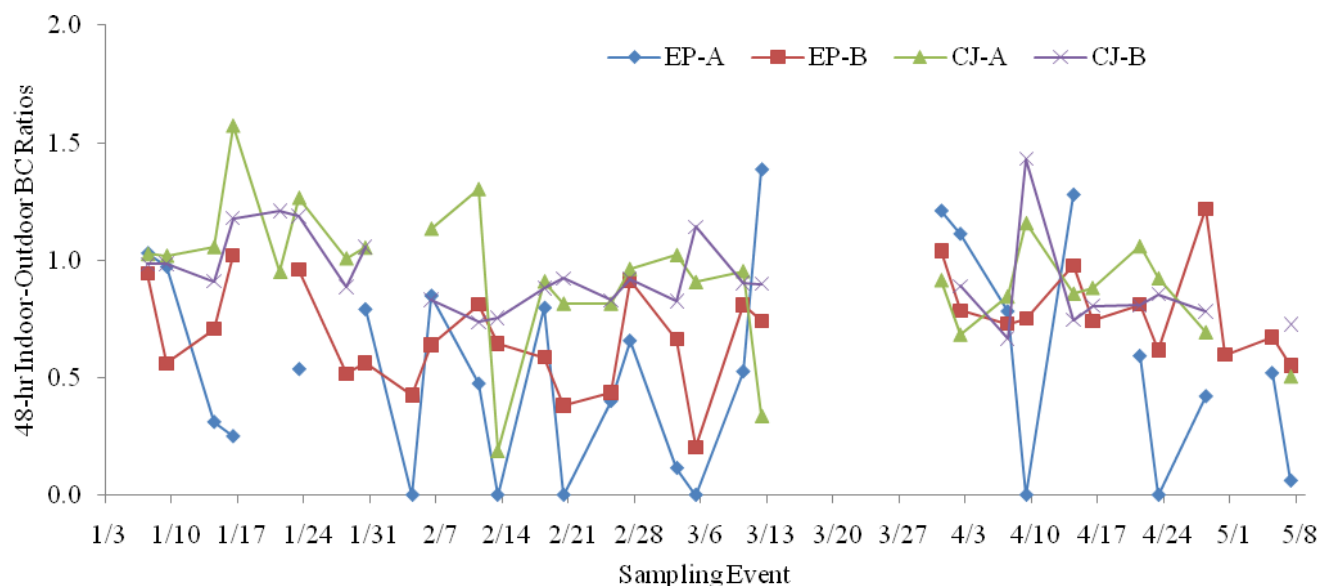
### 5.5 48-hr Indoor-Outdoor BC Ratios

Time series for I/O ratios for 48-hr BC concentrations are plotted in Figure 5-9. The statistical summary for the data and the spatial contrast across the four schools is shown in Table 5-5 and Figure 5-10, respectively.

**Table 5-5: Descriptive Statistics for I/O Ratios for BC**

Location	EP - A	EP - B	CJ - A	CJ - B
N	29	31	29	28
Mean	0.52	0.71	0.93	0.92
Median	0.52	0.71	0.95	0.89
Std. Dev	0.44	0.22	0.27	0.18
Maximum	1.39	1.22	1.57	1.43
Minimum	0.00	0.20	0.19	0.67
IQR	0.74	0.24	0.21	0.18

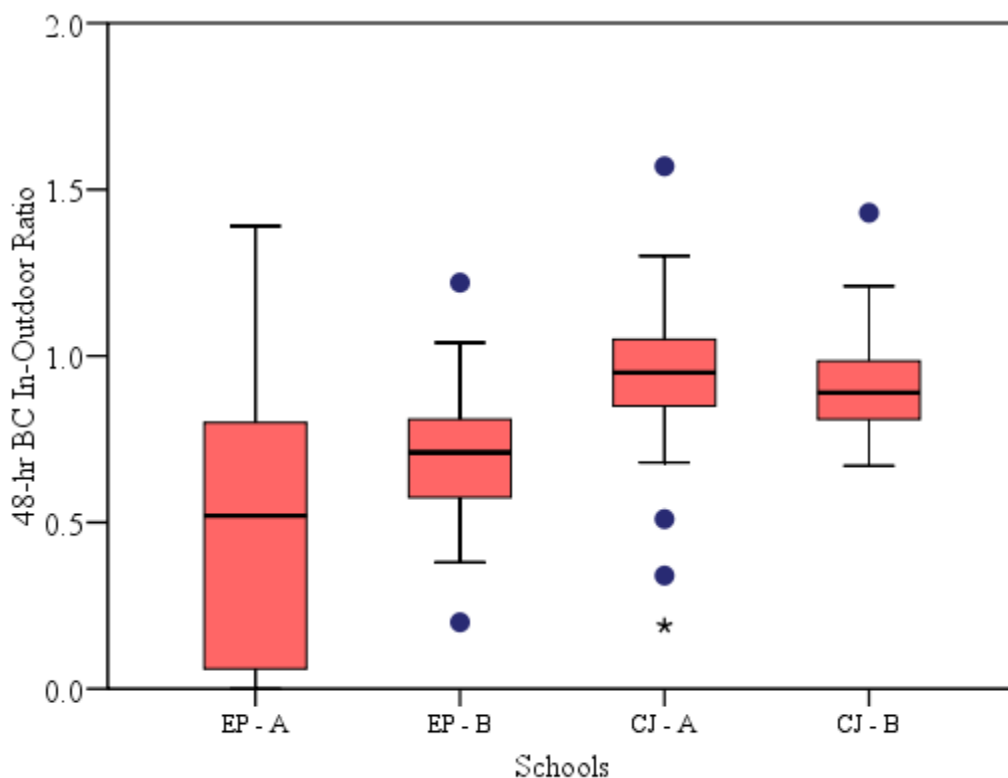
High I/O ratios for BC were observed at EP-B, CJ-A, and CJ-B relative to EP-A. BC is known to be a good indicator of incomplete combustions and tailpipe emissions, especially from diesel engines. The BC I/O ratio serves as another good indicator for building infiltration due to the general absence of indoor BC sources in these schools. This can also be attributed to the quantitative penetration of fine particles in indoor air (Wallace 1996). Mean (SD) ratios for BC were: 0.52(0.44) at EP-A, 0.71(0.22) at EP-B, 0.93 (0.27) at CJ-A and 0.92 (0.18) at CJ-B. The median ratios at the four schools were all above 0.50. The ratios computed for this study are comparable with the I/O ratios (~1.0) at schools near major roadways as observed by Janssen et al (2001). The minimum and maximum ratios at CJ-B were 0.67 and 1.43, respectively. Similarly, for school EP-B, the minimum and maximum ratios were 0.20 and 1.22 respectively.



**Figure 5-9: Time series for 48-hr BC I/O concentration ratios**

Gotschi (2002) demonstrated that indoor BC concentrations have their genesis predominantly in ambient air pollution. Indoor BC concentrations in schools have been reported by many researchers. Median concentrations of  $2 \mu\text{g}/\text{m}^3$  (Fromme 2005 (Indoor Air 2005, 15:

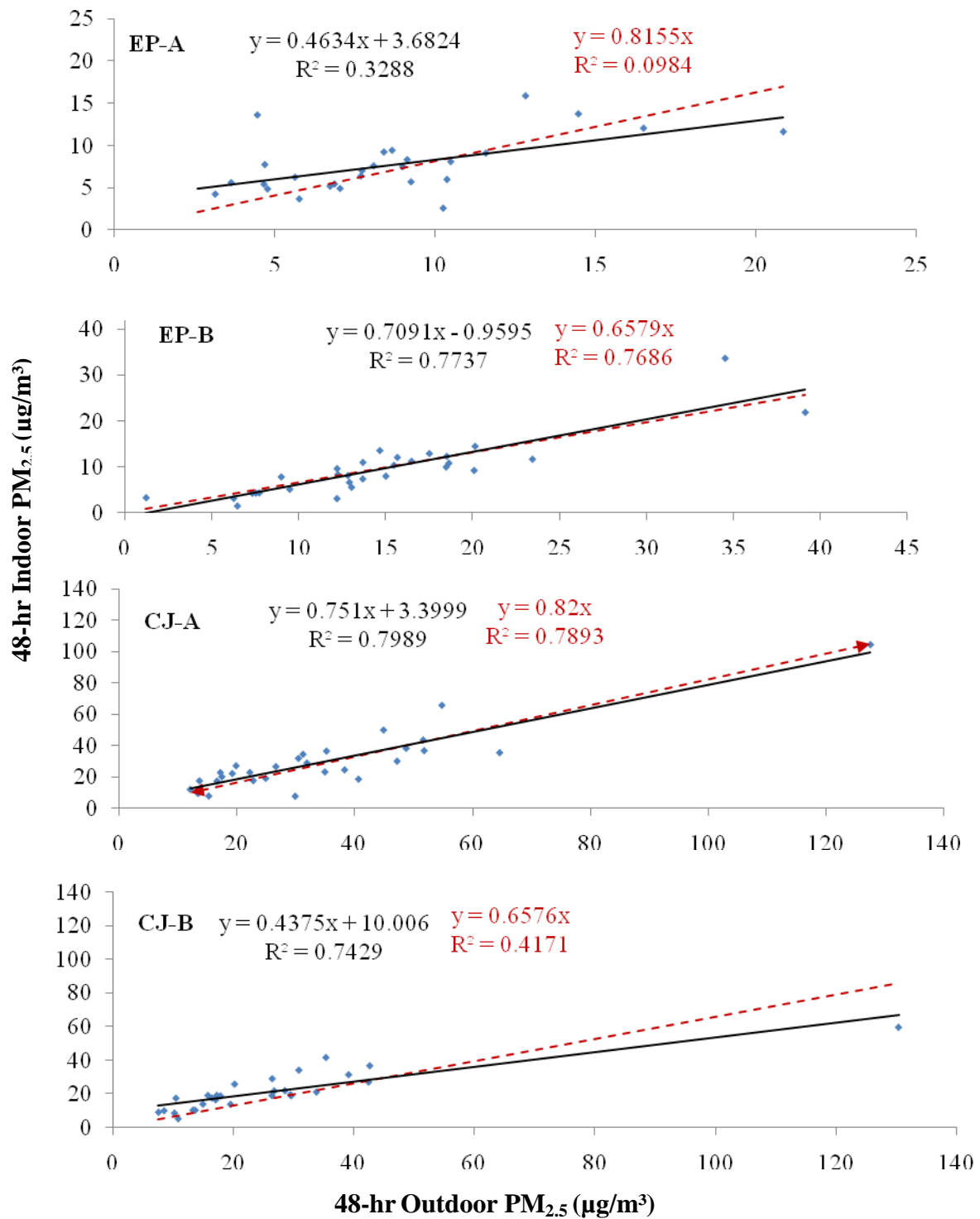
335-341); 10.2  $\mu\text{g}/\text{m}^3$  (Fromme 2008); 11.8  $\mu\text{g}/\text{m}^3$  (Janssen 2001) and 2.7  $\mu\text{g}/\text{m}^3$  in an elementary school (Ward et al 2007) have been reported indoors in literature.



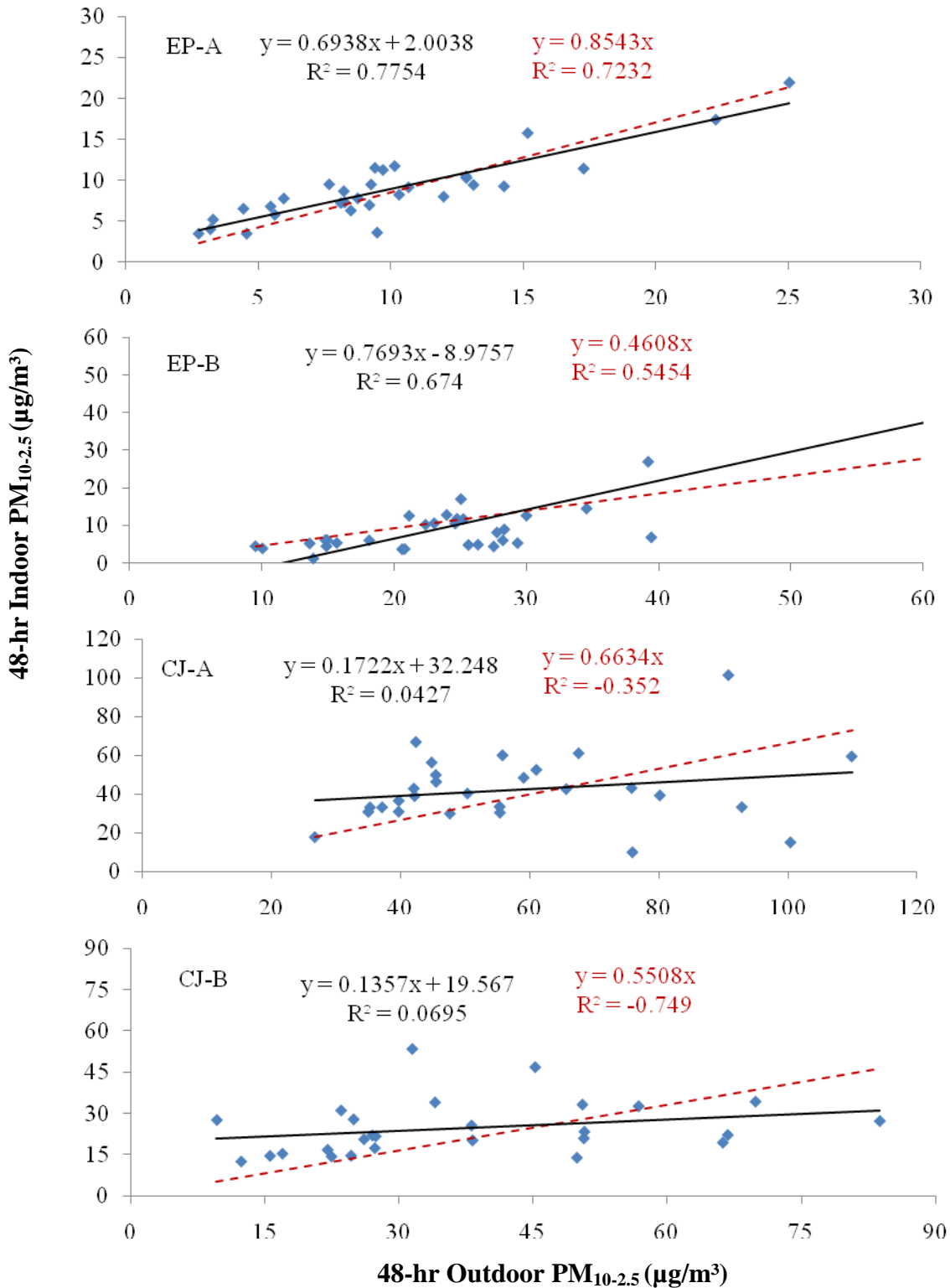
**Figure 5-10: Box plot for 48-hr BC indoor-outdoor ratios at the four schools**

## 5.6 R<sup>2</sup> Values for Indoor – Outdoor Pollutant Ratios

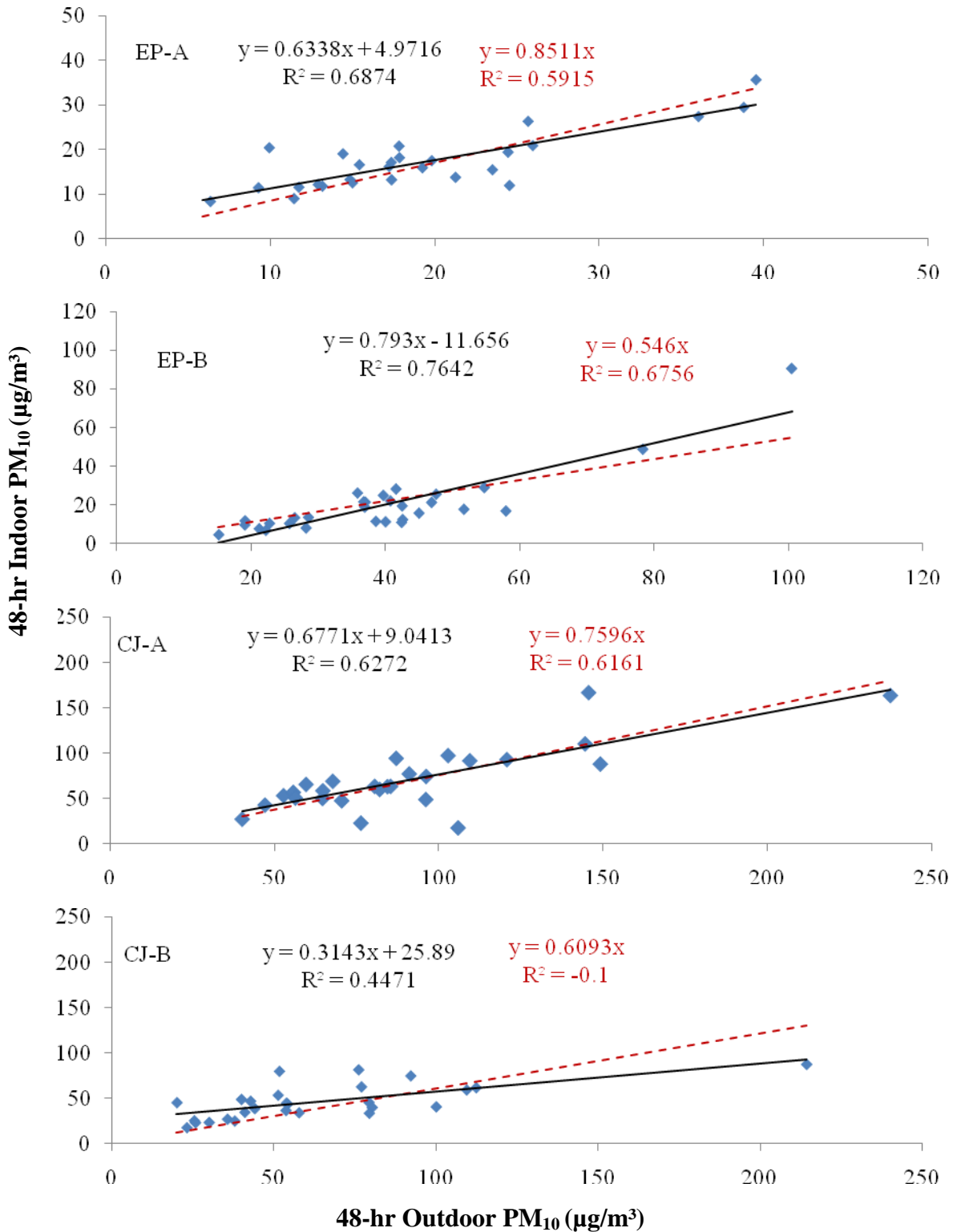
The R<sup>2</sup> values for paired indoor-outdoor data are computed to inspect the goodness of fit of a linear relationship. The graphical representation of the relationship between indoor and outdoor pollutant concentrations at each school is plotted in Figures 5-11, 5-12, 5-13, 5-14, 5-15 for PM<sub>2.5</sub>, PM<sub>10-2.5</sub>, PM<sub>10</sub>, NO<sub>2</sub>, and BC, respectively. In order to facilitate the comparisons of indoor and outdoor concentrations, the 1:1 line is also indicated in red. As mentioned previously, the indoor-outdoor analysis is influenced by several field conditions that were difficult to control in the experimental design or by the instruments.



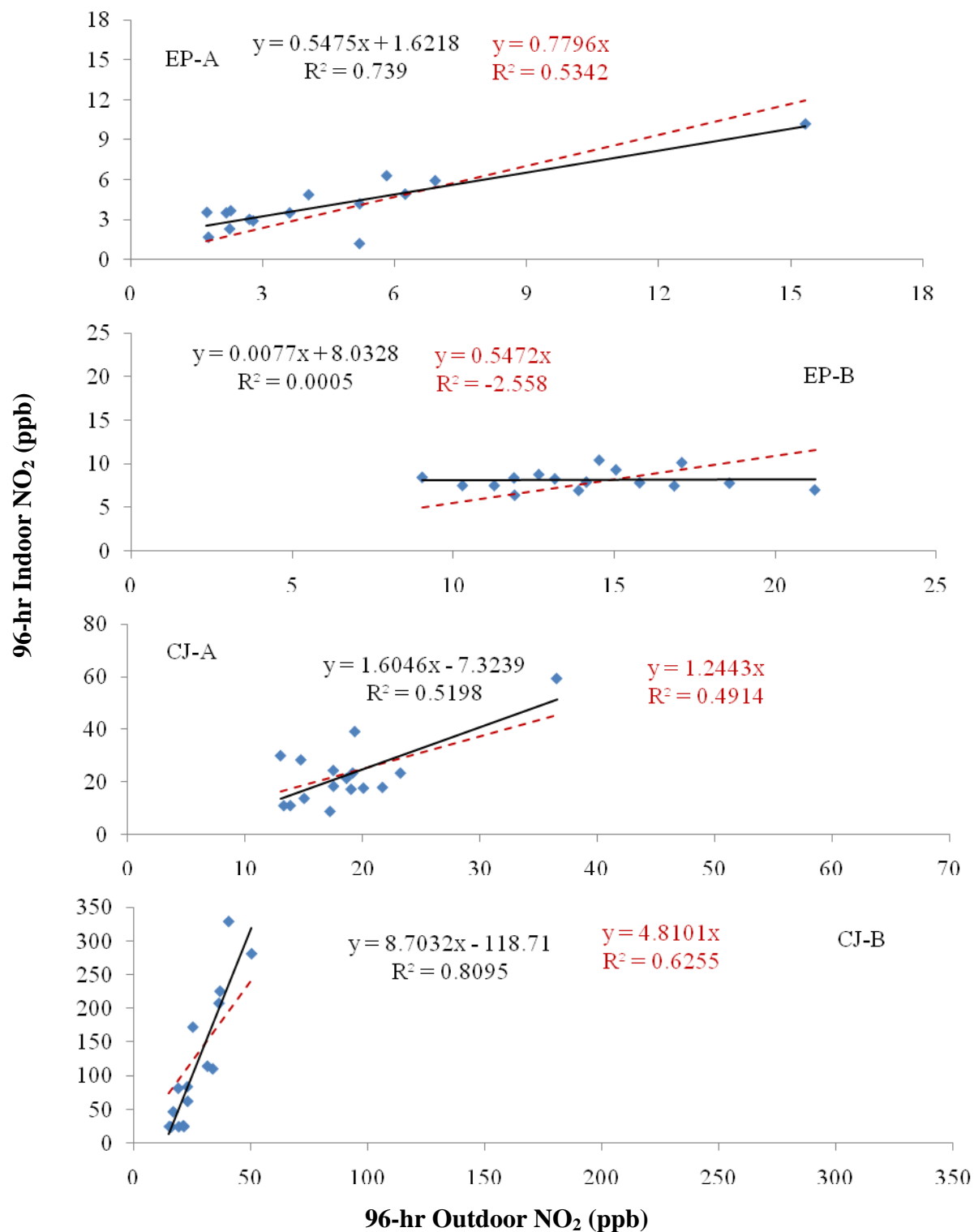
**Figure 5-11: Indoor concentrations as a function of outdoor concentrations for PM<sub>2.5</sub> (µg/m³)**



**Figure 5-12: Indoor concentrations as a function of outdoor concentrations for  $PM_{10-2.5}$  ( $\mu g/m^3$ )**

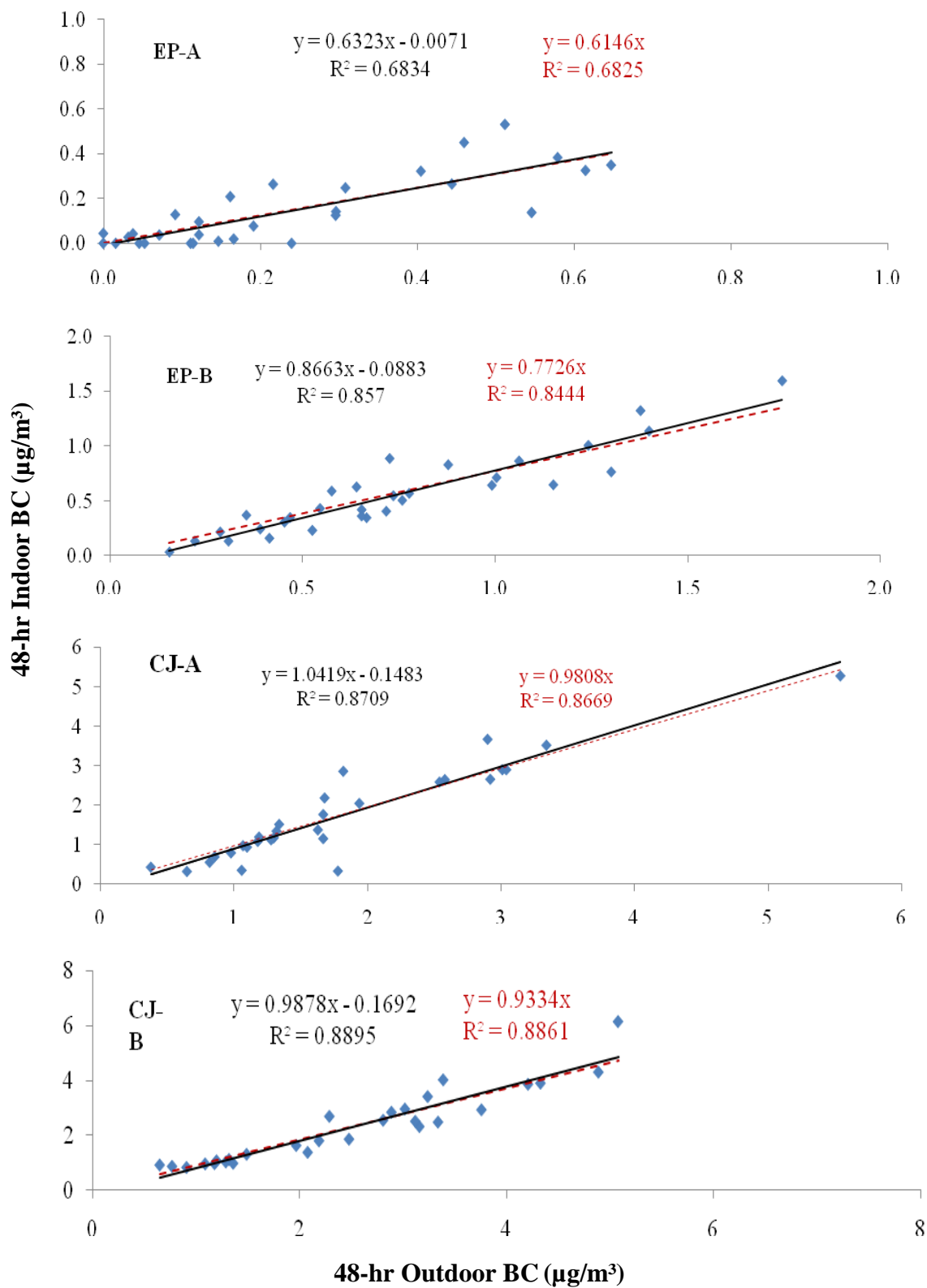


**Figure 5-13: Indoor concentrations as a function of outdoor concentrations for PM<sub>10</sub> (µg/m<sup>3</sup>)**



**Figure 5-14: Indoor concentrations as a function of outdoor concentrations for NO<sub>2</sub> (ppb)**





**Figure 5-15: Indoor concentrations as a function of outdoor concentrations for BC ( $\mu\text{g}/\text{m}^3$ )**

Correlation analyses showed a range of association between indoor and outdoor concentrations, suggesting variability in the influence of outdoor concentrations on indoor levels, both between pollutants (e.g., the indoor-outdoor  $R^2$  value at EP-B was 0.55 for  $PM_{10-2.5}$  compared to 0.77 for  $PM_{2.5}$ ) and across schools for the same pollutant (e.g., the indoor-outdoor  $R^2$  value for  $PM_{2.5}$  was 0.10 at EP-A compared to 0.77 at EP-B). Of all the measured pollutants, the indoor-outdoor BC levels displayed a very robust and strong relationship ( $R^2 \sim 0.68-0.89$ ) across the four schools in contrast to the other pollutant species, as is obvious from Figure 5-15. The low correlations observed between the indoor-outdoor  $PM_{10-2.5}$  at CJ-A and CJ-B reaffirm that resuspension of particles due to children's activities inside the indoor microenvironment dominate the  $PM_{10-2.5}$  levels in the two indoor microenvironments.

### 5.7 Pearson Correlation Coefficients for Indoor-Outdoor Concentrations for Pollutants

In this study, Pearson correlation coefficients were computed for the I/O concentrations of the pollutants monitored in this study. Table 5-6 details the 'r' value and the corresponding 'p' value for the pollutants. The results are tabulated as per the four school locations.

**Table 5-6: Pearson correlation coefficients between indoor-outdoor concentrations at the four schools for the studied pollutants**

School Sites	PM <sub>2.5</sub>		PM <sub>10-2.5</sub>		PM <sub>10</sub>		NO <sub>2</sub>		BC	
	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
<b>EP-A</b>	0.573	0.002	0.881	<0.001	0.833	<0.001	0.860	<0.001	0.824	<0.001
<b>EP-B</b>	0.880	<0.001	0.821	<0.001	0.874	<0.001	0.022	0.937	0.926	<0.001
<b>CJ-A</b>	0.894	<0.001	0.529	0.005	0.792	<0.001	0.721	0.002	0.933	<0.001
<b>CJ-B</b>	0.862	<0.001	0.264	0.184	0.669	<0.001	0.900	<0.001	0.943	<0.001

As can be seen from the above table, the correlations for I/O  $PM_{2.5}$  concentrations were significantly strong across all four sites. The strongest correlation is for school CJ-A ( $r=0.894$ ). Pearson's r value of 0.862 was obtained for the high exposure school in Ciudad Juarez. For the

two schools in El Paso, the 'r' value for PM<sub>2.5</sub> were 0.573 and 0.880 at EP-A and EP-B signifying strong correlations.

For the coarse fraction of PM, a significantly weak correlation was observed at CJ-B ( $r=0.264$ ,  $p=0.184$ ). This suggests that the majority of the coarse particles may have an indoor source, (because of the permanent movement of people in the library), and the indoor concentrations can only be partially ascribed to outdoor air. PM<sub>10-2.5</sub> correlations at both El Paso schools were significantly high ( $r>0.8$ ) indicating that ambient air contributed substantially to the indoor particles.

Strong correlations were observed at the four sites for PM<sub>10</sub>. These ranged from  $r=0.669$  at CJ-B to  $r=0.874$  ( $p<0.001$ ) at EP-B. The I/O correlations at the four schools were all statistically significant ( $p<0.001$ ). The  $r$  values at the low exposure schools in El Paso and Ciudad Juarez were 0.833 and 0.792 respectively. For NO<sub>2</sub>, the correlations were strong for sites EP-A, CJ-A and CJ-B. A weak correlation was obtained for the high exposure school in El Paso ( $p\text{-value}=0.937$ ). The correlations in the other three schools were significant ( $p<0.01$ ) with the  $r$  values ranging from 0.721 to 0.9. For BC concentrations, very strong correlations were obtained ( $r>0.8$ ) for all the four schools.

### **5.8 Paired sample t-test for indoor versus outdoor pollutant concentrations at each school**

The indoor and outdoor pollutant concentrations at each school were subjected to a paired sample t-test to determine if the concentrations for both the microenvironments were statistically and significantly distinguishable from each other. This was done for all the five pollutants of interest in this study. Table 5.7 shows the results from this analysis. 'IN' indicates indoor microenvironment and 'OUT' refers to outdoor microenvironment. The indoor and outdoor concentrations at the high exposure school in El Paso (EP-B) were statistically different from

each other ( $p > 0.0001$ ) for all the five pollutants. At school EP-A, indoor and outdoor concentrations for  $\text{NO}_2$  and BC were statistically distinguishable. For the two Ciudad Juarez schools,  $\text{PM}_{10-2.5}$  indoor and outdoor concentrations were significantly different.

**Table 5.7: Paired sample t-test for indoor and outdoor pollutant concentrations at the four schools**

Pollutants and School Microenvironment	Paired Differences					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
48-hr PM <sub>2.5</sub>								
IN_EPA - OUT_EPA	-.943	3.457	.665	-2.311	.424	-1.418	26	.1681
IN_EPB - OUT_EPB	-5.276	3.735	.682	-6.671	-3.882	-7.737	29	.0000
IN_CJA - OUT_CJA	-5.220	10.348	1.922	-9.156	-1.283	-2.716	28	.0112
IN_CJB - OUT_CJB	-4.748	14.149	2.674	-10.234	.739	-1.775	27	.0871
48-HR PM <sub>10-2.5</sub>								
IN_EPA - OUT_EPA	-1.036	2.471	.444	-1.943	-.130	-2.334	30	.0265
IN_EPB -OUT_EPB	-14.631	6.274	1.127	-16.932	-12.330	-12.985	30	.0000
IN_CJA -OUT_CJA	-15.202	19.540	3.761	-22.932	-7.472	-4.043	26	.0004
IN_CJB - OUT_CJB	-12.824	19.325	3.719	-20.468	-5.179	-3.448	26	.0019
48-hr PM <sub>10</sub>								
IN_EPA - OUT_EPA	-2.087	4.777	.919	-3.977	-.198	-2.270	26	.0317
IN_EPB - OUT_EPB	-19.832	8.637	1.577	-23.057	-16.607	-12.577	29	.0000
IN_CJA - OUT_CJA	-20.523	25.416	4.891	-30.577	-10.469	-4.196	26	.0003
IN_CJB - OUT_CJB	-17.469	30.893	5.945	-29.690	-5.248	-2.938	26	.0068
48-hr BC								
IN_EPA - OUT_EPA	-.094	.115	.021	-.137	-.051	-4.459	29	.0001
IN_EPB - OUT_EPB	-.189	.146	.026	-.242	-.135	-7.183	30	.0000
IN_CJA - OUT_CJA	-.072	.433	.080	-.237	.092	-.901	28	.3753
IN_CJB - OUT_CJB	-.200	.443	.084	-.372	-.028	-2.383	27	.0245
96-hr NO <sub>2</sub>								
IN_EPA -OUT_EPA	-10.256	2.183	.546	-11.419	-9.093	-18.794	15	.0000
IN_EPB - OUT_EPB	3.649	3.895	1.006	1.493	5.806	3.629	14	.0027
IN_CJA - OUT_CJA	-4.063	6.504	1.626	-7.529	-.597	-2.499	15	.0246
IN_CJB -OUT_CJB	96.131	96.541	24.135	44.688	147.575	3.983	15	.0012

## **6.0 Relationships between the Various Pollutants across the Study Sites**

### **6.1 Inter-site and Intra-pollutant correlation analyses**

Spatiotemporal variation in traffic pollutants is a very important feature that merits attention. Ambient pollutants like PM and NO<sub>2</sub> exhibit strong temporal and spatial variability. Temporal variability is primarily attributed to fluctuations in meteorological conditions and, perhaps, by temporal variations of both point and area emission sources. Spatial variability depends on the pollutant of interest and its proximity to source emissions. Traffic pollutants, like PM<sub>2.5</sub>, NO<sub>2</sub>, and BC, and resuspended PM from roadways, construction and demolition activities, and agricultural activities can lead to non-uniformity in spatial concentrations at neighborhood scales.

More specifically, these variations play a very crucial role in cohort studies than daily time-series studies. In daily time series studies, temporal correlations between sampling sites can nullify the effects of any possible pollutant concentration gradients on health effects estimates thereby eliminating the risk of large exposure misclassification errors. This is because in such studies the longitudinal correlations between health exposures and ambient concentrations are more crucial (Schwartz 2000, Zeger 2000) and absolute concentration differences are not as pivotal. However, in cohort studies, exposure estimates for various segments of the community depend on the gradients in the pollutant concentrations. As such, using an exposure variable from a central ambient monitoring site for the community can lead to massive exposure misclassifications and errors in risk estimates for the cohort. This may also lead to the concept of ecological fallacy, where the effects on a few are inferred from the effects of the aggregate (Dominici et al. 2003).

This chapter focuses on the temporal variations in the pollutant concentrations monitored during this study. The spatial variation is studied in great detail in Chapter 7. Inter-site and intra-pollutant correlations were computed for the measured pollutants, both indoors and outdoors. Correlation coefficients do not address the issue of spatial variability in absolute concentrations; instead, these coefficients are more adept at reflecting temporal similarity of paired sites (Pinto et al., 2004, Wilson et al., 2005). These coefficients always lie between -1 and 1. A correlation of +1 indicates a perfectly positive relationship between two variables signifying that the magnitudes of these two variables both increase or decrease proportionately. Alternatively, a correlation of -1 signifies a perfectly negative relationship between two variables i.e. when the magnitude of one variable increases, the magnitude of the other variable decreases proportionately and vice versa.

Significantly strong correlations were observed between the monitored pollutants at all the sites. The high correlations are suggestive that in spite of a variable degree of spatial heterogeneity that existed among the sites, similar temporal trends occur in pollutant concentrations across all the schools. The correlation values indicate that, albeit, the study sites were highly correlated, a variable degree of spatial heterogeneity existed among them. Tables 6-1 and 6-2 show the Spearman's correlation coefficients for the inter-site pollutants, indoors and outdoors, respectively. The correlations significant at the 0.05 level are highlighted. Correlations significant at 0.01 level are italicized and underlined.

The indoor  $PM_{2.5}$  correlations between the respective low and high exposure schools in each city exhibited a moderately strong and significant correlations ( $r = 0.60$  and  $0.62$ ). Strong correlations were observed for  $PM_{10-2.5}$  when EP-A was paired with EP-B ( $r = 0.92$ ), CJ-A ( $r = 0.90$ ), and between EP-B and CJ-A ( $r = 0.86$ ). Strong outdoor correlations ( $r > 0.85$ ) were

observed between EP-A and EP-B for both  $PM_{2.5}$  and  $PM_{10-2.5}$ . Correlations were significantly strong for the coarse fraction between all the sites. Black carbon concentrations were strong ( $r>0.68$ ) between the four schools except when CJ-B is paired with EP-A suggesting low traffic emissions around the El Paso low exposure school.  $NO_2$  concentrations were significant ( $r = 0.78$ ) between CJ-A and CJ-B, together with the strong correlation of  $r = 0.90$  between indoor BC for the two schools indicating that both schools in Ciudad Juarez were subjected to the similar strength of traffic emissions from outdoors. Significantly strong correlations indicating high temporal trends between the four schools and the corresponding CAMS sites for both indoor and outdoor microenvironment were observed. Indoor pollutant concentrations at the schools correlated moderately and significantly with their corresponding CAMS values.

In the present study, the three PM species, across all the sampling sites, were highly correlated with each other. Correlations were positive and robust for  $PM_{10-2.5}$  and  $PM_{10}$  ( $r>0.90$ ) and the same trend was observed between  $PM_{2.5}$  and  $PM_{10}$  ( $r>0.70$ ). Many studies have documented positive and strong correlations between  $PM_{2.5}$  and  $NO_2$  and have suggested the usage of  $NO_2$  as a surrogate for  $PM_{2.5}$  mass (Lam et al., 1999, Janssen et al., 2001, Miller et al., 2010). However, positive correlations between these two species was absent in this study. This can be attributed to the fact that there might be fugitive sources for  $PM_{2.5}$  other than traffic, especially in Ciudad Juarez where a lot of brick kilns are situated in close proximity to CJ-B (Blackman et al., 1997). Results from this study are however interesting in that significantly strong and positive correlations were found between  $NO_2$  and BC ( $r> 0.61$ ) confirming common emission sources for both these pollutants. In fact, it has been documented that in Ciudad Juarez approximately 72 percent of all  $NO_2$  emissions are apportioned to traffic emissions (SEMARNAT, 2006). BC is an important marker for incomplete diesel combustion emissions,

thereby, vindicating the strong and positive correlations observed between BC and NO<sub>2</sub> (Sarnat et al. 2010; von Schneidemesser et al. 2010). The strong NO<sub>2</sub>-BC correlations observed in this study are consistent with the findings by Lewne et al. (2004) and Miller et al. (2010), positing that PM<sub>2.5</sub> reflectance (i.e. BC) and not PM<sub>2.5</sub> mass is an appropriate proxy for NO<sub>2</sub> in most urban areas. Furthermore, strong correlations were not observed between BC and PM<sub>2.5</sub> either thereby suggesting possible influence of secondary sulfate or nitrate particles in the PM<sub>2.5</sub> mass composition (Gotschi et al., 2002), which maybe especially true for this arid region. The correlations between outdoor school concentrations and the CAMS sites were statistically significant ( $r > 0.53$ ) for the PM species and NO<sub>2</sub>.



Table 6-1: Inter-site and inter-pollutant Spearman's correlation coefficients – Indoor microenvironment

Pollutant		PM2.5						PM10-2.5						PM10						BC				NO2							
	Site	EPA	EPB	CJA	CJB	C12	C41	EPA	EPB	CJA	CJB	C12	C41	EPA	EPB	CJA	CJB	C12	C41	C49	EPA	EPB	CJA	CJB	EPA	EPB	CJA	CJB	C12	C37	C41
PM2.5	EPA	1																													
	EPB	0.60	1																												
	CJA	0.44	0.59	1																											
	CJB	0.00	0.35	0.62	1																										
	C12	0.38	0.71	0.64	0.86	1																									
	C41	0.35	0.71	0.75	0.82	0.95	1																								
PM10-2.5	EPA	0.63	0.75	0.94	0.60	0.69	0.81	1																							
	EPB	0.67	0.82	0.86	0.52	0.67	0.75	0.92	1																						
	CJA	0.73	0.55	0.87	0.35	0.48	0.67	0.90	0.86	1																					
	CJB	0.02	0.40	0.22	0.73	0.60	0.59	0.49	0.43	0.20	1																				
	C12	0.39	0.78	0.20	0.56	0.53	0.49	0.43	0.49	0.14	0.80	1																			
	C41	0.40	0.67	0.61	0.80	0.76	0.67	0.68	0.67	0.45	0.73	0.82	1																		
PM10	EPA	0.92	0.70	0.41	0.12	0.43	0.39	0.87	0.85	0.73	0.47	0.51	0.40	1																	
	EPB	0.57	0.95	0.63	0.48	0.76	0.71	0.85	0.93	0.66	0.58	0.75	0.69	0.71	1																
	CJA	0.62	0.59	0.92	0.52	0.65	0.78	0.92	0.88	0.95	0.18	0.15	0.55	0.47	0.66	1															
	CJB	0.02	0.40	0.53	0.94	0.84	0.84	0.49	0.43	0.33	0.81	0.70	0.89	0.20	0.60	0.48	1														
	C12	0.37	0.78	0.32	0.64	0.65	0.63	0.49	0.53	0.27	0.76	0.97	0.88	0.48	0.79	0.34	0.78	1													
	C41	0.37	0.71	0.67	0.84	0.80	0.80	0.75	0.76	0.50	0.73	0.80	0.97	0.44	0.75	0.60	0.89	0.87	1												
BC	EPA	-0.45	-0.02	-0.23	-0.36	0.07	0.00	-0.24	-0.38	-0.31	-0.15	-0.09	-0.24	-0.38	-0.14	-0.24	-0.15	-0.04	-0.24	-0.31	1										
	EPB	-0.40	-0.15	0.07	0.15	0.31	0.29	0.08	-0.21	0.00	0.21	-0.09	0.05	0.02	0.01	0.08	0.21	0.00	0.05	0.09	0.59	1									
	CJA	-0.45	-0.60	-0.24	-0.25	-0.20	-0.36	-0.70	-0.71	-0.33	-0.45	-0.26	-0.10	-0.66	-0.38	-0.15	-0.13	-0.18	-0.30	-0.36	0.54	0.31	1								
	CJB	-0.85	-0.65	-0.21	0.04	0.00	-0.10	-0.62	-0.58	-0.35	-0.13	-0.09	-0.13	-0.76	-0.25	-0.09	0.15	-0.03	-0.11	-0.22	0.62	0.45	0.90	1							
NO2	EPA	-0.42	-0.46	-0.19	-0.03	0.10	0.04	-0.38	-0.59	-0.30	-0.17	-0.26	-0.13	-0.42	-0.41	-0.10	0.11	-0.17	-0.16	-0.21	0.50	0.74	0.72	0.73	1						
	EPB	0.08	0.23	0.02	-0.20	0.04	0.03	0.21	0.34	0.24	-0.05	0.15	0.07	0.30	0.14	0.18	-0.21	0.11	0.14	0.27	-0.18	-0.08	-0.34	-0.20	-0.18	1					
	CJA	-0.49	-0.73	-0.46	-0.29	-0.48	-0.54	-0.83	-0.78	-0.56	-0.52	-0.43	-0.31	-0.79	-0.66	-0.38	-0.20	-0.38	-0.42	-0.59	0.10	-0.04	0.81	0.66	0.52	-0.24	1				
	CJB	-0.44	-0.75	-0.14	-0.06	-0.46	-0.47	-0.62	-0.69	-0.32	-0.39	-0.43	-0.24	-0.69	-0.65	-0.19	-0.08	-0.40	-0.38	-0.55	0.13	0.07	0.79	0.73	0.45	-0.51	0.78	1			
	C12	-0.71	-0.53	0.03	0.26	0.13	0.13	-0.31	-0.51	-0.22	-0.08	-0.39	-0.16	-0.50	-0.41	0.00	0.20	-0.28	-0.14	-0.17	0.51	0.81	0.51	0.71	0.87	-0.12	0.40	0.43	1		
	C37	-0.84	-0.57	0.14	0.31	0.01	0.01	-0.36	-0.57	-0.20	-0.03	-0.42	-0.18	-0.72	-0.52	0.02	0.26	-0.31	-0.18	-0.24	0.60	0.75	0.52	0.64	0.71	-0.19	0.42	0.46	0.90	1	
	C41	-0.81	-0.53	0.04	0.20	0.01	0.02	-0.34	-0.53	-0.15	-0.05	-0.31	-0.10	-0.63	-0.37	0.06	0.24	-0.23	-0.11	-0.18	0.51	0.78	0.59	0.76	0.76	-0.14	0.51	0.52	0.88	0.92	1

Table 6-2: Inter-site and inter-pollutant Spearman's correlation coefficients – Outdoor microenvironment

Pollutant		PM2.5						PM10-2.5						PM10							BC				NO2						
	Site	EPA	EPB	CJA	CJB	C12	C41	EPA	EPB	CJA	CJB	C12	C41	EPA	EPB	CJA	CJB	C12	C41	C49	EPA	EPB	CJA	CJB	EPA	EPB	CJA	CJB	C12	C37	C41
PM2.5	EPA	1																													
	EPB	0.85	1																												
	CJA	0.44	0.48	1																											
	CJB	0.56	0.76	0.57	1																										
	C12	0.64	0.69	0.75	0.76	1																									
	C41	0.64	0.69	0.63	0.80	0.95	1																								
PM10-2.5	EPA	0.90	0.88	0.53	0.83	0.77	0.87	1																							
	EPB	0.76	0.70	0.53	0.75	0.68	0.78	0.73	1																						
	CJA	0.50	0.72	0.57	0.93	0.71	0.83	0.88	0.90	1																					
	CJB	0.41	0.59	0.49	0.84	0.57	0.69	0.66	0.73	0.88	1																				
	C12	0.49	0.57	0.45	0.57	0.53	0.49	0.61	0.36	0.48	0.30	1																			
	C41	0.60	0.82	0.78	0.85	0.76	0.67	0.78	0.56	0.80	0.66	0.82	1																		
PM10	EPA	0.94	0.87	0.56	0.77	0.89	0.91	0.97	0.62	0.73	0.33	0.78	0.78	1																	
	EPB	0.88	0.93	0.53	0.81	0.74	0.77	0.86	0.90	0.84	0.65	0.45	0.73	0.81	1																
	CJA	0.55	0.74	0.70	0.94	0.72	0.83	0.83	0.88	0.96	0.81	0.53	0.84	0.73	0.82	1															
	CJB	0.42	0.61	0.54	0.91	0.62	0.71	0.64	0.73	0.89	0.96	0.41	0.74	0.38	0.64	0.88	1														
	C12	0.49	0.59	0.61	0.60	0.65	0.63	0.68	0.41	0.53	0.36	0.97	0.88	0.87	0.49	0.59	0.45	1													
	C41	0.68	0.87	0.69	0.87	0.80	0.80	0.90	0.64	0.83	0.66	0.80	0.97	0.90	0.79	0.86	0.74	0.87	1												
	C49	0.77	0.89	0.73	0.71	0.86	0.82	0.88	0.76	0.75	0.58	0.64	0.85	0.89	0.89	0.76	0.59	0.69	0.90	1											
BC	EPA	-0.39	-0.36	0.08	-0.15	-0.16	-0.26	-0.37	-0.12	-0.07	-0.02	-0.22	-0.25	-0.26	-0.27	0.01	0.07	-0.20	-0.34	-0.36	1										
	EPB	-0.18	-0.26	0.29	0.21	-0.01	-0.14	-0.26	0.11	0.32	0.55	-0.26	-0.06	-0.21	-0.06	0.33	0.59	-0.21	-0.17	-0.13	0.75	1									
	CJA	-0.54	-0.46	0.22	0.08	-0.10	-0.27	-0.54	-0.36	0.04	0.17	-0.01	0.10	-0.50	-0.38	0.10	0.23	0.01	-0.12	-0.26	0.83	0.68	1								
	CJB	-0.42	-0.50	0.08	0.29	0.10	0.04	-0.29	-0.15	0.29	0.51	0.10	0.05	-0.28	-0.34	0.27	0.55	0.13	0.08	-0.10	0.58	0.74	0.80	1							
NO2	EPA	-0.39	-0.31	0.23	0.38	-0.19	-0.09	-0.23	-0.04	0.50	0.67	-0.43	-0.16	-0.46	-0.17	0.44	0.62	-0.35	-0.17	-0.24	0.63	0.70	0.60	0.73	1						
	EPB	-0.38	-0.17	0.36	0.32	0.06	0.08	-0.17	-0.02	0.41	0.42	0.13	0.18	-0.03	-0.15	0.51	0.52	0.20	0.13	-0.05	0.83	0.61	0.78	0.73	0.67	1					
	CJA	-0.67	-0.53	0.09	-0.01	-0.28	-0.39	-0.67	-0.49	-0.09	-0.05	-0.32	-0.18	-0.59	-0.53	-0.02	0.05	-0.29	-0.30	-0.43	0.67	0.50	0.84	0.74	0.58	0.60	1				
	CJB	-0.11	0.02	0.29	0.25	0.35	0.27	0.08	0.37	0.43	0.47	-0.19	0.12	0.18	0.20	0.36	0.45	-0.05	0.11	0.15	0.65	0.53	0.60	0.61	0.56	0.57	0.44	1			
	C12	-0.27	-0.31	0.09	0.41	0.13	0.13	-0.18	0.12	0.49	0.64	-0.39	-0.16	-0.15	-0.10	0.39	0.61	-0.28	-0.14	-0.17	0.70	0.71	0.64	0.85	0.77	0.54	0.53	0.77	1		
	C37	-0.31	-0.36	0.25	0.51	0.01	0.01	-0.25	-0.05	0.55	0.73	-0.42	-0.18	-0.36	-0.19	0.50	0.72	-0.31	-0.18	-0.24	0.72	0.83	0.68	0.78	0.90	0.63	0.56	0.56	0.90	1	
	C41	-0.36	-0.29	0.15	0.38	0.01	0.02	-0.24	-0.02	0.45	0.62	-0.31	-0.10	-0.23	-0.16	0.42	0.65	-0.23	-0.11	-0.18	0.83	0.78	0.68	0.79	0.90	0.83	0.67	0.71	0.88	0.92	1

Longer averaging times can sometimes lead to bias in epidemiological studies as they may not accurately reflect the short-term variations in concentration gradients. Therefore, hourly correlations for the pollutant parameters between the various CAMS sites were computed to understand this feature and are shown in Table 6-3. All the pollutant correlations between the paired sites were statistically significant at  $p < 0.0001$  level. For the CAMS12 and CAMS 41 pair sites, correlations were strong for  $PM_{2.5}$  ( $r = 0.82$ ) and  $PM_{10-2.5}$  (0.78) conforming temporal similarity between these sites. Correlations were moderate to strong between the three CAMS sites for  $PM_{10}$  ( $r > 0.67$ ). Finally, for  $NO_2$ , the correlations were greater than 0.73 when CAMS 12, 37, and 49 were paired with each other.

**Table 6-3: Hourly correlations for the pollutant parameters between the CAMS sites**

Pollutant	CAMS SITES	CAMS12	CAMS37	CAMS49
$PM_{2.5}$	CAMS41	0.82		
$PM_{10-2.5}$	CAMS41	0.78		
$PM_{10}$	CAMS41	0.81		0.67
	CAMS49	0.67		
$NO_2$	CAMS37	0.73		
	CAMS41	0.82	0.76	

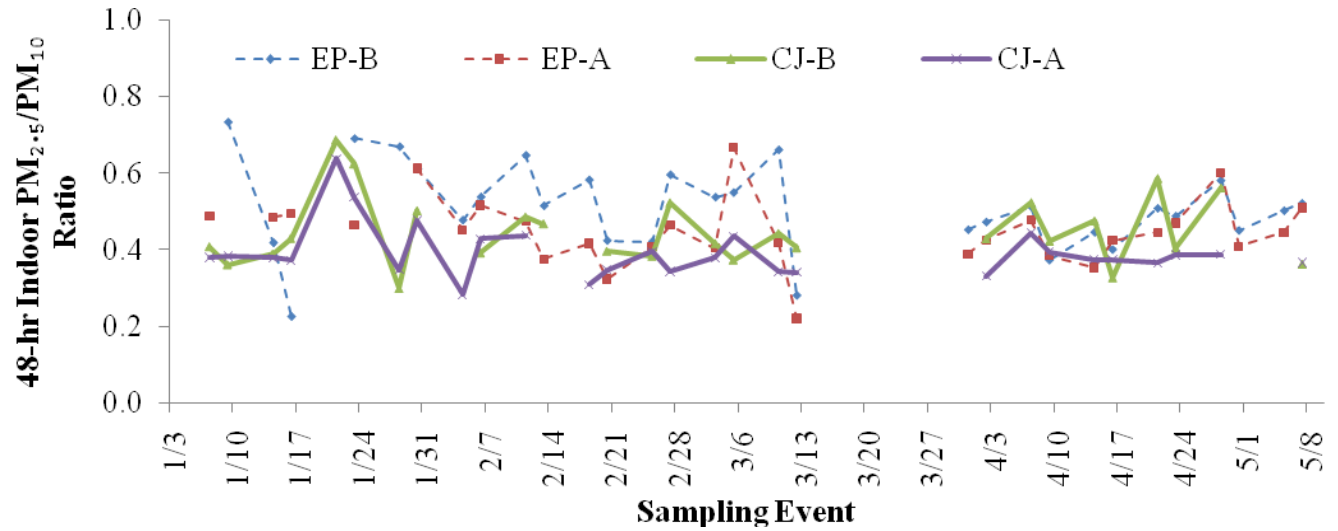
$P < 0.0001$ ,  $n = 3325 - 3563$

## 6.2 $PM_{2.5}/PM_{10}$ concentrations

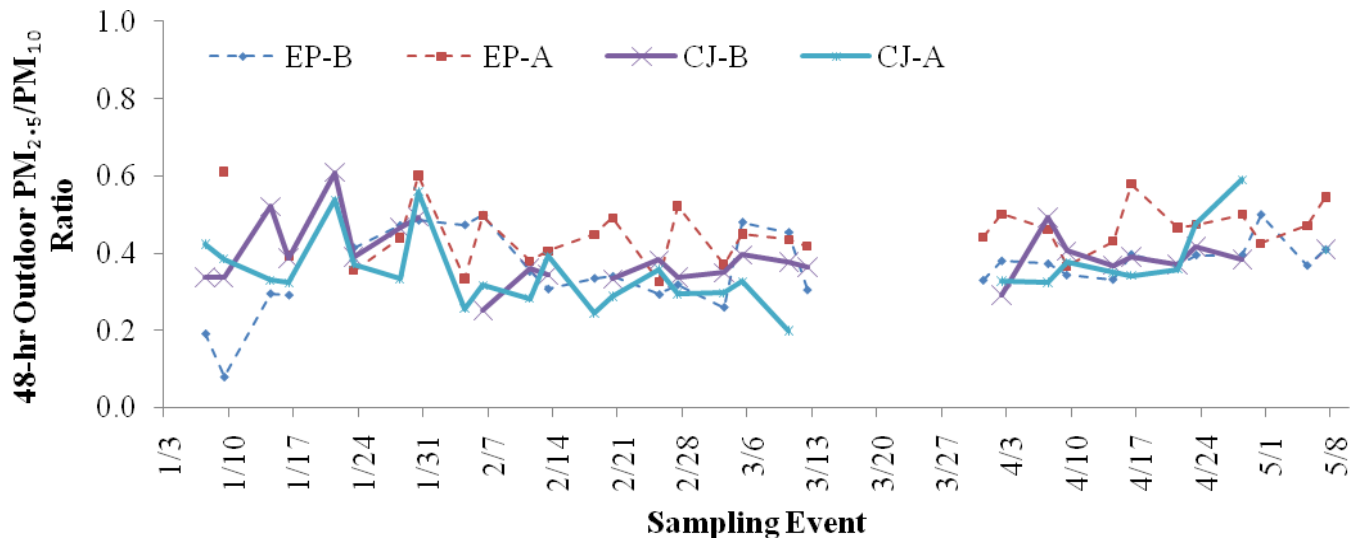
$PM_{2.5}/PM_{10}$  ratios were computed for both indoor and outdoor concentrations across the four school sites. Figures 6-1 and 6-2 are the temporal variation of the ratios across the four schools. Figure 6-2 also consists the  $PM_{2.5}/PM_{10}$  ratios from the TCEQ CAMS 12 and 41 sites. The summary statistics for the indoor and outdoor ratios are included in Table 6-4 and 6-5 and the spatial contrast between these ratios is featured in the clustered box plots in Figure 6-3. The mean indoor ratios varied from 0.39 (lowest) at CJ-A to 0.52 (highest) at CJ-B. The outdoor fine fraction constituted, on average, approximately 35 percent of the total PM at the high exposure

school in El Paso. School EP-A recorded the highest ratio of 0.45 for the study period. This could be attributed to lower  $PM_{10}$  associated with lower  $PM_{10-2.5}$  at this school. The two Ciudad Juárez schools recorded ratios similar to school EP-B (CJ-A: 0.36 and CJ-B: 0.39).

On average, the outdoor  $PM_{2.5}$  constituted approximately 40% of  $PM_{10}$  at the four schools. This ratio is higher than that observed at CAMS 12 (25.6%) and CAMS 41 (28.0%). These values are in agreement with the values reported by EPA (US EPA, 2000) and in the literature (Li et al., 2001) based on the data collected at the central monitoring sites. Li et al., 2001 reported that the fine fraction of PM accounts for 25% of the total mass detected in  $PM_{10}$ . The high ratios at the monitored schools in contrast to the CAMS sites is expected since the two high exposure schools were located in the near vicinity of busy roadways and the two low exposure schools were situated in populated residential areas. In general, the  $PM_{2.5}/PM_{10}$  ratios were higher indoors than outdoors since outdoor coarse particles are known to be less effective in infiltrating through building leaks and minor openings into the indoor microenvironment than fine particulate matter. All the above observations confirm that the coarse fraction of PM dominates  $PM_{10}$  in the Paso del Norte region and central monitoring sites may not mirror the true population exposure concentrations at the intra-urban level.



**Figure 6-1: Temporal variation for indoor 48-hr averaged  $PM_{2.5}/PM_{10}$  ratios**



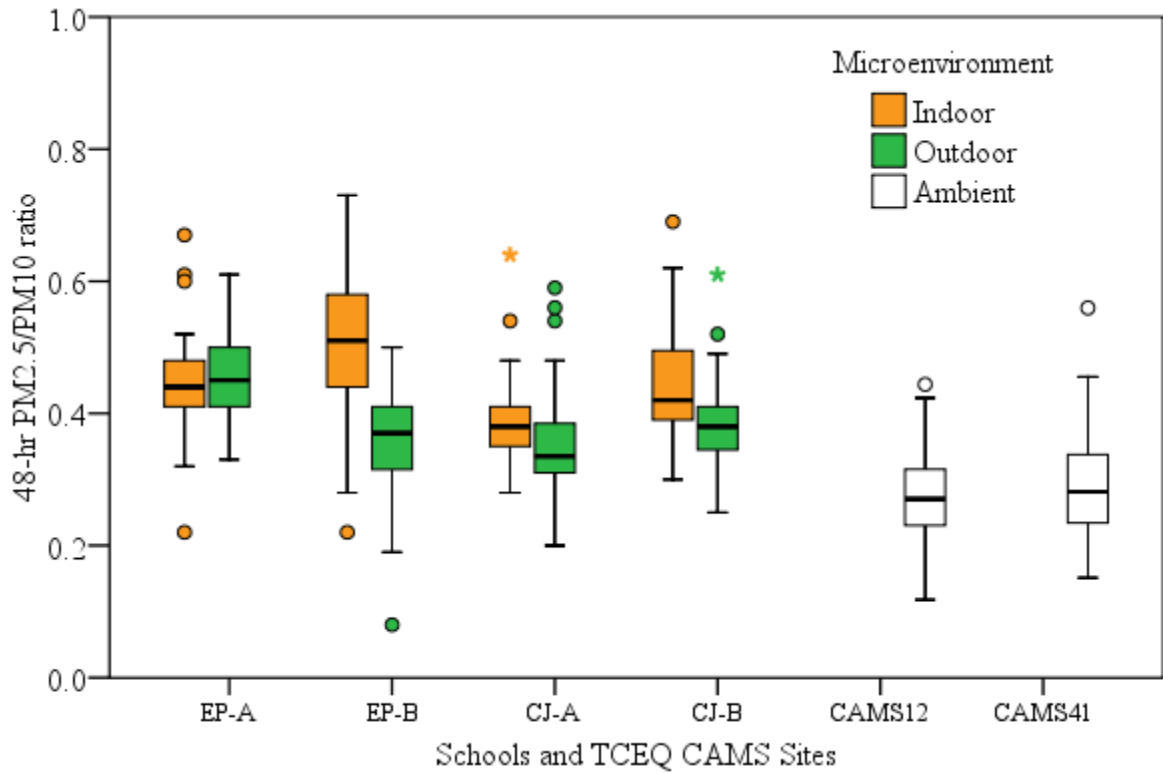
**Figure 6-2: Temporal variation for outdoor 48-hr averaged  $PM_{2.5}/PM_{10}$  ratios**

**Table 6-4: Indoor  $PM_{2.5}/PM_{10}$  ratios**

	EP -A	EP-B	CJ-A	CJ-B
N	32	32	31	30
Mean	0.45	0.52	0.39	0.45
Median	0.45	0.51	0.38	0.43
Std Dev	0.08	0.12	0.07	0.09
Maximum	0.67	0.73	0.64	0.69
Minimum	0.22	0.22	0.28	0.30
IQR	0.08	0.15	0.06	0.10

**Table 6-5: Outdoor PM<sub>2.5</sub>/PM<sub>10</sub> ratios**

	EP -A	EP-B	CJ-A	CJ-B
N	31	33	30	29
Mean	0.45	0.35	0.36	0.39
Median	0.45	0.35	0.34	0.38
Std Dev	0.12	0.11	0.09	0.08
Maximum	0.81	0.50	0.59	0.61
Minimum	0.04	0.05	0.20	0.25
IQR	0.10	0.10	0.08	0.06



**Figure 6-3: Clustered box plot for 48-hr PM<sub>2.5</sub>/PM<sub>10</sub> ratios at four schools and TCEQ CAMS Sites**

### 6.3 BC/PM<sub>2.5</sub> Concentrations

The summary statistics for 48-hr indoor and outdoor BC/PM<sub>2.5</sub> ratios is shown in Tables 6-6 and 6-7, respectively. The temporal variations for indoor and outdoor BC/PM<sub>2.5</sub> ratios at the four schools are shown in Figures 6-4 and 6-5, respectively. Figure 6-6 is the clustered box plot

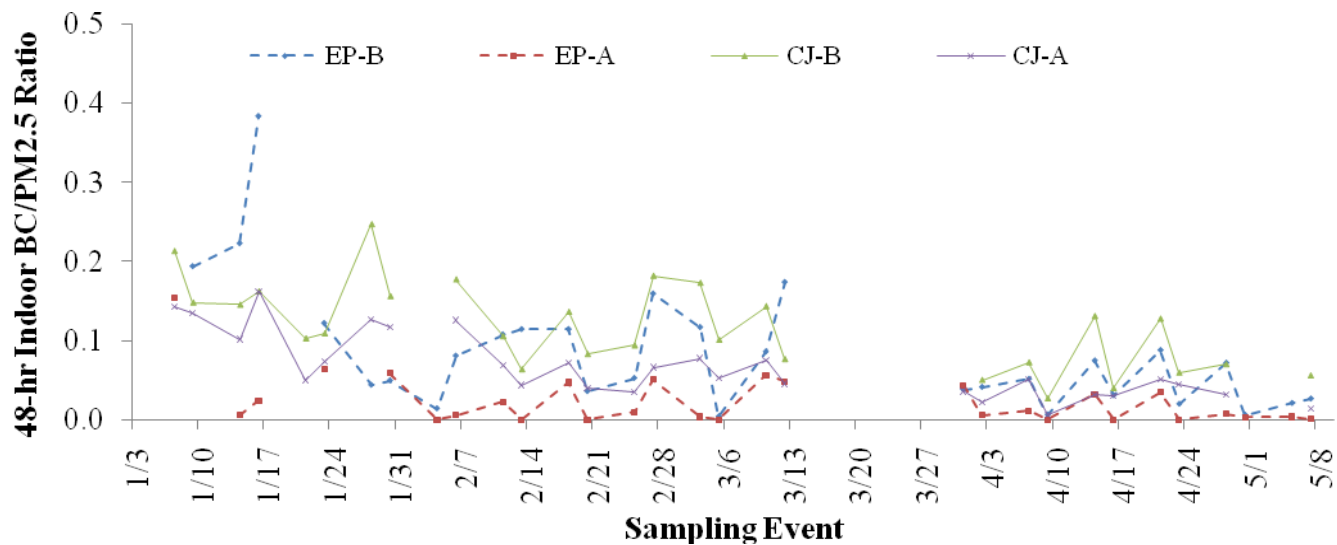
for BC/PM<sub>2.5</sub> ratios for both indoor and outdoor microenvironments. The indoor BC/PM<sub>2.5</sub> ratios show a median of 0.01 (range: 0.00-0.15) at EP-A, 0.06 (range: 0.00-0.38) at EP-B, 0.05 (range: 0.01-0.16) at CJ-A and 0.11 (range: 0.03-0.25) at CJ-B. For the outdoor BC/PM<sub>2.5</sub> ratios, the median values were 0.02 for EP-A, 0.06 at EP-B, and CJ-A; and 0.11 at CJ-B. As expected, the BC concentrations at the El Paso low exposure school accounted for four percent of the PM<sub>2.5</sub> compared to 11 percent for school CJ-B. The visual analysis of the clustered box plots in Figure 6-6 suggests that the outdoor ratios at the two low exposure schools were lower in contrast to the respective high exposure schools in both the cities.

**Table 6-6: Summary statistics of indoor BC/PM<sub>2.5</sub> ratios**

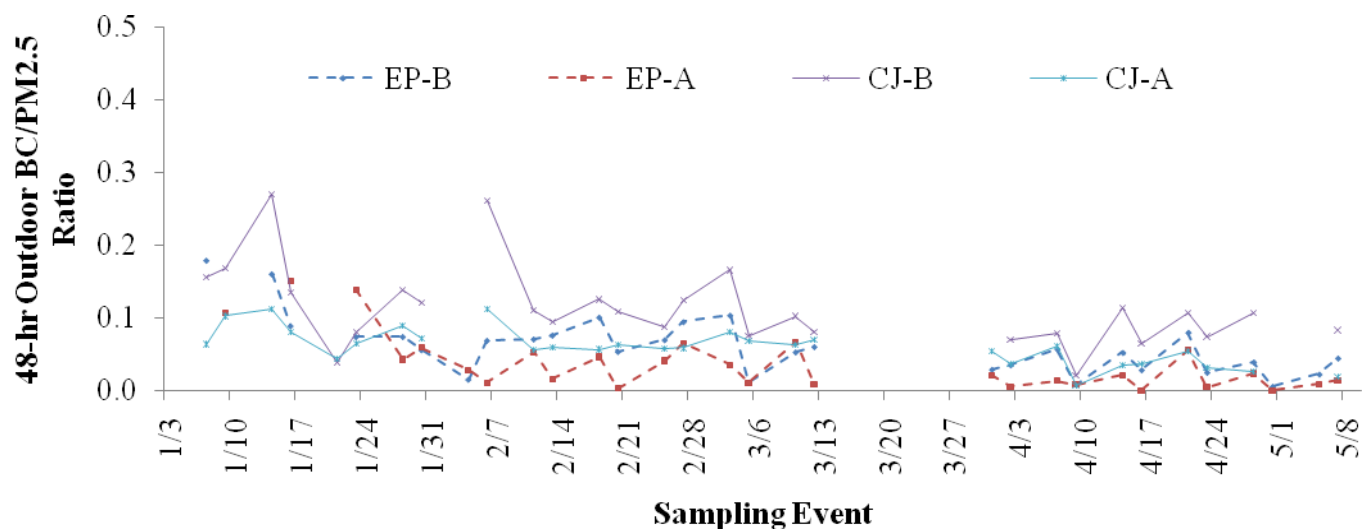
	EP -A	EP-B	CJ-A	CJ-B
N	29	30	29	28
Mean	0.02	0.08	0.07	0.12
Median	0.01	0.06	0.05	0.11
Std Dev	0.03	0.08	0.04	0.05
Maximum	0.15	0.38	0.16	0.25
Minimum	0.00	0.00	0.01	0.03
IQR	0.04	0.08	0.04	0.08

**Table 6-7: Summary statistics of outdoor BC/PM<sub>2.5</sub> ratios**

	EP -A	EP-B	CJ-A	CJ-B
N	29	30	29	28
Mean	0.04	0.06	0.06	0.11
Median	0.02	0.06	0.06	0.11
Std Dev	0.04	0.04	0.03	0.06
Maximum	0.15	0.18	0.11	0.27
Minimum	0.00	0.01	0.01	0.02
IQR	0.04	0.05	0.03	0.05

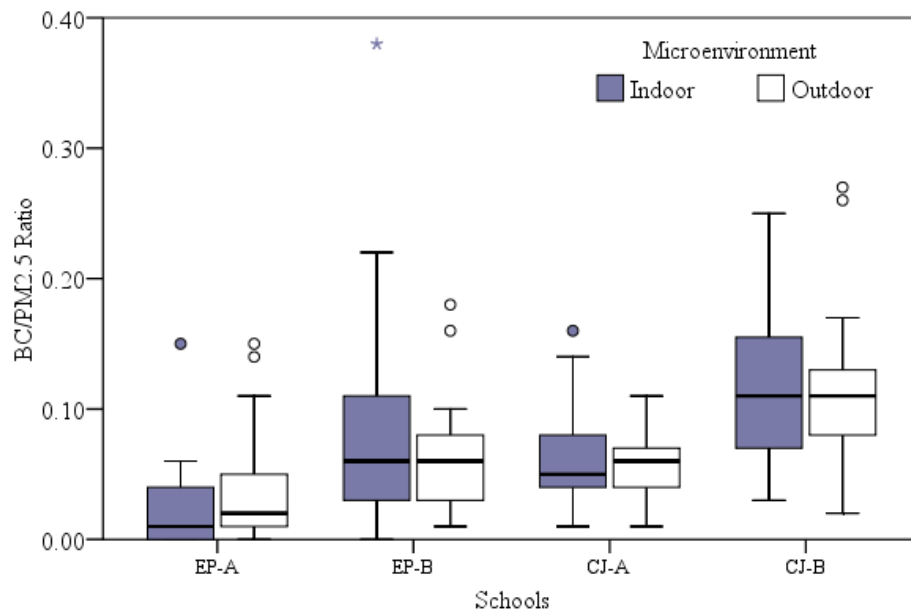


**Figure 6-4: Temporal variation for indoor 48-hr averaged BC/PM<sub>2.5</sub> ratios**



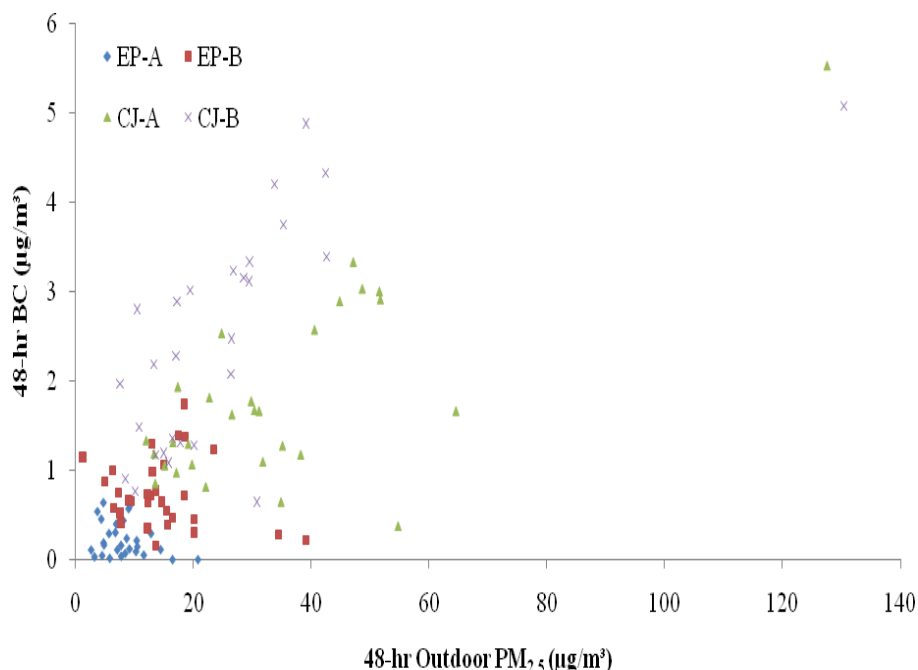
**Figure 6-5: Temporal variation for outdoor 48-hr averaged BC/PM<sub>2.5</sub> ratios**





**Figure 6-6: Box plot for 48-hr BC/PM<sub>2.5</sub> ratios at the four schools**

Figure 6-7 is the scatter plot of outdoor BC versus outdoor PM<sub>2.5</sub> at the four schools. The regression equations are presented below the figure. The  $R^2$  values between BC and PM<sub>2.5</sub> are around 0.5 for the two Ciudad Juarez schools, compared to  $< 0.1$  for the El Paso schools. This may imply that PM<sub>2.5</sub> in Ciudad Juarez was more associated with traffic emissions than that of El Paso.



**EP-A:**  $y = -0.0138x + 0.3396$ ,  $R^2 = 0.0836$ ; **EP-B:**  $y = -0.0091x + 0.8791$ ,  $R^2 = 0.0336$ , **CJ-A:**  $y = 0.0347x + 0.6121$ ,  $R^2 = 0.5494$ ; **CJ-B:**  $y = 0.0365x + 1.5239$ ,  $R^2 = 0.4314$

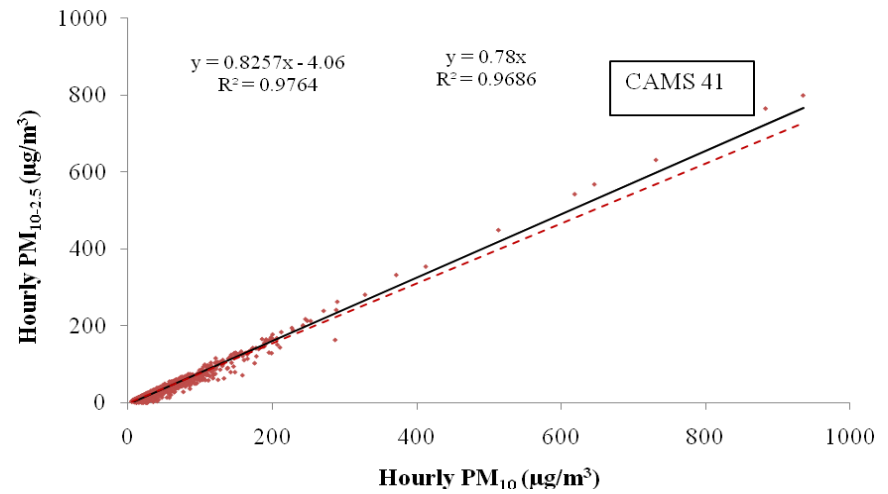
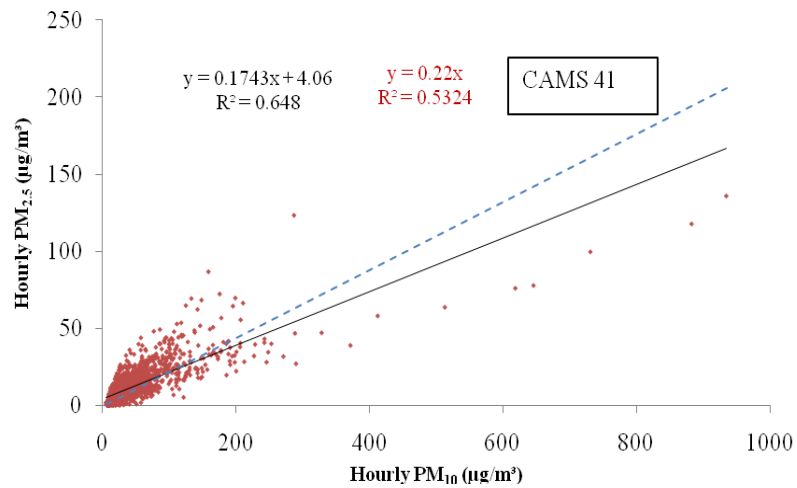
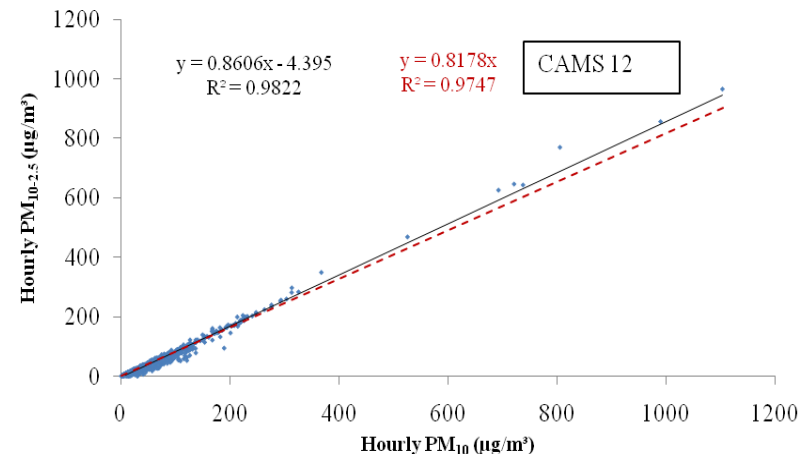
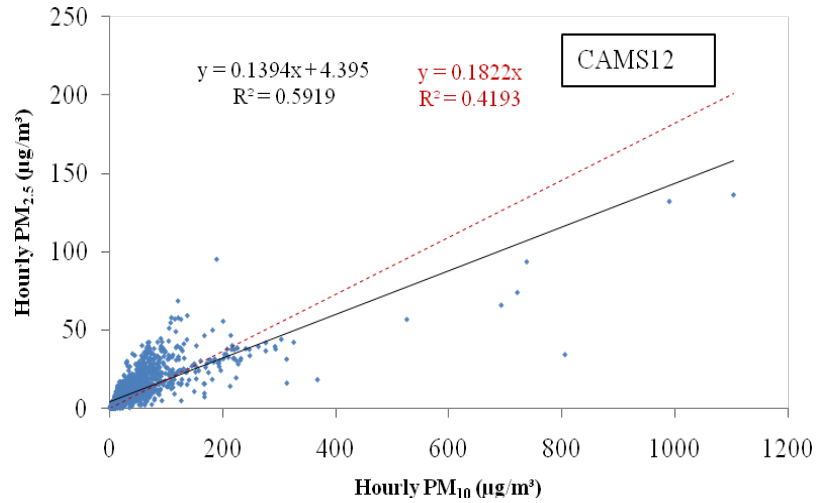
**Figure 6-7: Scatter plot of outdoor BC ( $\mu\text{g}/\text{m}^3$ ) versus outdoor PM<sub>2.5</sub> ( $\mu\text{g}/\text{m}^3$ ) for the four school sites**

#### 6.4 Correlations between the three PM species at Schools and TCEQ CAMS sites

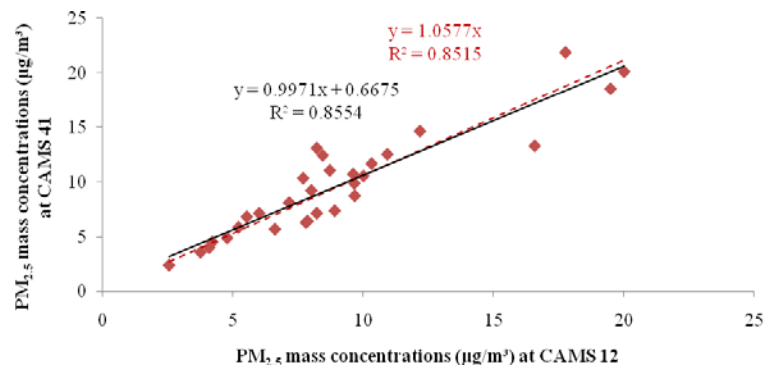
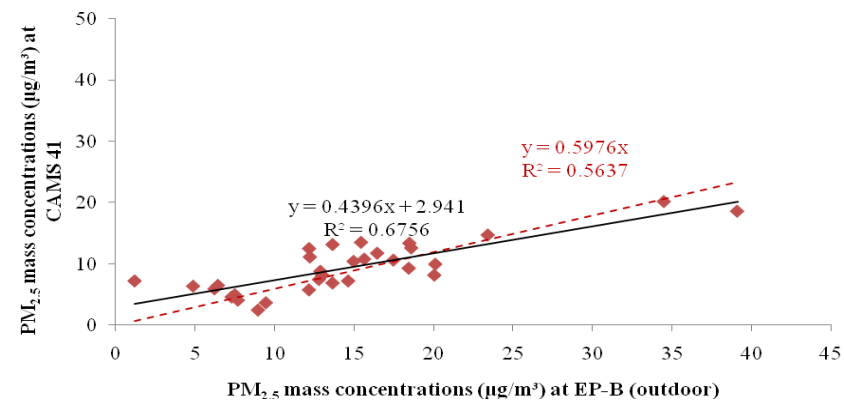
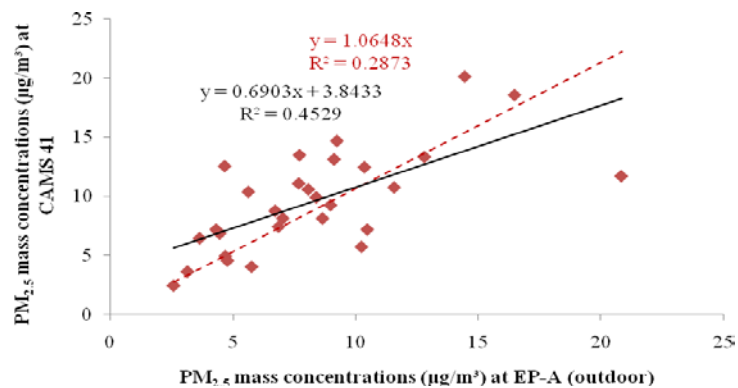
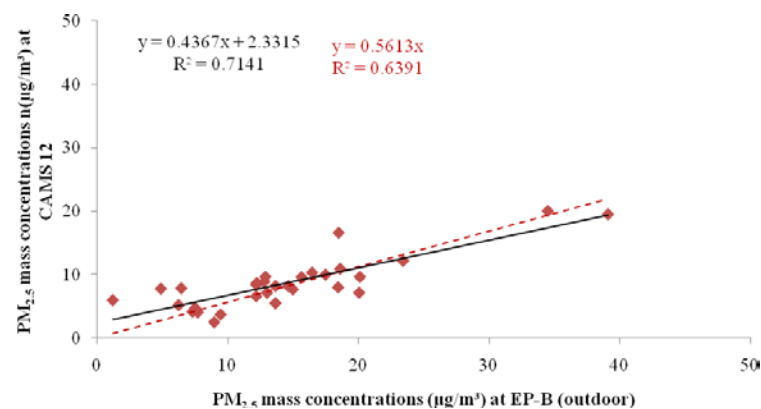
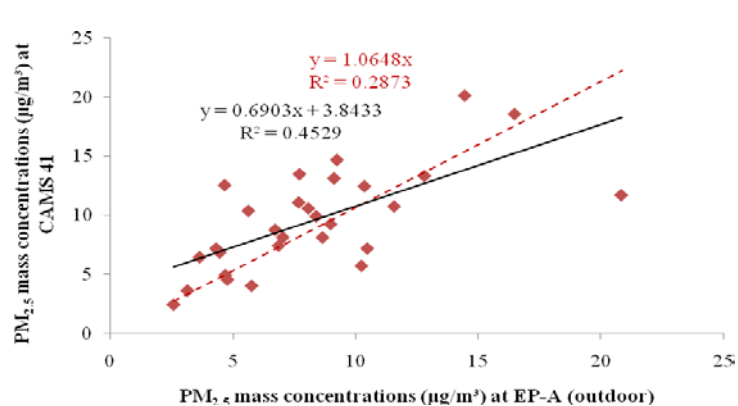
Correlation analyses was performed to understand the relationships between PM<sub>2.5</sub>, PM<sub>10-2.5</sub>, and PM<sub>10</sub> pollutants. Figure 6-8 illustrates the graphs showing the analyses based on hourly values obtained from TCEQ CAMS 12 and 41 sites. High  $R^2$  values ( $\sim 0.98$ ) between PM<sub>10</sub> and PM<sub>10-2.5</sub> suggests that the coarse component of PM dominates in this desert region. The  $R^2$  values between PM<sub>2.5</sub> and PM<sub>10</sub> were moderately strong (around 0.6) for both the CAMS stations. The dotted line in red is the straight fit (1:1) line with a zero intercept.

The scatter plots for 48-hr PM<sub>2.5</sub> between the various sites are shown in Figure 6-9. Similarly, the scatter plots for 48-hr PM<sub>10</sub> between the sites are shown in Figure 6-10a and 6-10b. The  $R^2$  value for PM<sub>2.5</sub> and PM<sub>10</sub> for the CAMS 12-41 pair sites was 0.855 and 0.903 suggesting

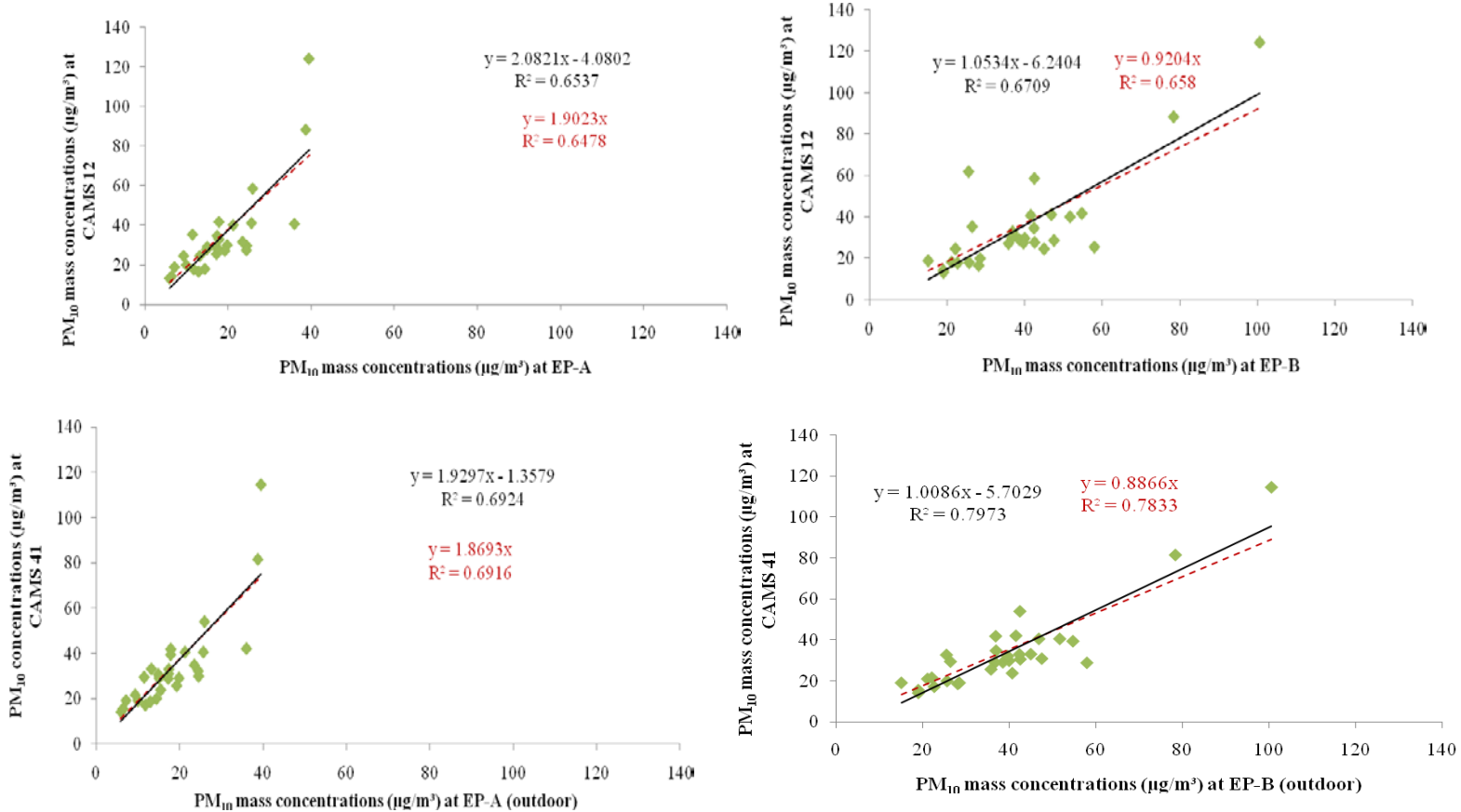
that the concentrations for these PM species were similar. Similar values were obtained for  $PM_{10}$  when CAMS 49 was paired with CAMS 12 and CAMS 41. The  $R^2$  value for  $PM_{10}$  between CJ-A and CAMS 49 was 0.27 with a slope of 0.29. These values suggest the difference in the concentrations profiles for these two sites during the study period.



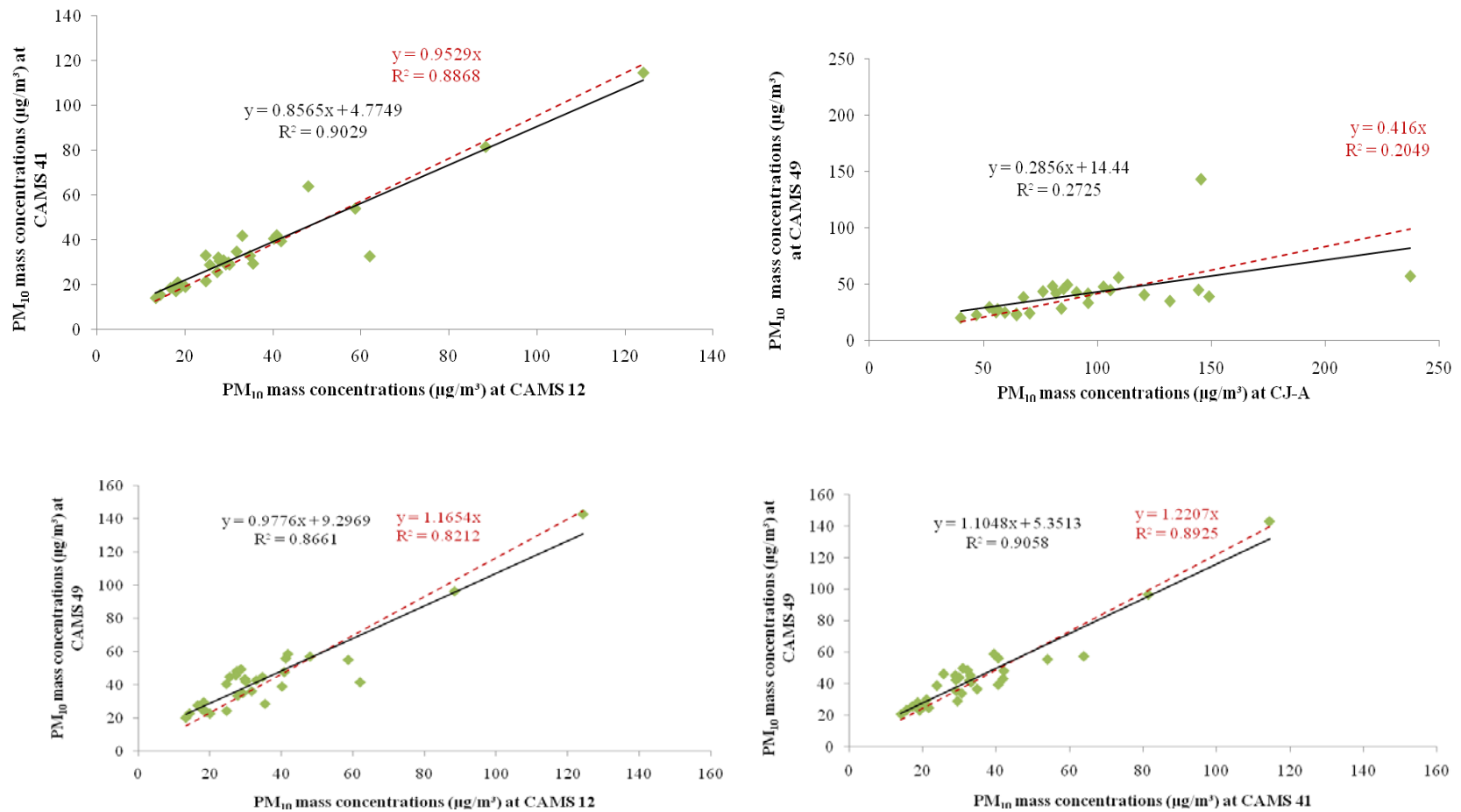
**Figure 6-8: Hourly correlations between the various PM species at CAMS 12 and CAMS 41 sites.**



**Figure 6-9: 48-hr scatter plots for the PM<sub>2.5</sub> species between the schools and TCEQ CAMS sites.**



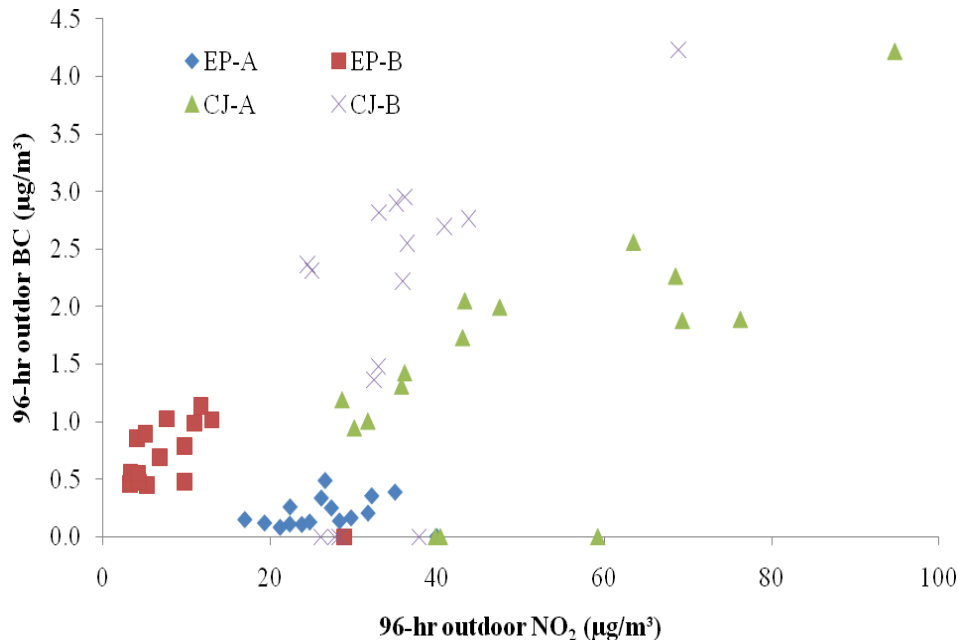
**Figure 6-10a: Scatter plots for PM<sub>10</sub> concentrations between the schools and TCEQ CAMS sites**



**Figure 6-10b: Scatter plots for 48-hr PM<sub>10</sub> concentrations between the various sites**

## 6.5 Relationship of NO<sub>2</sub> with BC and PM<sub>2.5</sub>

BC and PM<sub>2.5</sub> concentrations were regressed against NO<sub>2</sub> as shown in Figures 6.11 and 6.12, respectively. This analyses was undertaken to determine the traffic contribution to BC and PM<sub>2.5</sub> at the study sites. This analysis was based on the assumption that outdoor NO<sub>2</sub> is a good primer for traffic emissions. The 48-hr BC and PM<sub>2.5</sub> values were averaged to a 96-hr concentration period to match with the 96-hr concentrations. Furthermore, the NO<sub>2</sub> concentrations in ppb were converted to  $\mu\text{g}/\text{m}^3$  to match the units similar to the other two pollutants. The conversion factor of 1 ppb = 1.881  $\mu\text{g}/\text{m}^3$  was utilized for the analysis.



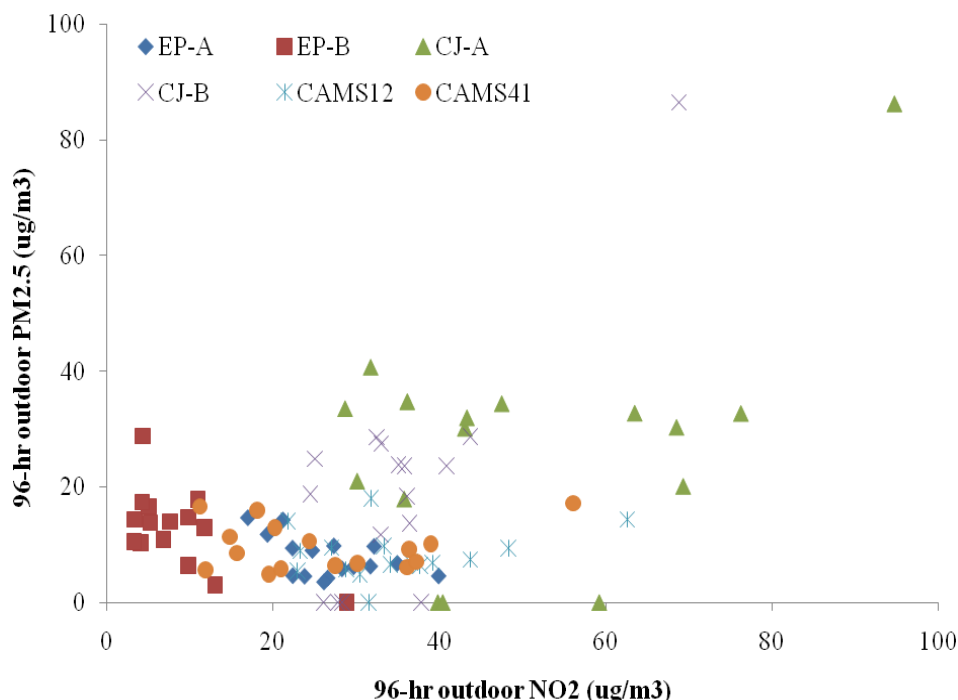
**EP-A:**  $y = 0.003x + 0.116$ ,  $R^2 = 0.02$ ; **EP-B:**  $y = -0.014x + 0.807$ ,  $R^2 = 0.08$ ; **CJ-A:**  $y = 0.037x - 0.357$ ,  $R^2 = 0.44$ ; **CJ-B:**  $y = 0.074x - 0.689$ ,  $R^2 = 0.35$

**Figure 6-11: Scatter plot of outdoor BC versus NO<sub>2</sub> at the four schools**

The intercept  $c$  in the linear regression equation  $\text{BC} = m\text{NO}_2 + c$  and  $\text{PM}_{2.5} = m\text{NO}_2 + c$  represents the amount of BC and PM<sub>2.5</sub> not related to traffic emissions, respectively. The regression equations for each school are shown below the figures. The  $R^2$  values between NO<sub>2</sub> and BC for school CJ-A and CJ-B is 0.44 and 0.35, respectively. These were higher than 0.02



and 0.08 obtained for school EP-A and EP-B, respectively. Similarly, the regression of  $PM_{2.5}$  on  $NO_2$  yielded varying intercepts for the four schools and TCEQ CAMS sites suggesting the influence of fugitive emission sources other than traffic.  $NO_2$  could also be apportioned to Western Refinery or other point sources around the area.



**EP-A:**  $y = -0.313x + 16.24$ ,  $R^2 = 0.29$ ; **EP-B:**  $y = -0.65x + 18.32$ ,  $R^2 = 0.39$ ; **CJ-A:**  $y = 0.497x + 2.773$ ,  $R^2 = 0.22$ ; **CJ-B:**  $y = 1.609x - 36.182$ ,  $R^2 = 0.67$ ; **CAMS12:**  $y = 0.079x + 5.678$ ,  $R^2 = 0.04$ ; **CAMS41:**  $y = 0.033x + 8.854$ ,  $R^2 = 0.01$

**Figure 6-12: Scatter plot of outdoor  $PM_{2.5}$  versus  $NO_2$  at the four schools and TCEQ CAMS sites.**

## **7.0 Spatial Contrast between the four schools and TCEQ CAMS sites**

### **7.1 Pollutant spatial variation studies in the PdN region**

Previous studies in the Paso del Norte region have characterized traffic air pollutants and demonstrated substantive spatial variation at the intra-urban level (Li et al., 2001, 2003; Garcia et al., 2005, Jeon et al., 2001, Noble et al., 2003, Einfield & Church, 1995). In addition, to traffic emissions, source density, spatial and temporal variability in pollutant concentrations can be ascribed to meteorology (winter temperature inversions and subsequent high PM levels), topography, industrial emissions population density, long-range transport, domestic heating, atmospheric chemistry, and physical processes (Gotschi 2005, Hazenkamp-von Arx M et.al., 2004). PM pollution in this region has been characterized by many researchers (Li 2001, 2003; Jeon 2001, Arrieta 2003, Noble 2003, Paschold 2003a). Li et al 2001, for example, found higher fine and coarse PM concentrations in their Ciudad Juárez sites compared to El Paso sites and imputed the same to major anthropogenic sources such as high number of unpaved roads, brick kilns, automobiles, and point sources of industrial pollution.

In a winter-pilot study conducted in El Paso, February 1999, Gonzales et al. (2005) reported concentration gradients ranging from 11.0 to 37.5 ppb for seven-day mean NO<sub>2</sub> levels across 20 elementary schools and four air quality monitoring stations (CAMS 6, 12, 30 and 41). The lowest concentrations during the study period were recorded in their Northeast sampling sites, which were located at higher elevations, and the corresponding high concentrations were at Chamizal monitoring station near the US-Mexico Border. Their results are in line with the results obtained from this study with school EP-A recording the lowest mean in contrast to school EP-B in the lower valley. Furthermore, the results and subsequent regression analyses performed by

the researchers confirmed a decrement in NO<sub>2</sub> concentrations with increasing distance from major roadways and international border crossings.

Temporal variations in CO, NO<sub>2</sub>, ultrafine PM, and accumulation PM were observed in a 21 day winter study conducted in 1999 at two sites: Downtown El Paso and Chamizal National Memorial (Noble et al. 2003). The concentration gradients at these two sites, adjacent to major traffic highways, followed a trend with morning and evening commuting hours. The 24-hr integrated sample mean for PM<sub>2.5</sub> and PM<sub>10</sub> for the Downtown site were 20(9) and 91(50) µg/m<sup>3</sup>, respectively. For the same study period, the Chamizal site recorded a mean of 17(9) µg/m<sup>3</sup> for PM<sub>2.5</sub> and 61(31) µg/m<sup>3</sup> for PM<sub>10</sub>. The hourly mean for NO<sub>2</sub> were 34(11) and 28(9) ppb for the Downtown and Chamizal site, respectively. One notices that these values are higher than what are reported in this study, which could be the consequence of the frequently occurring adverse meteorological conditions in the winter.

Einfeld and Church (1995) documented that winter season PM<sub>10</sub> levels were highest in the El Paso-Ciudad Juarez downtown areas and the concentrations gradients increased toward the Mexican side. Mukerjee et al. (2004) monitored NO<sub>2</sub> and other traffic pollutants for three consecutive weeks, from November 19 to December 17, 1999, at two CAMS sites (CAMS 6 and CAMS 41) for different sampling periods – four day weekday and three day weekend. The pooled data for the weekday and weekly measurements yielded mean concentrations of 37.4 and 29.7 ppb for CAMS 6 and CAMS 41 respectively. The close proximity of CAMS6 to downtown areas may have resulted in higher concentrations in contrast to CAMS41. They further documented that the NO<sub>2</sub> concentrations were spatially uniform in the Central El Paso area.

Holguin et al. (2007) investigated the association of traffic pollutants with asthma severity in children at 22 elementary schools and five homes in a study conducted in Ciudad

Juarez from December 2002 to September 2003. CJ-A and CJ-B were two of the participating schools in this study. Both PM<sub>2.5</sub> and NO<sub>2</sub> were monitored at CJ-B whereas only NO<sub>2</sub> was monitored at CJ-A. The 48-hr mean for PM<sub>2.5</sub> at CJ-B for the study period was 21.7(13) µg/m<sup>3</sup>. The 12-day mean for NO<sub>2</sub> at CJ-A and CJ-B were 25.2(7.9) and 30.9(9.5) ppb, respectively. The spatial contrast observed between these two schools for NO<sub>2</sub> concentrations are mirrored in the present study too with school CJ-A, 18.8(5.6) µg/m<sup>3</sup>, recording lower concentrations than CJ-B, 26.8(10.2) ppb.

In order to evaluate this spatial non-uniformity, a series of analyses were conducted to evaluate the spatial variability between the indoor and outdoor concentrations at the four schools and the ambient concentrations from TCEQ CAMS sites. Specifically, Coefficient of Divergence (COD) and δP<sub>90</sub> (90<sup>th</sup> percentile of absolute concentration differences) between all the sites were calculated to elucidate the spatial heterogeneity in this region.

## **7.2 Coefficient of Divergence Analyses**

The indoor and outdoor pollutant COD values for the various site-pairs are shown in Tables 7-1 and 7-2, respectively. A COD value of less than equal to 0.2 for pollutant data sets from two sites implies spatial homogeneity between these two sites. A COD value of 1 suggests spatial non-uniformity between the two paired sites (Pinto et al., 2004).

**Table 7-1: Indoor coefficient of divergence (COD) values for the monitored pollutants**

Microenvironment		Indoor						
Pollutant	Site	EP-B	CJ-A	CJ-B	CAMS12	CAMS41	CAMS49	CAMS37
<b>PM<sub>2.5</sub></b>	<b>EP-A</b>	0.24	0.58	0.51	0.21	0.22		
	<b>EP-B</b>		0.53	0.46	0.21	0.21		
	<b>CJ-A</b>			0.24	0.53	0.51		
	<b>CJ-B</b>				0.42	0.41		
	<b>CAMS12</b>							
<b>PM<sub>10-2.5</sub></b>	<b>EP-A</b>	0.19	0.66	0.51	0.47	0.46		
	<b>EP-B</b>		0.68	0.54	0.50	0.49		
	<b>CJ-A</b>			0.33	0.38	0.37		
	<b>CJ-B</b>				0.20	0.19		
	<b>CAMS12</b>							
<b>PM<sub>10</sub></b>	<b>EP-A</b>	0.17	0.62	0.49	0.37	0.36	0.45	
	<b>EP-B</b>		0.61	0.48	0.33	0.33	0.42	
	<b>CJ-A</b>			0.29	0.42	0.41	0.33	
	<b>CJ-B</b>				0.25	0.23	0.16	
	<b>CAMS12</b>							
<b>BC</b>	<b>EP-A</b>	0.74	0.86	0.90				
	<b>EP-B</b>		0.50	0.58				
	<b>CJ-A</b>			0.25				
	<b>CJ-B</b>							
<b>NO<sub>2</sub></b>	<b>EP-A</b>	0.44	0.70	0.89	0.67	0.70		0.57
	<b>EP-B</b>		0.45	0.77	0.39	0.43		0.30
	<b>CJ-A</b>			0.59	0.20	0.21		0.29
	<b>CJ-B</b>				0.62	0.60		0.70

**Table 7-2: Outdoor coefficient of divergence (COD) values for the monitored pollutants**

Microenvironment		Outdoor						
Pollutant	Site	EP-B	CJ-A	CJ-B	CAMS12	CAMS41	CAMS49	CAMS37
<b>PM<sub>2.5</sub></b>	<b>EP-A</b>	0.35	0.6	0.51	0.17	0.17		
	<b>EP-B</b>		0.43	0.33	0.31	0.29		
	<b>CJ-A</b>			0.20	0.58	0.56		
	<b>CJ-B</b>				0.5	0.49		
	<b>CAMS12</b>					0.09		
<b>PM<sub>10-2.5</sub></b>	<b>EP-A</b>	0.45	0.73	0.59	0.45	0.43		
	<b>EP-B</b>		0.42	0.25	0.19	0.16		
	<b>CJ-A</b>			0.28	0.47	0.47		
	<b>CJ-B</b>				0.32	0.31		
	<b>CAMS12</b>					0.13		
<b>PM<sub>10</sub></b>	<b>EP-A</b>	0.39	0.69	0.56	0.32	0.32	0.42	
	<b>EP-B</b>		0.42	0.26	0.17	0.14	0.27	
	<b>CJ-A</b>			0.24	0.5	0.50	0.41	
	<b>CJ-B</b>				0.36	0.34	0.10	
	<b>CAMS12</b> <b>CAMS41</b>					0.1	0.16 0.14	
<b>BC</b>	<b>EP-A</b>	0.63	0.78	0.84				
	<b>EP-B</b>		0.38	0.49				
	<b>CJ-A</b>			0.21				
	<b>CJ-B</b>							
<b>NO<sub>2</sub></b>	<b>EP-A</b>	0.59	0.65	0.74	0.65	0.56		0.68
	<b>EP-B</b>		0.16	0.31	0.15	0.15		0.18
	<b>CJ-A</b>			0.22	0.08	0.23		0.1
	<b>CJ-B</b>				0.23	0.36		0.2
	<b>CAMS12</b> <b>CAMS41</b>					0.2		0.09 0.26

The COD values for the outdoor PM varied from a low of 0.18, 0.16 and 0.14 to a high of 0.60, 0.73 and 0.69 for PM<sub>2.5</sub>, PM<sub>10-2.5</sub>, and PM<sub>10</sub> respectively between schools EP-A and CJ-A. A COD value of 0.35 between the two schools in El Paso confirms intra-city spatial variability. For the two schools in Ciudad Juarez, a COD value of 0.20 underscores the fact that the outdoor PM<sub>2.5</sub> concentrations at these two sites were similar. PM<sub>2.5</sub> concentrations can vary at the intra-urban level due to many factors (Daniels et al., 2001, Pinto et al., 2004). Local sources of PM<sub>2.5</sub> emissions (such as major arterial roads surrounding schools EP-B, CJ-B), transient events like dust storms, and topographic barriers (such as EP-A on the foothill east of the Franklin

Mountains) are some factors that may contribute to this phenomenon. Also, occasional high wind events may result in localized differences in absolute concentrations for PM between the sampled sites.

High COD values ( $>0.45$ ) for  $PM_{10-2.5}$  were observed when EP-A was paired with EP-B, CJ-A and CJ-B, compared to the relatively lower COD value of 0.25 for the pairings of EP-B and CJ-B and 0.28 between the two Ciudad Juarez schools. This again affirms a high degree of spatial heterogeneity between EP-A (low exposure school) and the other three schools. Coarse PM is strongly influenced by local topography and meteorological events, such as wind speed and wind direction, that vary in smaller time scales, in the order of minutes to hours. Also, the largest fraction that compose coarse portion settle by gravity rapidly as they move away from the source. EP-A is approximately 10 miles from the high exposure school EP-B and in a substantially low traffic area. It is, therefore, not surprising to see that the  $PM_{10-2.5}$  COD value between EP-A and EP-B is much higher than that for  $PM_{2.5}$ . The non-uniformity between the high and low exposure zone becomes more pronounced in  $PM_{10-2.5}$ , a pollutant that is less related to traffic activities. Similarly for  $PM_{10}$ , the two high exposure schools have COD value of 0.26 when paired amongst each other, which is in contrast to COD values greater than 0.2 ( in this case around 0.39, 0.56, 0.69) when EP-A is paired with EP-B, CJ-A, and CJ-B. This suggests that the two school sites in El Paso were more heterogeneous than the schools in Ciudad Juarez for  $PM_{10}$  concentrations.

COD values were calculated for  $NO_2$  and BC concentrations between the various sites. Similar to the PM data, the COD values for  $NO_2$  and BC at the two El Paso schools exhibit spatial non-uniformity with COD values being around 0.59 and 0.63 respectively. The highest COD value of 0.74 suggests spatial non-uniformity between sites EP-A and CJ-A for  $NO_2$ , in

contrast to the two Ciudad Juárez schools being spatially homogeneous with a COD value 0.22. The lowest COD value (0.21) for BC concentrations was observed between CJ-A and CJ-B in contrast to the highest COD value (0.84) observed when EP-A is paired with CJ-A.

COD values were also calculated between outdoor school concentrations and the ambient concentrations for the PM species and NO<sub>2</sub> from the TCEQ CAMS sites. There was strong agreement in pollutant concentrations measured at CAMS 41 and CAMS 12, as the COD varies narrowly between 0.09 and 0.13 for the PM species. Coarse PM at CAMS 12 and CAMS 41 are considered good indicators in the high exposure zone since all COD values for PM<sub>10</sub> and PM<sub>10-2.5</sub> are below 0.2. The PM<sub>10</sub> COD values of 0.16 and 0.14 between CAMS 49 and CAMS 12 and between CAMS 49 and CAMS 41, respectively suggest spatial uniformity between the three sites. The CODs for NO<sub>2</sub> range from a low of 0.10 (CAMS 37 and CJ-A) to a high of 0.68 (CAMS 37 and EP-A). For CAMS 37 and CAMS 12, the NO<sub>2</sub> COD value is the lowest at 0.09 which corroborates the fact that for traffic surrogates like NO<sub>2</sub> central ambient monitoring sites may not reflect the actual concentrations experienced by various sites within the same airshed.

In addition, CODs were computed between the indoor pollutant concentrations at the four schools and the CAMS sites. In El Paso, the spatial non-uniformity between the CAMS sites and the indoor microenvironment at the two schools is confirmed with the CODs being greater than 0.2 for PM<sub>2.5</sub>, greater than 0.33 for PM<sub>10-2.5</sub> and 0.46 and higher for PM<sub>10</sub>. The indoor PM COD values between the Ciudad Juárez schools and CAMS sites further concurs spatial heterogeneity except when CJ-B is paired with CAMS 12 (0.2) and CAMS 41 (0.19) for PM<sub>10-2.5</sub> concentrations. The absolute concentrations for indoor NO<sub>2</sub> at schools EP-A, EP-B, and CJ-B differed considerably with the concentrations at CAMS 12, CAMS 41, and CAMS 37 as is evident from higher COD values that varied from 0.39 (EP-B and CAMS 12) to 0.70 (EP-A and



CAMS 41; CJ-B and CAMS 37). The COD values for CJ-A were, in contrast, a little lower than the other three schools (0.20, 0.21, 0.29 when paired with CAMS 12, 41, and 37, respectively) suggesting more homogeneity for NO<sub>2</sub> between this school and the three CAMS sites.

These relatively high COD values between the indoor and outdoor concentrations at the four schools and the corresponding CAMS sites substantiate the need for school-based monitoring. Indeed, the United States Environment Protection Agency recommends monitoring in close vicinity to schools instead of the central site monitoring methodology, which is in practice in most urban areas, for identifying the best environmental health indicator for sensitive populations like school-going children.

COD values were also computed for the hourly data available from the CAMS sites for the pollutants of interest in this study. These COD values are shown in Table 7-3. The analysis suggests that the spatial distribution for the PM species was spatially uniform between CAMS 12 and CAMS 49. However, CODs were slightly higher (~ 0.26) for PM<sub>10</sub> concentrations when CAMS 49 was paired with CAMS 12 and CAMS 37. The spatial distribution for NO<sub>2</sub> between CAMS 12, 37, and 41 spanned a wide range as is evident from the COD values between these sites (CAMS12 – 37: **0.28**; CAMS 12 – 41: **0.53**; CAMS 37 – 41: **0.55**).

**Table 7-3: COD values for hourly pollutant data between CAMS sites** (N = 3327-3559)

Pollutant	CAMS SITES	CAMS12	CAMS37	CAMS49
PM <sub>2.5</sub>	CAMS41	0.23		
PM <sub>10-2.5</sub>	CAMS41	0.22		
PM <sub>10</sub>	CAMS41	0.19		0.26
	CAMS49	0.27		
NO <sub>2</sub>	CAMS37	0.28		
	CAMS41	0.53	0.55	

### **7.3 Studies utilizing COD analyses to investigate spatial pollutant variations**

Overall, the CODs obtained in this study are comparable to the results reported in literature. Pinto et al (2004) reported  $PM_{2.5}$  COD values ranging from 0.06 to 0.24 for metropolitan areas in central and eastern United States and 0.07-0.48 for areas in western part of the country. These analyses were performed by using data from approximately 1000 sites spanning 27 Metropolitan Statistical Areas (MSA) across the United States. In addition, CODs ranging from 0.13 to 0.54 for  $PM_{10}$  were reported by Wilson (2006) in New Zealand for 10 background sites which were approximately nine km from a Central Monitoring Site. Wongphatarakul et al., (1998) reported  $PM_{2.5}$  COD values ranging from 0.099 to 0.225 in six southern California cities. The sites were influenced by varying sources of emissions – a feature that was observed in this study too with Ciudad Juarez sites being influenced by varying emission sources than the two El Paso schools. Spatial variation was also studied by Krudysz and colleagues for size fractionated PM mass, OC, EC, and trace elements in the Long Beach area of California (Krudysz et al., 2008). COD values suggested that PM mass and OC concentrations were spatially uniform across the four sampled sites. Kim et al. (2005) reported mean COD values of 0.22 for  $PM_{2.5}$  concentrations at St. Louis, Missouri. More recently, a unique study assessing the spatiotemporal variations in fine particulate matter components conducted in Israel, Jordan and the Palestinian towns and cities utilized COD statistics (Sarnat et al., 2010). COD values were higher between Nablus (Palestine) and the other six sampled sites. CODs were higher between Amman (Jordan) and the remaining sites, except when this city was paired with East Jerusalem ( $COD < 0.2$ ). The authors attributed the spatial variability to strong local source contributions.

#### 7.4 $\delta P_{90}$ Analysis

The 90<sup>th</sup> percentile of absolute pollutant concentration differences ( $\delta P_{90}$ ) between two paired sites is an additional measure that indicates the level of spatial uniformity. These values were calculated for, both, outdoor and indoor concentrations across the study sites, and are shown in Tables 7-4 and 7-5, respectively.  $\delta P_{90}$  values for EP-A and CJ-A site pairing (69.17 and 41.5  $\mu\text{g}/\text{m}^3$  for  $\text{PM}_{10-2.5}$  and  $\text{PM}_{2.5}$ , respectively) quantified the high degree of spatial variability in overall PM levels across the schools. Within El Paso,  $\delta P_{90}$  values between EP-A and EP-B for  $\text{PM}_{10-2.5}$  and  $\text{PM}_{2.5}$  were 14.0 and 20.8  $\mu\text{g}/\text{m}^3$ , respectively. For the two Ciudad Juarez schools,  $\delta P_{90}$  values between CJ-A and CJ-B were 32.3 and 20.6  $\mu\text{g}/\text{m}^3$  for  $\text{PM}_{10-2.5}$  and  $\text{PM}_{2.5}$ , respectively. This suggests that within the two El Paso schools, there is less heterogeneity in  $\text{PM}_{10-2.5}$  pollutant concentrations versus the two Ciudad Juarez schools monitored in this study.

The absolute magnitude of relative differences between the various sites was investigated for BC and  $\text{NO}_2$  levels too. The BC and  $\text{NO}_2$   $\delta P_{90}$  values were 0.88  $\mu\text{g}/\text{m}^3$  and 12.64 ppb (between EP-A and EP-B) and 1.63  $\mu\text{g}/\text{m}^3$  and 19.69 ppb (between CJ-A and CJ-B), respectively. High  $\delta P_{90}$  values (3.53  $\mu\text{g}/\text{m}^3$  for BC and 34.14 ppb for  $\text{NO}_2$ ) for EP-A and CJ-B site pairing also indicated high spatial variability of these pollutants across the schools. In contrast to  $\delta P_{90}$  PM, the within city  $\delta P_{90}$  concentration differences for these pollutants corresponded to the traffic zones, with higher  $\delta P_{90}$  BC and  $\text{NO}_2$  recorded between the Ciudad Juarez schools (CJ-A and CJ-B) compared to the two El Paso schools (EP-A and EP-B).

**Table 7-4:  $\delta P_{90}$  values for the monitored pollutants (Outdoor)**

Microenvironment		Outdoor						
Pollutant	Site	EP-B	CJ-A	CJ-B	CAMS12	CAMS41	CAMS49	CAMS37
<b>PM<sub>2.5</sub></b>	<b>EP-A</b>	14.00	41.45	29.33	4.81	5.11		
	<b>EP-B</b>		34.76	17.97	11.24	11.87		
	<b>CJ-A</b>			20.64	42.36	42.33		
	<b>CJ-B</b>				29.57	30.43		
	<b>CAMS12</b>					3.56		
<b>PM<sub>10-2.5</sub></b>	<b>EP-A</b>	20.77	69.17	50.92	34.85	21.64		
	<b>EP-B</b>		51.05	27.60	29.58	20.10		
	<b>CJ-A</b>			32.33	65.22	61.81		
	<b>CJ-B</b>				50.41	45.95		
	<b>CAMS12</b>					11.58		
<b>PM<sub>10</sub></b>	<b>EP-A</b>	37.43	113.19	77.87	32.48	25.78	33.64	
	<b>EP-B</b>		80.05	44.30	20.33	16.20	13.74	
	<b>CJ-A</b>			44.86	104.61	106.42	97.79	
	<b>CJ-B</b>				73.03	73.22	67.58	
	<b>CAMS12</b>					12.64	18.76	
	<b>CAMS41</b>						17.98	
<b>BC</b>	<b>EP-A</b>	0.88	2.43	3.53				
	<b>EP-B</b>		1.64	2.83				
	<b>CJ-A</b>			1.63				
	<b>CJ-B</b>							
<b>NO<sub>2</sub></b>	<b>EP-A</b>	12.64	17.67	34.14	18.99	14.74		21.75
	<b>EP-B</b>		9.00	24.63	8.22	5.83		8.88
	<b>CJ-A</b>			19.69	4.47	10.85		5.87
	<b>CJ-B</b>				19.50	23.26		19.15
	<b>CAMS12</b>					6.75		4.59
	<b>CAMS41</b>							10.41

$\delta P_{90}$  values were also calculated between outdoor school concentrations and the ambient concentrations for the PM species and NO<sub>2</sub> from the TCEQ CAMS sites. The PM<sub>10</sub>  $\delta P_{90}$  values of 97.79 and 67.58  $\mu\text{g}/\text{m}^3$  between CAMS 49 and CJ-A, and between CAMS 49 and CJ-B, respectively, suggest spatial non-uniformity between the three sites. The  $\delta P_{90}$  values for PM<sub>2.5</sub> varied from 4.81  $\mu\text{g}/\text{m}^3$  (EP-A - CAMS 12) to 42.36  $\mu\text{g}/\text{m}^3$  (CJ-A - CAMS 12). There was a strong agreement in PM<sub>2.5</sub> concentrations measured at CAMS 12 and CAMS 41 as the  $\delta P_{90}$  value between these two paired sites was 3.56  $\mu\text{g}/\text{m}^3$ , in comparison to  $\delta P_{90}$  values of 11.58  $\mu\text{g}/\text{m}^3$  and 12.64  $\mu\text{g}/\text{m}^3$  recorded for PM<sub>10-2.5</sub> and PM<sub>10</sub>, respectively. The  $\delta P_{90}$  values for NO<sub>2</sub> range from a

low of 4.47 ppb (CAMS 12 and CJ-A) to a high of 23.26 (CAMS 41 and CJ-B). For CAMS 37 and CAMS 12, the NO<sub>2</sub>  $\delta P_{90}$  value is the lowest at 4.59 ppb which corroborates the fact that using an exposure variable for traffic surrogates, like NO<sub>2</sub>, from central ambient monitoring can lead to exposure misclassifications with possible repercussions for air epidemiologic studies.

**Table 7-5:  $\delta P_{90}$  values for the monitored pollutants (Indoor)**

Microenvironment		Indoor						
Pollutant	Site	EP-B	CJ-A	CJ-B	CAMS12	CAMS41	CAMS49	CAMS37
<b>PM<sub>2.5</sub></b>	<b>EP-A</b>	6.04	34.31	25.30	6.34	6.65		
	<b>EP-B</b>		30.85	24.26	5.30	4.97		
	<b>CJ-A</b>			21.74	36.23	34.97		
	<b>CJ-B</b>				22.75	23.54		
	<b>CAMS12</b>							
	<b>CAMS41</b>							
<b>PM<sub>10-2.5</sub></b>	<b>EP-A</b>	4.72	47.62	25.59	40.69	23.21		
	<b>EP-B</b>		45.56	28.18	41.96	23.13		
	<b>CJ-A</b>			37.62	31.29	32.90		
	<b>CJ-B</b>				21.94	17.53		
	<b>CAMS12</b>							
<b>PM<sub>10</sub></b>	<b>EP-A</b>	9.11	79.69	48.10	42.61	27.70	35.07	
	<b>EP-B</b>		73.42	50.31	24.79	22.37	34.91	
	<b>CJ-A</b>			64.29	66.49	60.87	50.38	
	<b>CJ-B</b>				36.19	30.58	29.97	
	<b>CAMS12</b>							
<b>BC</b>	<b>EP-A</b>	0.76	2.64	3.54				
	<b>EP-B</b>		2.04	2.79				
	<b>CJ-A</b>			1.53				
	<b>CJ-B</b>							
<b>NO<sub>2</sub></b>	<b>EP-A</b>	6.75	31.01	245.69	18.90	14.95		20.67
	<b>EP-B</b>		27.80	245.87	15.66	12.11		18.29
	<b>CJ-A</b>			203.75	18.54	19.72		17.01
	<b>CJ-B</b>				227.16	228.36		229.09
	<b>CAMS12</b>							
	<b>CAMS41</b>							

Additionally, the 90<sup>th</sup> percentile of the absolute pollutant concentration differences CODs were computed between the indoor pollutant concentrations at the four schools and the CAMS sites. In El Paso, the spatial non-uniformity between the CAMS sites and the indoor microenvironment at the two schools is accentuated especially for PM<sub>10-2.5</sub> and PM<sub>10</sub> being

greater than  $20 \mu\text{g}/\text{m}^3$ . The indoor  $\delta\text{P}_{90}$  values between the Ciudad Juárez schools and CAMS sites further concurs spatial heterogeneity especially when CJ-A is paired with CAMS 12 ( $66.49 \mu\text{g}/\text{m}^3$ ), CAMS 41 ( $60.87 \mu\text{g}/\text{m}^3$ ) and CAMS 49 ( $50.38 \mu\text{g}/\text{m}^3$ ) for  $\text{PM}_{10}$  concentrations. The absolute concentrations for indoor  $\text{NO}_2$  at schools EP-A, EP-B, and CJ-B differed considerably with the concentrations at CAMS 12, CAMS 41, and CAMS 37 as is evident from  $\delta\text{P}_{90}$  values that varied from 12.11 ppb (EP-B and CAMS 41) to approximately 228 ppb (when CJ-B is paired with CAMS 12, 41 and 37). The differences in contrast for CJ-A were a little lower than the other three schools (approximately 18 ppb when paired with CAMS 12, 41, and 37) suggesting more homogeneity for  $\text{NO}_2$  between the indoor microenvironment of this school and the three CAMS sites than the high exposure school CJ-B.

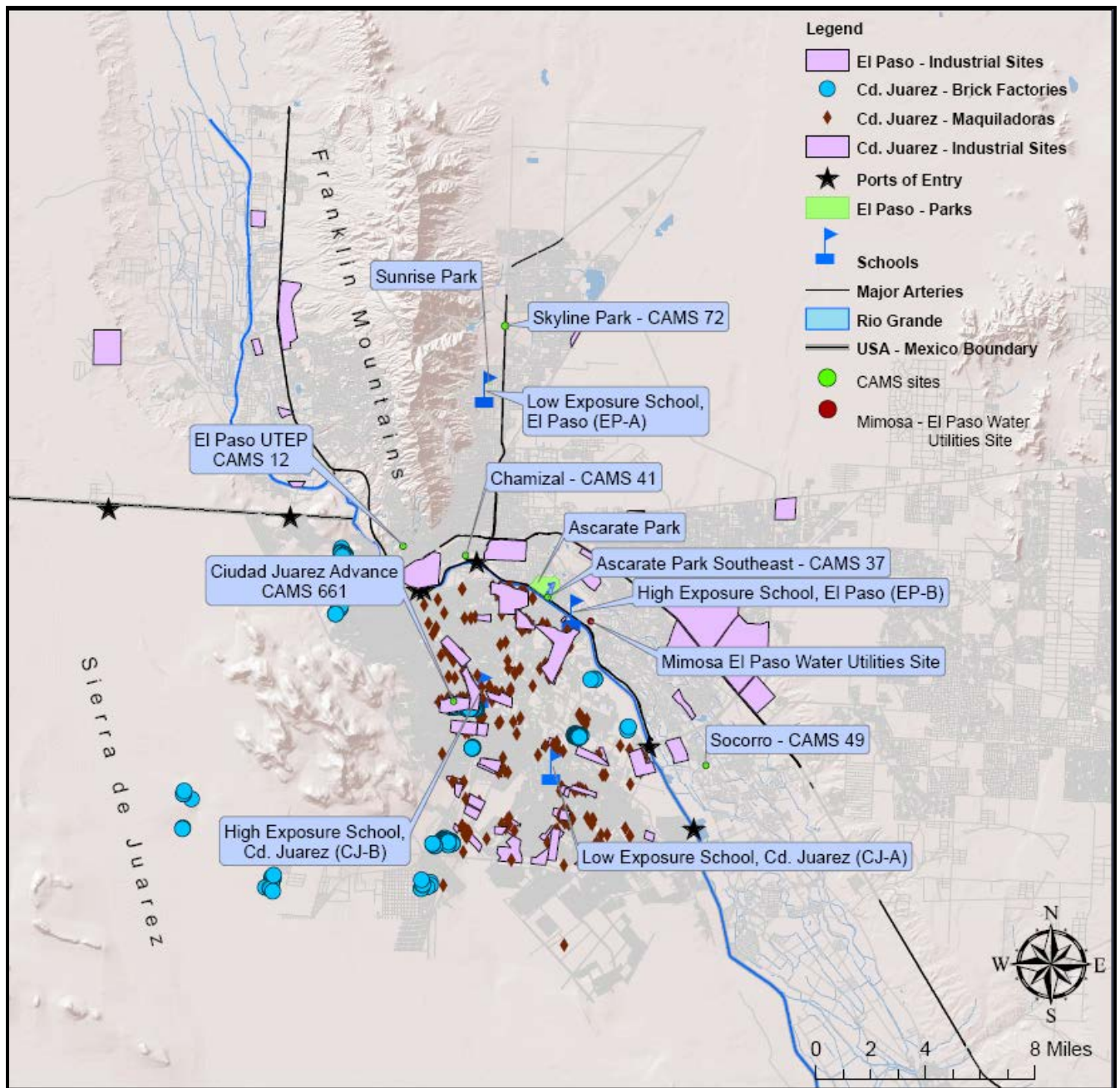
The  $\delta\text{P}_{90}$  analysis was also conducted for the hourly concentrations available from the TCEQ CAMS sites. This approach was undertaken to identify any changes in the concentration profiles of the pollutants at the hourly scale. The spread of concentrations between the selected site pairs was high for the pollutant metrics, except for  $\text{PM}_{2.5}$  ( $7.87 \mu\text{g}/\text{m}^3$  - CAMS 12 and 41 site pair). High  $\delta\text{P}_{90}$  values between CAMS 49 and CAMS 12 ( $43.22 \mu\text{g}/\text{m}^3$ ), and CAMS 49 and CAMS 41 ( $42.15 \mu\text{g}/\text{m}^3$ ) concurs the fact that spatial heterogeneity in  $\text{PM}_{10}$  concentrations exists at the intra-urban level in this border region. The  $\text{NO}_2$   $\delta\text{P}_{90}$  values were in the teens for the CAMS 12, 37 and 49 site pairs.

**Table 7-6: Hourly Delta  $\delta\text{P}_{90}$  VALUES between the CAMS sites (N = 3327-3559)**

Pollutant	CAMS SITES	CAMS12	CAMS37	CAMS49
$\text{PM}_{2.5}$	CAMS41	7.87		
$\text{PM}_{10-2.5}$	CAMS41	20.68		
$\text{PM}_{10}$	CAMS41	25.78		42.15
	CAMS49	43.22		
$\text{NO}_2$	CAMS37	15.7		
	CAMS41	12	16.2	

## **7.5 Comparison with other studies assessing heterogeneity in pollutant concentrations at the community levels**

In this study, spatial heterogeneity in both the size fractions of PM is evident across the two exposure zones in both the cities. In El Paso, the close proximity of school EP-B to an area source (border highway) led to elevated levels in contrast to the low concentrations observed at EP-A. The close vicinity of CJ-B to two major roadways and the biggest bus terminal and peripheral unpaved roads around CJ-A may have led to elevated levels of PM in Ciudad Juarez. However, the Ciudad Juarez PM results from this study negate the contrast between the low and high exposure zones thereby having repercussions for children's exposure to these pollutants. The within- and between- city concentration gradients mirror the influence of local sources of emissions on these pollutants (Gotschi 2005). Sector level emissions data (SNIFF: Sistema Nacional de Informacion de Fuentes Fijas) from Ciudad Juárez attribute the majority of PM pollution to unpaved roads, transportation, and brick kilns (Blackman, 2004). Brick kilns lack smoke stacks; therefore, PM emissions are not dispersed by wind, and high concentrations are observed in the vicinity of the brick kilns (Blackman, 2006). SNIFF data imputes approximately 72 percent of NO<sub>x</sub> emissions to vehicular emissions. Figure 7-1 is a GIS map featuring various point and area sources of pollutants in the Paso del Norte region. This observation is reflected in our outdoor school NO<sub>2</sub> concentrations, too, with the high exposure schools in both the cities recording higher values than their corresponding low exposure schools.



**Figure 7-1: Map featuring various point and area sources of pollutants in the Paso del Norte region**

Lebret et al., (2000); Cyrus et al., (2004) documented intra-urban spatial variation in nitrogen dioxide concentrations. Similarly, Roorda-Knappe et al. (1998) reported higher concentration gradients for  $\text{NO}_2$  and black carbon near motorways and a negative correlation with increasing distance from the roadways. These results are in line with other studies reporting



decreasing levels of NO<sub>2</sub> from roadways seeing high traffic (Gilbert et al 2003; Beckerman et al 2008). Kim et al., 2004 reported differences of approximately 23% for NO<sub>2</sub> concentrations between schools near roadways versus schools with no traffic sources.

Hoek et al. (2002); Roemer et.al, (2001) reported that PM concentration gradients are higher near roadways than background sites, and this variation is more pronounced for black carbon concentrations. For our study, BC accounted for approximately 12% of the measured PM<sub>2.5</sub> mass, which is lower than 15-19% measured by Cyrus et al., (2003). Several other studies have documented that black carbon concentrations are influenced more by traffic emissions compared to PM mass concentrations (Cyrus 2003, Fischer 2000, Kinney 2000, Janssen 2001, Oglesby 2000, Noullett 2006). PM<sub>2.5</sub> values ranging from 37 to 47 µg/m<sup>3</sup> have been reported by Kinney and colleagues for their study conducted at three traffic sites and one background sites in Harlem, New York City (Kinney et al., 2000). For the same study, the elemental carbon concentration ranged from 1.5 to 6.2 µg/m<sup>3</sup>.

The between-cities differences in pollutant gradients in our study are more pronounced than the within-city differences suggesting the influence of major anthropogenic sources of pollution in Ciudad Juarez. The inter-site and inter-pollutant correlation analyses from Chapter 6 should be used in combination with Coefficient of Divergence and analyses to better understand spatiotemporal characteristics of traffic pollutants in the Paso del Norte region. High correlations for pollutants between the various sampled sites was not suggestive of relative homogeneity; therefore, relative measures like Coefficient of Divergence and the 90<sup>th</sup> percentile of absolute concentration differences can help elucidate the patterns of spatial variation in this region as was accomplished in this research

## 8.0 Associations between Measured Pollutants and eNO Measurements

This chapter describes the epidemiological associations between pollutants and eNO measurements. Pollutant concentrations from indoor and outdoor microenvironment, and from the TCEQ CAMS sites were averaged over a period of 96-hr to aid in comparisons with NO<sub>2</sub>, which was monitored over a 96-hr period. Effect estimates, confidence intervals, p-values and interquartile ranges were computed for these analyses. Point plots of the pollutant-specific estimate as well as their respective confidence intervals were plotted. In the tables and figures, IN denoted measurements inside the school microenvironment and OUT denotes the measurements in the outdoor microenvironment. CAMS sites in close proximity to these respective schools were matched for the ambient concentrations analysis. The effects estimates, upper confidence limits (UCL), and the lower confidence limits (LCL) obtained from individual pollutant models were each divided by the mean eNO for the respective school, multiplied by 100, and finally this value was further multiplied by the Interquartile range (IQR) of the pollutant to obtain the % change in eNO per IQR increase in pollutant. The overall effect estimates or UCL and LCL are calculated as formula is as follows:

Effect Estimates = (effect estimates/ mean eNO)\*100\*IQR, or

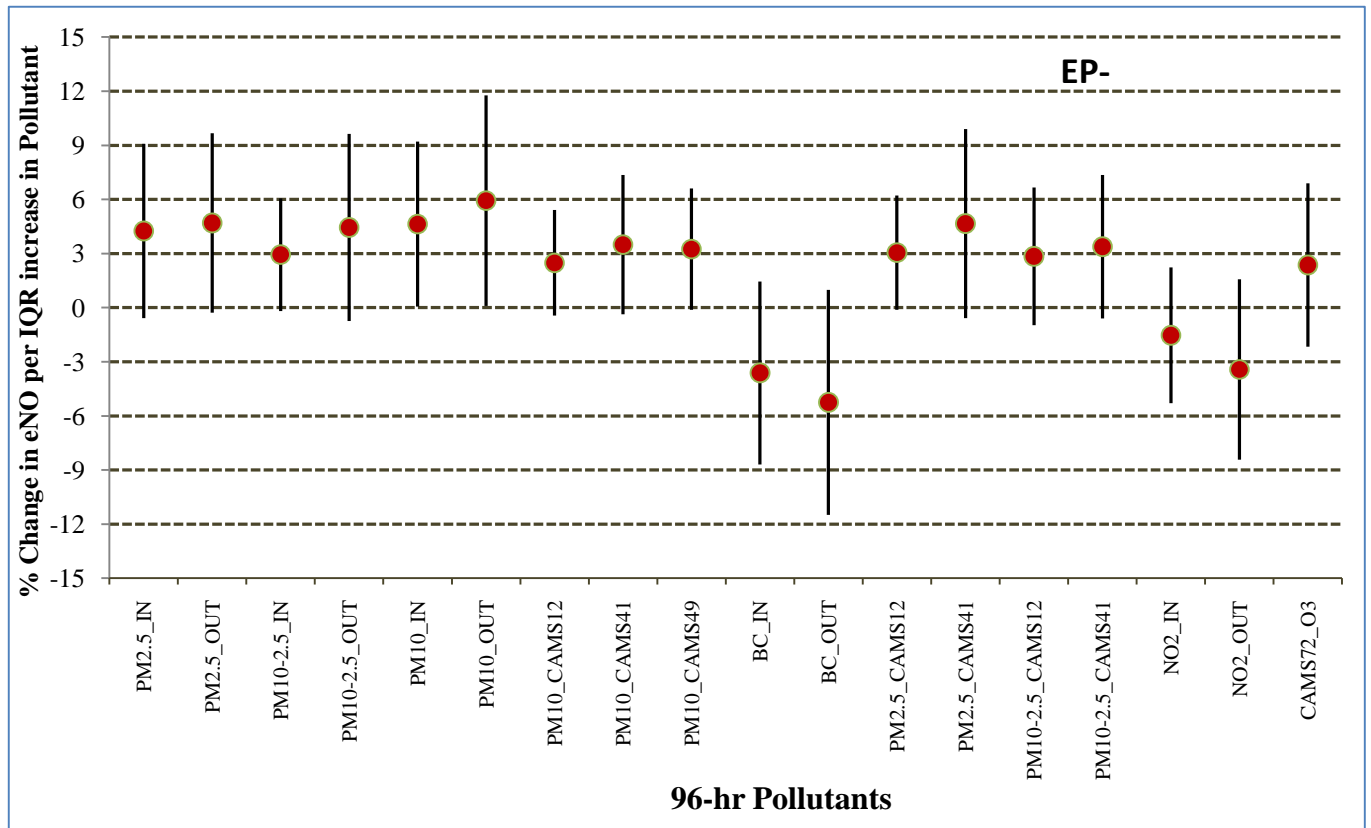
UCL, or LCL = (UCL, or LCL/mean eNO)\*100\*IQR.

Figures 8-1 through 8-4 are the plots depicting percent change in eNO and 95% for IQR increases in 96- hour averaged pollutant concentrations at the four schools. Separate models were run for each pollutant from the different microenvironments. Significant was assessed at  $\alpha = 0.05$ . At school EP-A, statistically significant associations were found for both indoor and outdoor PM<sub>10</sub>. Table 8-1 presents the effect estimates, confidence intervals, p-values and interquartile ranges. Figure 8-1 shows the percent changes in eNO and 95% CIs for IQR

increases in weekly average of various pollutants from the indoor and outdoor microenvironment of school EP-A and CAMS sites.

**Table 8-1: Effect estimates and 95% CIs per IQR increase from 96-hr models for the association of eNO with the measured pollutants at school EP-A**

Microenvironment	Effect Estimates	UCL	LCL	p-value	IQR
PM2.5_IN	4.25	9.09	-0.58	0.084	3.39
PM2.5_OUT	4.70	9.67	-0.27	0.064	5.13
PM10-2.5_IN	2.94	6.06	-0.18	0.065	2.95
PM10-2.5_OUT	4.45	9.64	-0.74	0.093	5.87
PM10_IN	4.63	9.21	0.05	0.047	6.84
PM10_OUT	5.94	11.77	0.10	0.046	10.32
PM10_CAMS12	2.48	5.41	-0.45	0.096	13.34
PM10_CAMS41	3.50	7.36	-0.36	0.075	16.81
PM10_CAMS49	3.24	6.60	-0.11	0.058	18.02
BC_IN	-3.62	1.46	-8.69	0.161	0.18
BC_OUT	-5.25	0.99	-11.49	0.098	0.21
PM2.5_CAMS12	3.05	6.21	-0.11	0.058	3.41
PM2.5_CAMS41	4.66	9.91	-0.58	0.081	6.34
PM10-2.5_CAMS12	2.85	6.66	-0.97	0.143	14.36
PM10-2.5_CAMS41	3.38	7.35	-0.59	0.095	13.38
NO2_IN	-1.53	2.23	-5.30	0.422	2.46
NO2_OUT	-3.43	1.58	-8.43	0.179	4.71
CAMS72_O3	2.37	6.89	-2.16	0.304	12.35

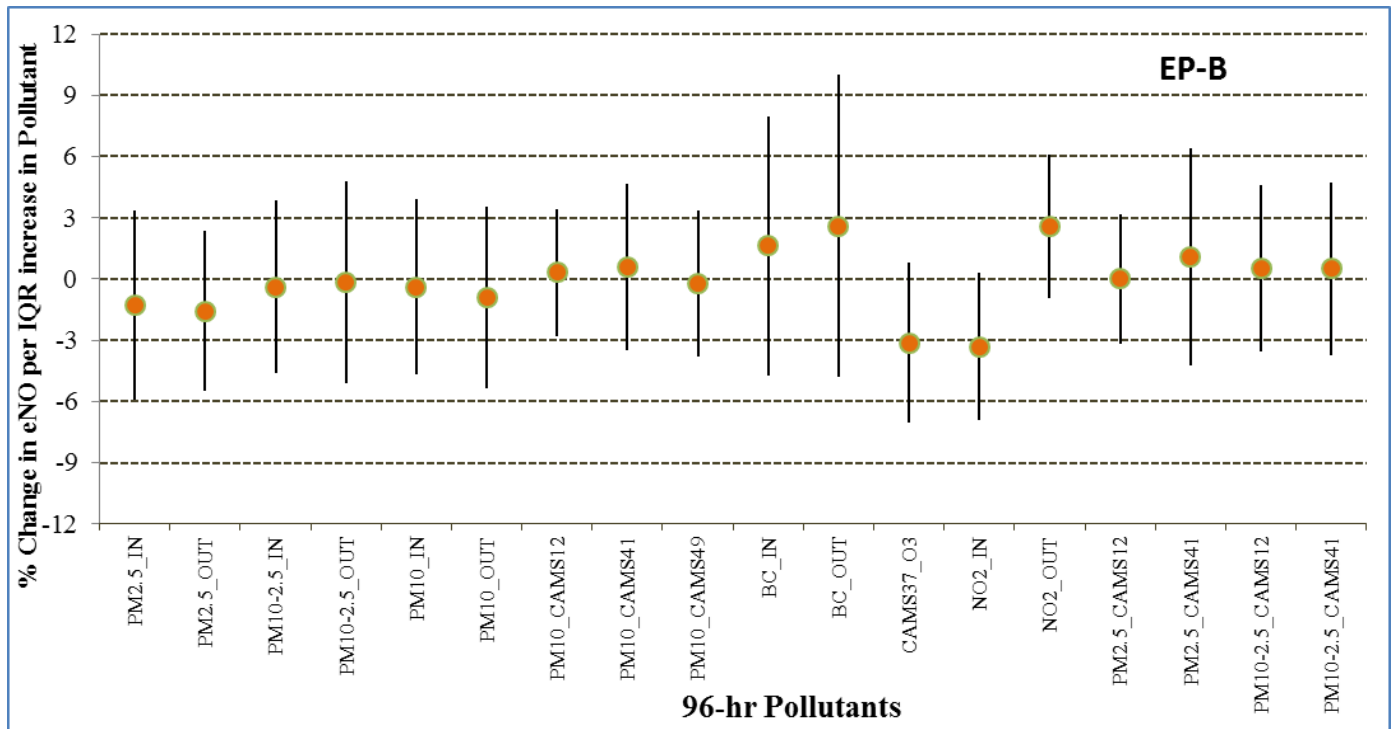


**Figure 8-1: Percent change in eNO and 95% CIs for IQR increases in 96-hr averaged pollutant concentrations at school EP-A**

At EP-B, positive but statistically weak associations were found only for BC at both the indoor and outdoor microenvironment. Associations were strongest and statistically significant for PM<sub>2.5</sub> and PM<sub>10</sub> at school CJ-A. These associations were observed for both the indoor and outdoor microenvironment at this school. Effect estimates were higher for PM<sub>10-2.5</sub> but statistically weak. It may be possible that the measured PM pollutant may a better primer of the true causal agents (i.e., specific sources or chemical components of PM). Associations were robust between the eNO health endpoint and indoor and outdoor microenvironment. These associations were statistically significant too. In addition, PM<sub>2.5</sub> at CAMS 12 and CAMS 41 was significant with eNO at this school. Individual pollutant models at school CJ-B showed strong and statistically significant associations for outdoor NO<sub>2</sub> and eNO.

**Table 8-2: Effect estimates and 95% CIs per IQR increase from 96-hr models for the association of eNO with the measured pollutants at school EP-B**

Microenvironment	Effect Estimates	UCL	LCL	p-value	IQR
PM2.5_IN	-1.28	3.36	-5.93	0.586	6.51
PM2.5_OUT	-1.56	2.33	-5.46	0.430	5.89
PM10-2.5_IN	-0.39	3.84	-4.62	0.855	5.47
PM10-2.5_OUT	-0.17	4.78	-5.12	0.945	6.07
PM10_IN	-0.38	3.93	-4.70	0.861	5.56
PM10_OUT	-0.92	3.53	-5.38	0.683	6.06
PM10_CAMS12	0.33	3.44	-2.78	0.835	3.61
PM10_CAMS41	0.59	4.66	-3.47	0.774	4.25
PM10_CAMS49	-0.21	3.36	-3.79	0.906	4.70
BC_IN	1.61	7.95	-4.72	0.616	5.34
BC_OUT	2.60	9.98	-4.78	0.487	5.26
CAMS37_O3	-3.13	0.78	-7.04	0.116	7.15
NO2_IN	-3.33	0.28	-6.94	0.071	7.01
NO2_OUT	2.56	6.07	-0.95	0.152	1.10
PM2.5_CAMS12	0.00	3.17	-3.17	0.999	4.17
PM2.5_CAMS41	1.05	6.37	-4.27	0.697	4.96
PM10-2.5_CAMS12	0.53	4.62	-3.56	0.798	4.36
PM10-2.5_CAMS41	0.49	4.74	-3.75	0.82	4.57



**Figure 8-2: Percent change in eNO and 95% CIs for IQR increases in 96-hr averaged pollutant concentrations at school EP-B**

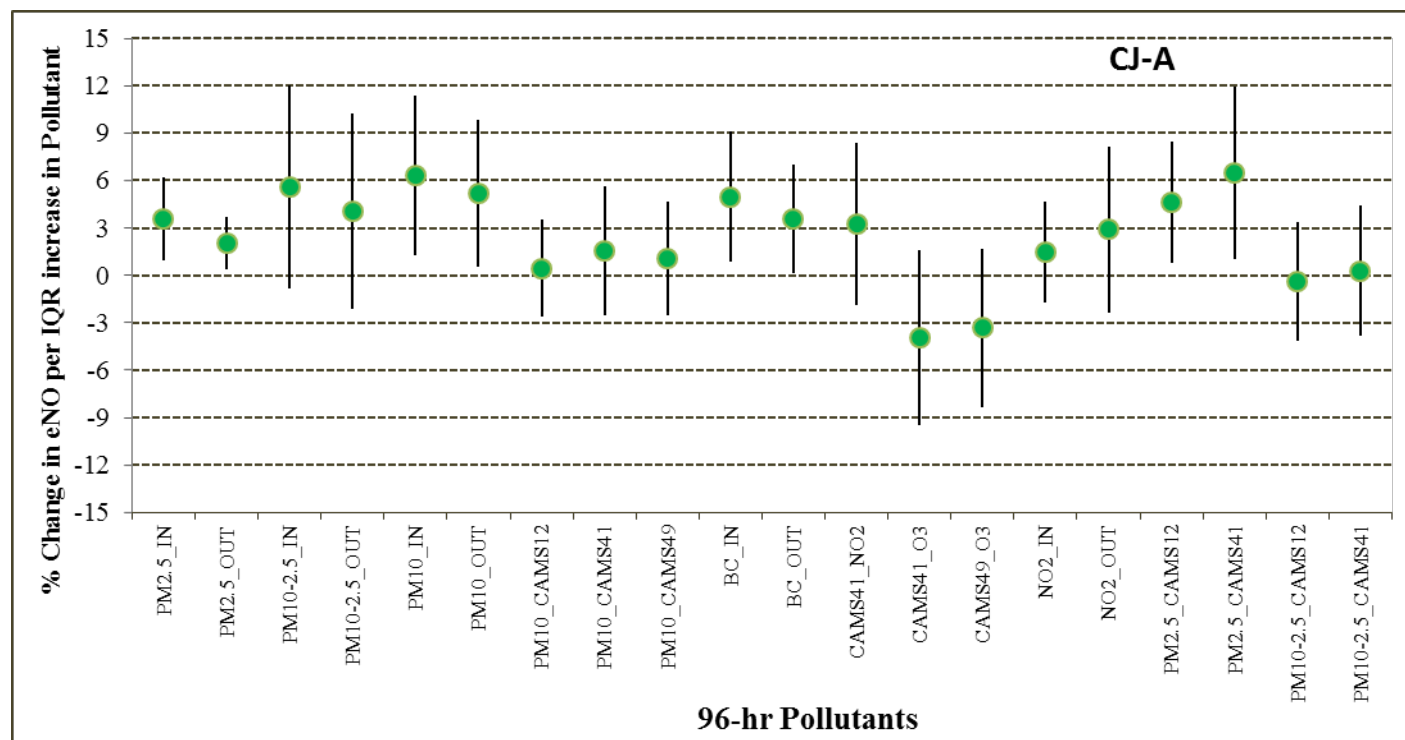
**Table 8-3: Effect estimates and 95% CIs per IQR increase from 96-hr models for the association of eNO with the measured pollutants at school CJ-A**

Microenvironment	Effect Estimates	UCL	LCL	p-value	IQR
PM2.5_IN	3.57	6.20	0.94	0.008	13.17
PM2.5_OUT	2.03	3.72	0.35	0.018	8.99
PM10-2.5_IN	5.60	12.03	-0.82	0.087	22.96
PM10-2.5_OUT	4.06	10.22	-2.10	0.195	28.68
PM10_IN	6.32	11.36	1.27	0.015	38.11
PM10_OUT	5.21	9.85	0.57	0.028	43.29
PM10_CAMS12	0.45	3.51	-2.62	0.774	13.34
PM10_CAMS41	1.55	5.62	-2.53	0.455	16.81
PM10_CAMS49	1.08	4.67	-2.52	0.555	18.02
BC_IN	4.98	9.11	0.85	0.019	1.26
BC_OUT	3.59	7.03	0.16	0.040	0.91
CAMS41_NO2	3.28	8.40	-1.84	0.208	10.66
CAMS41_O3	-3.98	1.56	-9.51	0.158	14.12
CAMS49_O3	-3.33	1.65	-8.31	0.189	10.67
NO2_IN	1.48	4.65	-1.70	0.361	12.72
NO2_OUT	2.90	8.13	-2.33	0.275	16.70
PM2.5_CAMS12	4.62	8.48	0.76	0.019	3.41
PM2.5_CAMS41	6.47	11.92	1.02	0.020	6.34
PM10-2.5_CAMS12	-0.39	3.40	-4.18	0.839	14.36
PM10-2.5_CAMS41	0.29	4.42	-3.85	0.891	13.38

The results obtained from this study are comparable to those found in other studies that had asthmatic children as study participants (Barraza-Villarreal et al., 2008; Delfino et al., 2006; Liu et al., 2009). The magnitudes of effects observed were lower than those reported for an asthmatic children's cohort in Seattle (Koenig et al., 2005). The researchers in this study reported 25-30% change in eNO for  $10 \mu\text{g}/\text{m}^3$  and attributed this to their subpopulation being at a higher risk for airway inflammation.

The associations obtained from these results may come with some caveats. The exposure metrics utilized in this study were indirect and were assumed to be actually related to both traffic emissions as well as corresponding personal exposures to these pollutants. Even though school CJ-A was the designated low exposure school, the associations between various PM metrics and eNO were found to be the strongest and significant for this school. It is possible that factors like baseline differences in socio-demographic factors, asthma control and access to health care may

be the factors contributing to these results. Indeed, researchers have documented the association between differential traffic-emissions exposures with respect to socioeconomic status of subjects (Gunier et al., 2003; Bell et al., 2005).

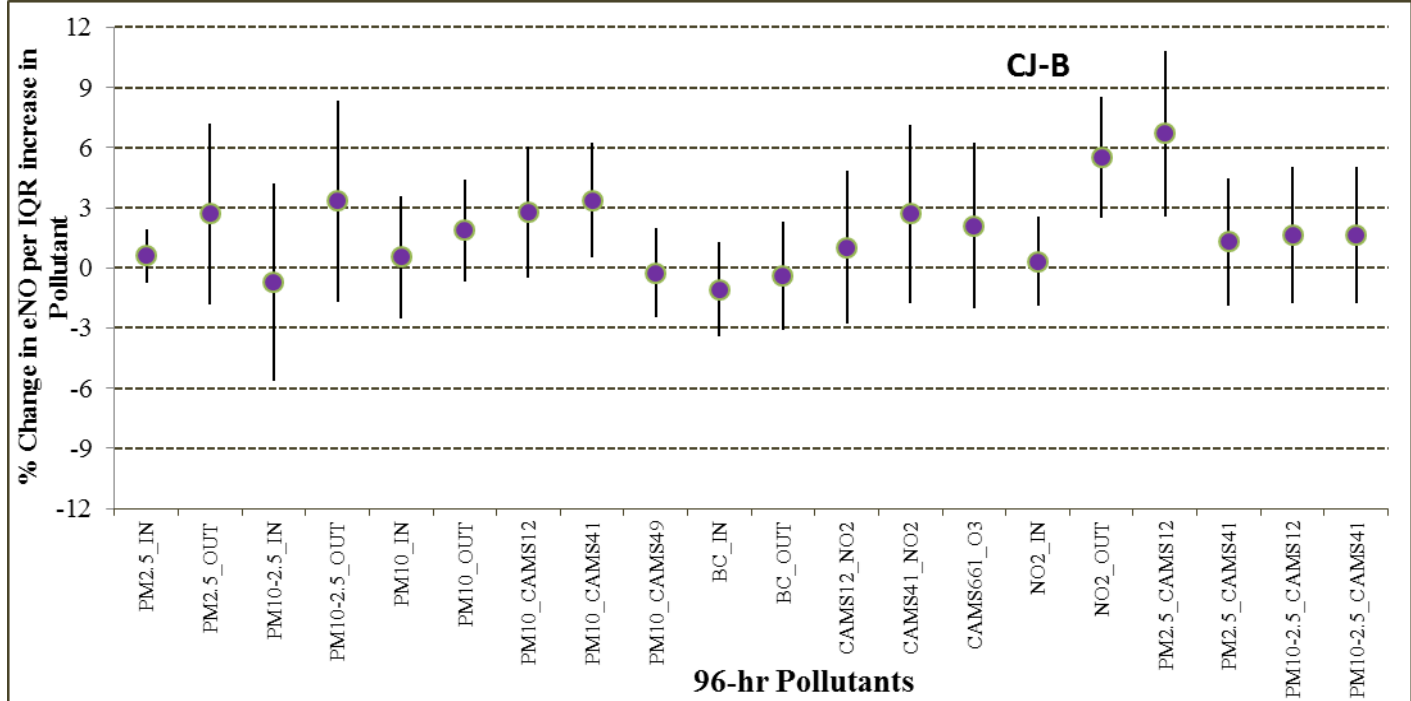


**Figure 8-3: Percent change in eNO and 95% CIs for IQR increases in 96-hr averaged pollutant concentrations at school CJ-A**

The associations between the various pollutant metrics and eNO were based on the results from a panel-based study. Panel-based studies have far fewer observations than population-based studies which may impact the robustness of the results. It is plausible that an extreme observation from a single subject may be exerting undue influence on overall model results. Therefore the results obtained should be viewed with caution. More detailed and further analyses for the associations between the pollutant measurements and eNO measurements are presented elsewhere (Sarnat et al., 2011, under review).

**Table 8-4: Effect estimates and 95% CIs per IQR increase from 96-hr models for the association of eNO with the measured pollutants at school CJ-B**

Microenvironment	Effect Estimates	UCL	LCL	p-value	IQR
PM2.5_IN	0.59	1.94	-0.76	0.388	9.87
PM2.5_OUT	2.69	7.18	-1.80	0.238	10.23
PM10-2.5_IN	-0.71	4.22	-5.63	0.777	27.88
PM10-2.5_OUT	3.34	8.36	-1.69	0.192	24.97
PM10_IN	0.54	3.60	-2.52	0.726	38.01
PM10_OUT	1.86	4.43	-0.70	0.154	13.34
PM10_CAMS12	2.79	6.08	-0.51	0.097	16.81
PM10_CAMS41	3.36	6.22	0.50	0.022	18.02
PM10_CAMS49	-0.25	1.98	-2.48	0.828	0.83
BC_IN	-1.07	1.26	-3.40	0.366	0.64
BC_OUT	-0.40	2.28	-3.08	0.768	6.03
CAMS12_NO2	1.01	4.82	-2.80	0.601	11.96
CAMS41_NO2	2.70	7.14	-1.75	0.233	14.12
CAMS661_O3	2.09	6.23	-2.05	0.320	1.27
NO2_IN	0.33	2.56	-1.89	0.769	5.09
NO2_OUT	5.50	8.53	2.48	0.000	3.41
PM2.5_CAMS12	6.70	10.85	2.56	0.002	6.34
PM2.5_CAMS41	1.29	4.47	-1.89	0.426	14.36
PM10-2.5_CAMS12	1.65	5.05	-1.76	0.342	13.38
PM10-2.5_CAMS41	1.65	5.05	-1.76	0.342	13.38



**Figure 8-4: Percent change in eNO and 95% CIs for IQR increases in 96-hr averaged pollutant concentrations at school CJ-B**



## **9.0 Comparison with the 2010 Study**

This dissertation comprises air quality data that was obtained from two monitoring campaigns in Spring 2008 and Spring 2010. The Spring 2010 air monitoring campaign, funded by the Mickey Leland National Urban Air Toxics Research Center, was undertaken at four schools in El Paso (Li et al., 2011). Three schools for the 2010 campaign were in the Lower Valley region of El Paso and were designated as schools in high exposure zone. School EP-B was one of these three schools. School EP-A in the Northeastern part of the city was the low exposure school in the 2010 monitoring campaign too. Air quality and subsequent respiratory health measurements for an asthmatic cohort were obtained from school EP-B. The same set of measurements were also obtained from school EP-A. Two additional schools, which were in close proximity - ~ two miles from EP-B, were chosen for concurrent air monitoring only. This was deemed necessary to identify any fugitive or idiosyncratic sources of air pollution impacting this neighborhood. Health related data was not obtained from these two other schools in the Lower Valley. The Spring 2010 monitoring campaign started on March 1, 2010 and ended on June 04, 2010. Measurements were not performed during spring break because the classes were not in session. The air quality data from schools EP-A and EP-B from both the studies are compared and discussed below. The data from the other two schools from the 2010 study are not presented here.

### **Comparison with the 2010 study**

This section summarizes and compares the results of the two studies. The pollutants monitored in the 2010 study were 48-hr integrated  $PM_{2.5}$ ,  $PM_{10-2.5}$  and 96-hr  $NO_2$ . Instruments used for the 2010 study were identical to that used in the 2008 study. The outdoor location for the pollutant measurements was exactly the same for both the studies – rooftops of the school

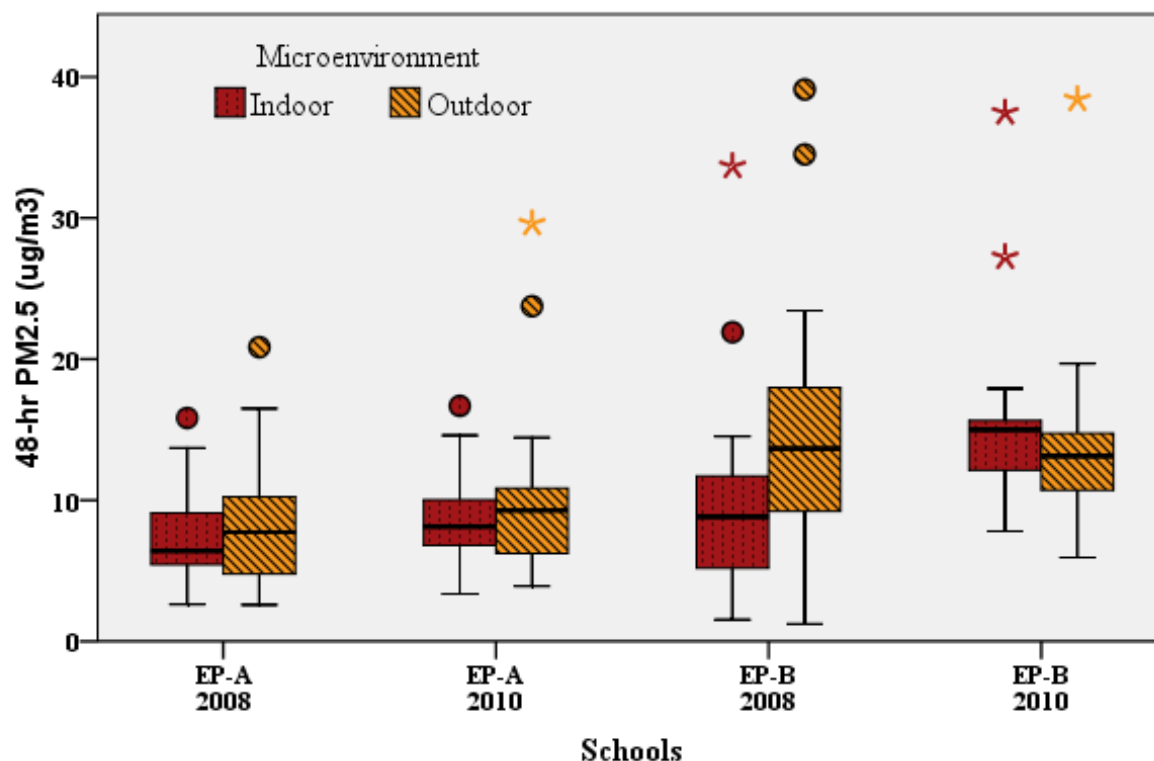
buildings. The indoor sampling at school EP-A was the same – the computer room. However, at school EP-B, the library was selected for the indoor monitoring. The library was constantly visited by the children and many reading sessions were conducted in this microenvironment. The indoor air monitoring station was set up on top of one of the book shelves approximately 5 ft above the ground. The outdoor sampling location in the 2010 study was similar to the previous study (rooftops).

### 9.1 48-hr PM<sub>2.5</sub>

The summary statistics for the 48-hr indoor and outdoor PM<sub>2.5</sub> concentrations at the two schools are presented in Table 9-1. The results are compared to the 2008 study graphically in Figure 9-1.

**Table 9-1: Summary statistics for PM<sub>2.5</sub> (µg/m<sup>3</sup>) – 2010 study**

Microenvironment		Indoor		Outdoor	
Locations		EP A	EP – B	EP -A	EP - B
Valid N		21	23	23	26
Mean		8.4	15	9.8	14
Median		8.1	15	9.3	13
Std. Deviation		3.1	6.0	6.0	6.1
Minimum		3.4	7.8	3.9	6.0
Maximum		17	37	30	38
Quartiles	.25	6.8	12	6.2	11
	.75	10	16	11	15



**Figure 9-1: Comparison of 48-hr PM<sub>2.5</sub> data at the two schools between 2008 and 2010**

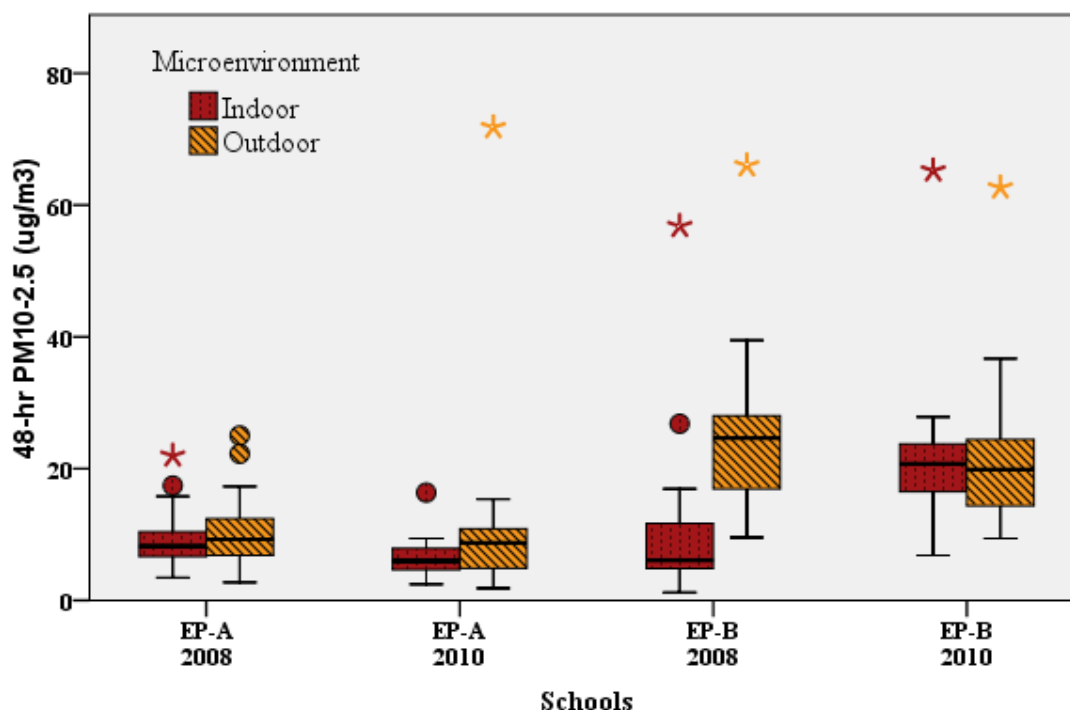
The mean indoor PM<sub>2.5</sub> concentrations at EP-A were 7.47 and 8.12  $\mu\text{g}/\text{m}^3$  for 2008 and 2010, respectively, signifying similar microenvironment conditions between the two studies. However, the values at EP-B differ considerably between the two studies - 9.56 (2008) and 14.99  $\mu\text{g}/\text{m}^3$  (2010). As mentioned, the room monitored in 2008 experienced less human traffic (only teachers) and was kept closed at all times. The effectiveness of the evaporative cooler on PM reduction became pronounced in a room where indoor emissions were kept at minimum in 2008 at EP-B. However, the mean concentrations were higher in the second study due to constant resuspension of particles initiated by student activities all day long. The outdoor PM<sub>2.5</sub> concentrations at the two schools for both study periods were consistent with each other, 8.26 vs 9.85  $\mu\text{g}/\text{m}^3$  at EP-A and 13.58 vs 14.52  $\mu\text{g}/\text{m}^3$  at EP-B.

## 9.2 48-hr PM<sub>10-2.5</sub>

The summary statistics for PM<sub>10-2.5</sub> for both the microenvironments at EP-A and EP-B for the 2008 study are shown in Table 9-2. Figure 9-2 compares the summary statistics of the two studies in box plots. For indoor concentrations, the mean concentrations at EP-A for the 2008 and 2010 studies were 8.89 and 6.40  $\mu\text{g}/\text{m}^3$  respectively. The comparisons between the two studies for the indoor microenvironment at EP-B showcase interesting results. The mean indoor concentration of 21.22  $\mu\text{g}/\text{m}^3$  in 2010 study is more than twice the mean of 9.89  $\mu\text{g}/\text{m}^3$  observed in 2008. The change in the indoor location at this school can explain this difference. The outdoor mean concentrations of 10.85  $\mu\text{g}/\text{m}^3$  and 21.23  $\mu\text{g}/\text{m}^3$  observed in the 2010 study for the low and high exposure schools are almost the same as were observed in the 2008 study- 9.93 at EP-A and 24.52 at EP-B. The coarse fraction of PM is influenced by geologic sources; therefore, the near similar concentrations observed temporally between the two studies are expected.

**Table 9-2: Summary statistics for PM<sub>10-2.5</sub> ( $\mu\text{g}/\text{m}^3$ ) - 2010 study**

Microenvironment		Indoor		Outdoor	
Locations		EP -A	EP - B	EP -A	EP - B
Valid N		21	23	23	26
Mean		6.4	21	11	21
Median		6.0	21	8.7	20
Std. Deviation		3.0	11	14	11
Minimum		2.5	6.9	1.8	9.4
Maximum		16	65	72	63
Quartiles	.25	4.7	17	4.9	14
	.75	7.9	24	11	24



**Figure 9-2: Box plot for the 2008 and 2010 48-hr PM<sub>10-2.5</sub> at EP-A and EP-B**

A visual inspection of the box plot suggests spatial heterogeneity across the two schools for both the study periods. A maximum concentration of  $66.01 \mu\text{g}/\text{m}^3$  was observed at school EP-B during a sandstorm that occurred on April 09, 2008. In 2010, an episodic high of  $62.66 \mu\text{g}/\text{m}^3$  was observed during a dust storm on April 29 at the same school.

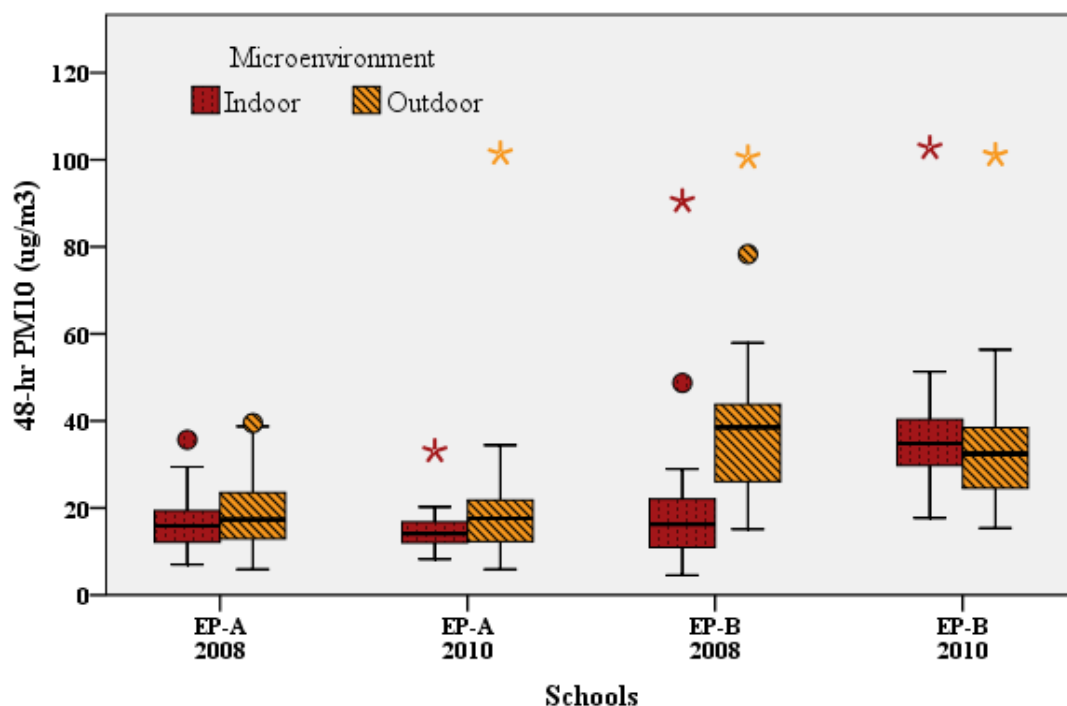
### 9.3 48-hr PM<sub>10</sub>

Table 9-3 shows the summary statistics for the 2010 48-hr PM<sub>10</sub> data. Figure 9-3 shows the comparison between the two studies. The median concentrations for indoor PM<sub>10</sub> at EP-A for 2008 and 2010 study period were  $15.87$  and  $14.12 \mu\text{g}/\text{m}^3$ , respectively. At EP-B, the median indoor concentrations were  $16.27$  (2008) and  $34.80$  (2010)  $\mu\text{g}/\text{m}^3$ . The median outdoor concentrations at school EP-A were almost the same –  $17.34$  in 2008 and  $17.61 \mu\text{g}/\text{m}^3$  in 2010. The mean outdoor concentration at EP-B was twice the concentrations recorded at EP-A in 2008

and 2010, thereby confirming spatial non-uniformity between these two schools with possible repercussions for personal exposures of asthmatic children in these two schools.

**Table 9-3: Summary statistics for PM<sub>10</sub> (µg/m<sup>3</sup>) – 2010 study**

Microenvironment		Indoor		Outdoor	
Locations		EP -A	EP - B	EP -A	EP - B
Valid N		21	23	23	26
Mean		15	37	21	35
Median		14	35	18	32
Std. Deviation		5.3	17	19	17
Minimum		8.3	18	5.9	15
Maximum		33	100	100	100
Quartiles	.25	12	30	12	26
	.75	17	40	22	38



**Figure 9-3: Box plot for the 2008 and 2010 48-hr PM<sub>10</sub> at EP-A and EP-B**

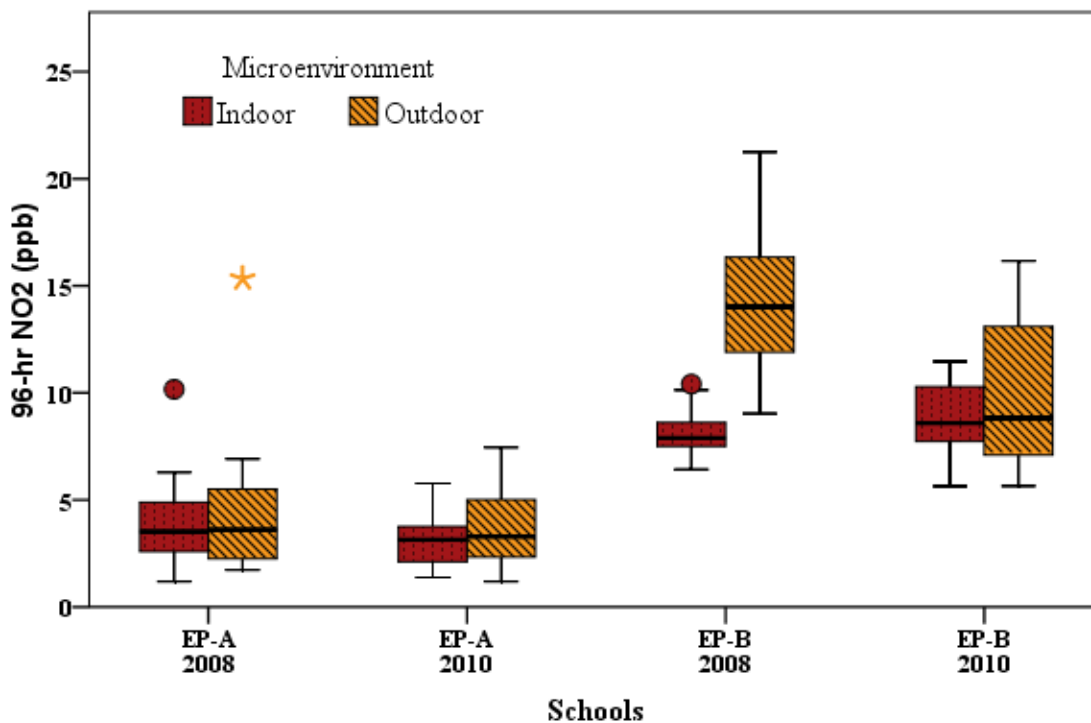
#### 9.4 96-hr NO<sub>2</sub>

The summary statistics for 96-hr integrated NO<sub>2</sub> are shown in Table 9-4 for the 2010 study. Figure 9-4 shows the box plots for indoor and outdoor concentrations at the two schools.

As expected, low concentrations were observed at the low exposure school. As mentioned before, the high exposure school was adjoining the US Border Highway and resulted in high outdoor concentrations of NO<sub>2</sub> at this school.

**Table 9-4: Summary statistics for NO<sub>2</sub> (ppb)-2010 study**

Microenvironment		Indoor		Outdoor	
Locations		EP -A	EP - B	EP -A	EP - B
Valid N		13	13	14	14
Mean		3.29	8.84	3.58	9.61
Median		3.14	8.59	3.29	8.82
Std. Deviation		1.38	1.77	1.74	3.29
Minimum		1.38	5.64	1.19	5.65
Maximum		5.77	11.46	7.45	16.16
Quartiles	.25	2.11	7.73	2.37	7.18
	.75	3.76	10.29	4.74	12.13



**Figure 9-4: Box plot for the 2008 and 2010 96-hr NO<sub>2</sub> at EP-A and EP-B**

The indoor mean concentrations at both the schools are very similar between the two study periods. For the 2008 study period, the indoor concentrations at EP- A and EP-B were

3.96(2.20) and 8.14(1.10) ppb, respectively. During the second monitoring campaign, the concentrations in the same microenvironment at EP-A and EP-B were 3.29(1.38) and 8.84(1.77) ppb, respectively. This suggests the absence of any indoor sources and the influence of indoor concentrations by outdoor concentrations. In addition, the spatial non-uniformity observed between the two schools during the two study periods confirms the zoning selection procedure between the high and the low traffic density schools.

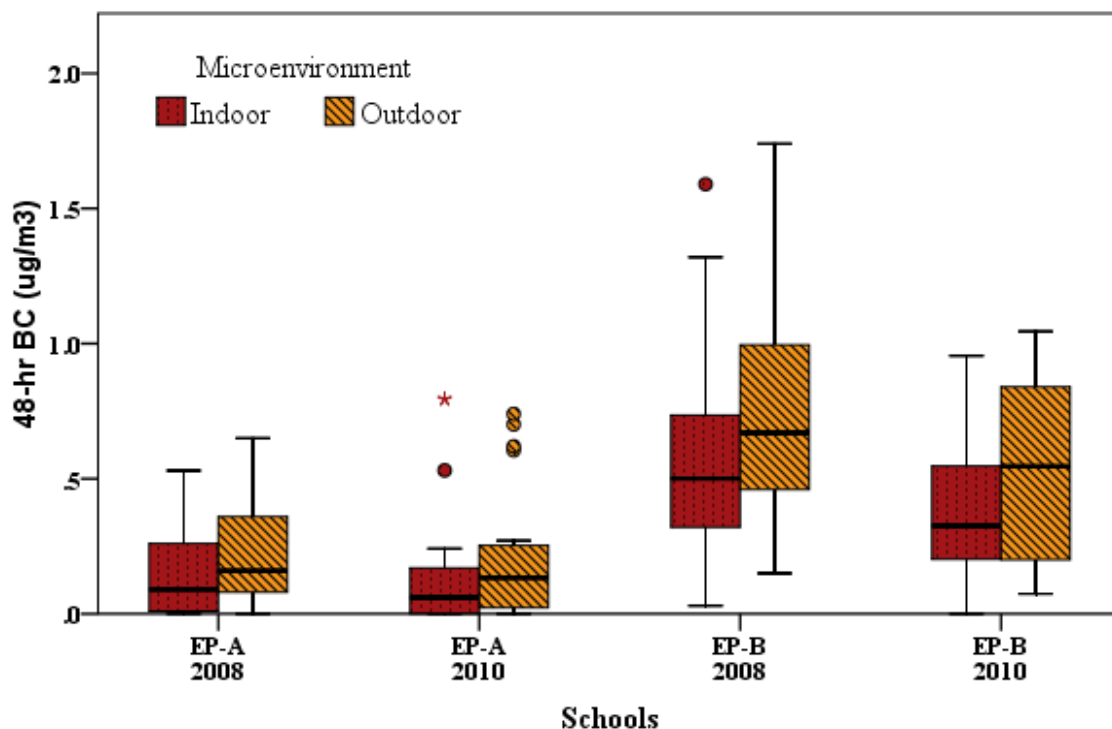
### 9.5 48-hr Black Carbon

Summary statistics for BC are shown in Table 9-5 and Figure 9-5. The indoor mean concentration at EP-A stayed relatively the same from 2008 to 2010 at 0.14 and 0.16  $\mu\text{g}/\text{m}^3$ , respectively, but decreased from 0.56 to 0.38  $\mu\text{g}/\text{m}^3$  at EP-B. Outdoor concentrations also varied in a narrow range from 0.23 to 0.21  $\mu\text{g}/\text{m}^3$  at EP-A, and 0.75 to 0.53  $\mu\text{g}/\text{m}^3$  at EP-B for the two study periods. Albeit, the concentrations recorded at both schools are very small in terms of magnitude, the contrast between the low and high exposure schools is evident from both studies.

**Table 9-5 Descriptive statistics for BC ( $\mu\text{g}/\text{m}^3$ ) - 2010 study**

		Indoor		Outdoor	
Locations		EP - A	EP - B	EP - A	EP - B
Valid N		21	23	23	26
Mean		0.16	0.38	0.21	0.53
Median		0.06	0.33	0.13	0.55
Std. Deviation		0.24	0.25	0.24	0.32
Minimum		0.00	0.00	0.00	0.07
Maximum		0.80	0.96	0.74	1.05
Percentiles	25	0.00	0.20	0.02	0.21
	75	0.17	0.55	0.25	0.82





**Figure 9-5 Box plot for the 2008 and 2010 48-hr BC at EP-A and EP-B**

The results for all the pollutant metrics between both the studies suggest similarity in the pollutant concentrations. The near similar concentrations for the El Paso schools during the two study periods suggest the reduced possibility of these concentrations being affected by any fugitive sources of emissions. The Ciudad Juarez schools, indeed, may have been impacted by such emissions like fugitive dust etc.

## 10.0 Conclusions

The findings presented in this dissertation are the results of the first binational traffic air pollution and health effects study that was concurrently conducted at four elementary schools in the two sister cities of El Paso, Texas, USA and Ciudad Juárez, Chihuahua, Mexico. Two schools in each city were in a high traffic exposure zone and the other two were in the low traffic exposure zone. 58 physician diagnosed asthmatic children across the four schools were recruited to participate in the repeated measures health based study. The results of this study provide important insights into the environmental, health and demographic factors that influence the susceptibility of sensitive populations like school going asthmatic children to various traffic pollutant metrics. The link between air pollution and health effects has received a lot of scholarly attention, but little is known about variations in children's exposure at within-city and between-city levels. This research helped bridge this research gap by elucidating the types of environmental health indicators that are required to assess traffic pollution exposures within this border community. Several types of indicators, including central ambient, school out- and indoor pollutant monitoring were examined, which were subsequently used to predict children's respiratory health. This helped assess which indicators were ideal for assessing children's health and where these indicators should be located to maximize their validity and overall effectiveness. Based on the results and analyses presented in this dissertation, the following conclusions can be posited:

- This study characterized and quantified five air pollutants ( $PM_{2.5}$ ,  $PM_{10-2.5}$ ,  $PM_{10}$ ,  $NO_2$  and BC), indoors and outdoors, at four schools. Weekly health outcome data of exhaled nitric oxide (eNO) measurements were administered to the study cohort.

- Outdoor PM concentrations exhibited distinct spatial variation both within and between the cities. Across all four schools, CJ-A recorded mean outdoor concentrations six times higher than EP-A for  $PM_{10-2.5}$  and four times higher for  $PM_{2.5}$ . Within El Paso, outdoor PM concentrations were more than two-fold higher at the high traffic exposure school EP-B than at the low traffic school EP-A for  $PM_{10-2.5}$ . While CJ-A was located in the low traffic zone, the higher concentrations were likely due to high levels of fugitive dust, as suggested also by the higher  $PM_{10-2.5}$  concentrations at this site.
- Outdoor BC and  $NO_2$  levels exhibited high spatial variability across the four schools, ranging from means of  $0.23 \mu g/m^3$  and 4.5 ppb at EP-A, respectively, to  $2.48 \mu g/m^3$  and 26.8 ppb at CJ-B, respectively. In contrast to total PM levels, the within city concentration differences for these pollutants confirmed the veritableness of the school selection in the two traffic zones, with higher BC and  $NO_2$  levels recorded at EP-B and CJ-B compared to EP-A and CJ-A, respectively.
- PM pollution in this region is dominated by coarse PM ( $PM_{10-2.5}$ ) and fine fraction ( $PM_{2.5}$ ) accounts for approximately 25-30% of the total mass in  $PM_{10}$ . Although the levels of coarse PM indoors were less than outdoors due to various filtration mechanisms ( in El Paso), the ratio of  $PM_{2.5}/PM_{10}$  increased to approximately 35-40% due to increased food traffic in school and possible resuspension of dust in this microenvironment.
- Traffic-related PM pollution was confounded by the ubiquitous fugitive dust emissions, whether from unpaved roads or bare soil surfaces, such that both fine and coarse PM ( $PM_{2.5}$  and  $PM_{10-2.5}$ ) measured in the low-traffic zone surpassed those measured in the high-traffic zone in Ciudad Juarez. Thus, BC and  $NO_2$  would be better traffic pollution indicators than PM. On the contrary, levels of all ambient pollutants measured in the high

traffic zone exceeded those measured in the low traffic zone in El Paso where almost all streets were paved.

- Absolute (90<sup>th</sup> percentile of the absolute concentration differences) and relative measures (Coefficient of Divergence) were utilized to study spatial variation in pollutant concentrations across all the sites. Specifically, strong spatial heterogeneity in air pollutant concentrations exists in the region with all pollutants concentrations higher in Ciudad Juarez than in El Paso. Relatively high COD values between the indoor and outdoor concentrations at the four schools and the corresponding TCEQ CAMS sites substantiates the need for school-based monitoring, as suggested by the United States Environment Protection Agency, instead of the central site monitoring methodology which is in practice in most urban areas, for identifying the best environmental health indicator for sensitive populations like school-going asthmatic children.
- Indoor air pollution, in general, was found to be well associated with outdoor air pollution, although differences existed among all schools in student activities, building tightness, use of ventilation system, temperature control devices, and building materials. Intra-pollutant and inter-site correlation analyses were performed and further supported this observation.
- Positive associations between eNO and numerous pollutant metrics were observed with magnitudes of effect ranging from 1 to 3% increases in eNO per IQR increases of the 96-hr pollutant concentrations. Associations were stronger and significant for PM species especially at CJ-A. Associations differed significantly across the four schools reflecting both the heterogeneity in pollutant concentrations and cohort characteristics.

- It is understood that the trends observed in the pollutant concentrations during the study period may vary temporally if different seasons are taken into account due to the short duration of the study and that the weekend concentration profiles for the various pollutants might be different since sampling was undertaken only during weekdays.
- Air pollution is a potpourri of many pollutants and the complexity of these multi-pollutant mixtures makes it difficult to parse out the culprit agents in environmental exposure studies. Nevertheless, the aims of this study were achieved by providing indoor and outdoor exposure concentration estimates for characterizing children's exposure during weekdays and by demonstrating that central ambient monitoring alone may not generate representative pollutant concentrations in urban areas that experience varying levels of traffic and other fugitive sources of emissions.
- Pollutant sampling in different microenvironments and different exposure zones, as executed in this study, are therefore central toward estimating the true exposure of sensitive populations, such as school-age asthmatic children, to these pollutants.
- This research attempted to provide preliminary information concerning several critical research needs of the Paso del Norte border region. This will be of vital importance in evaluating the effectiveness of pollution reduction initiatives with respect to improving public health. The sister cities of Ciudad Juárez and El Paso were an apt location for conducting the exposure and health assessment given the high concentrations of traffic-related pollutants, the high number of individuals living in close proximity to congested roadways, and the geophysical conditions in the area leading to elevated traffic pollution levels.

- Air pollutants are indifferent to man-made borders between two sovereign nations and cannot be traced to any one specific jurisdiction. For example, airborne emissions from coal fired power plants in the Midwest find their way to the east coast of the United States, thereby impacting the quality of life there. Emissions from brick kilns and burning of scrapwood and refuse material for heating and cooking in economically depressed neighborhoods of Ciudad Juárez can imperil the respiratory health of asthmatic children both in Ciudad Juárez and El Paso. The Rio Grande, which serves as the International Border between both these nations can exercise no power toward preventing the movement of trans-boundary air pollution. Air pollution problems for this region are inter-connected. Therefore, resolving complex binational air pollution problems requires a synergistic approach and a strong involvement of various stakeholders from both the nations.

Given the international context of the study area that shares the same air shed but experiences varying gradients of traffic pollutant concentrations and socioeconomic status at the community levels, the results obtained would definitely contribute to literature. In addition, the results would aid in evaluating the effectiveness of pollution reduction strategies with respect to public health as outlined by Border 2012 strategies in majority-minority communities of the US-Mexico border region and eventually provide a fulcrum of leverage to health policy makers in better understanding the associations between traffic air pollutants and various health endpoints, thereby shaping opinions and catalyzing actions for stricter air quality standards.

### ***Recommendations and Future work***

The chemical speciation of the fine particulate matter filter could provide valuable information on the particle toxicity, mutagenity and allergic potential of these particles. There is

an inadequate mechanistic understanding of PM health effects. As such, it is imperative to determine the chemical components that may lead to adverse health effects in asthmatic children. Source apportionment studies may throw light at the origin of these pollutant emissions.

Future studies should also consider measuring pollutant concentrations across all seasons. This research was conducted for just a semester; seasonal differences in environmental and personal exposures need to be investigated too. In this study, sampling was not done during the spring break or during the weekends. As such, the characterization of indoor-outdoor ratios for the various pollutants during these periods of non-activity could not be achieved. It would be worthwhile to do sampling during holidays etc. to understand how particle generation occurs when there is no human movement- especially for schools like EP-A and EP-B which saw indoor-outdoor ratios approaching unity for almost all the pollutants.

## References

- Abu-Allaban M, Gillies JA, Gertler AW, Clayton R, Proffitt, 2007. Motor vehicle contributions to ambient PM<sub>10</sub> and PM<sub>2.5</sub> at selected urban areas in the USA. *Environmental Monitoring Assessment* 132: 155-163.
- Adamkiewicz G, Ebelt S, Syring M, Slater J, Speizer FE, Schwartz J, Suh H, Gold DR, 2004. Association between air pollution exposure and exhaled nitric oxide in an elderly population. *Thorax* 59(3): 204-209.
- Adar SD, Gold DR, Coull BA, Schwartz J, Stone PH, Suh HH, 2007. Focused exposures to airborne traffic particles and heart rate variability in the elderly. *Epidemiology* 18(1): 95-103.
- Adgate JL, Ramachandran G, Pratt GC, Waller LA, Sexton K, 2002. Spatial and temporal variability in outdoor, indoor and personal PM<sub>2.5</sub> exposure. *Atmospheric Environment* 36: 3255-3265.
- Ali M, Athar M, 2008. Air pollution due to traffic, air quality monitoring along three sections of National Highway N-5, Pakistan. *Environmental Monitoring and Assessment* 136: 219-226.
- Alili F, Momas I, Callais F, Le Moullec Y, Sacre C, Chiron M, Flori JP, 2001. Exposure to traffic pollution: Comparison between measurements and a model. *Arch Environ Health* 56: 552-558.
- Arrieta DE, Ontiveros CC, Li WW, Garcia JH, Jacob MS, McDonald D, Burchiel SW, Washburn BS, 2003. Aryl hydrocarbon receptor-mediated activity of particulate organic matter from the Paso Del Norte airshed along the U.S.-Mexico border. *Environmental Health Perspectives* 111(10): 1299-1305
- Ashmore MR, Dimitroulopoulou C, 2009. Personal exposure of children to air pollution. *Atmospheric Environment* 43: 128-141.
- ATS/ERS, 2005. Recommendations for standardized procedures for the online and offline measurement of exhaled lower respiratory oxide and nasal nitric oxide. *American Journal of Respiratory and Critical Care Medicine* 152: 609-612.
- Aust AE, Ball JC, Hu AA, Lighty JS, Smith KR, Straccia AM, Veranth JM, Young WC, 2002. Particle characteristics responsible for effects on human lung epithelial cells. *Res Rep Health Effect Institute*, 110: 1-65.



- Baertsch-Ritter N, Keller J, Dommen J, Prevot ASH, 2004. Effects of various meteorological conditions and spatial emission resolutions on the ozone concentration and ROG/NO<sub>x</sub> limitation in the Milan area. *Atmospheric Chemistry Physics* 4:423-438.
- Bang J, Murr L, 2003. Utilization of Selected Area Electron Diffraction (SAED) Patterns for Characterization of Air Submicron Particulate Matter collected by a Thermophoretic Precipitator. *Journal of the Air and Waste Management Association* 53: 1-10.
- Barraza-Villarreal A, Sunyer J, Hernandez-Cadena L, Escamilla-Nunez MC, Sienra-Monge JJ, Ramirez-Aguilar M, et al. 2008. Air pollution, airway inflammation, and lung function in a cohort study of Mexico City schoolchildren. *Environmental Health Perspectives* 116(6): 832-838.
- Bates D 1995. The effects of air pollution on children. *Environmental Health Perspectives* 103(6): 49-53.
- Baxter LK, Barzyk TM, Vette AF, Croghan C, Williams RW, 2008. Contributions of diesel truck emissions to indoor elemental carbon concentrations in homes in proximity to Ambassador Bridge. *Atmospheric Environment* 42(40): 9080-9086.
- Baxter LK, Clougherty JE, Laden F, Levy JI, 2007. Predictors of concentrations of nitrogen dioxide, fine particulate matter, and particle constituents inside of lower socioeconomic status urban homes. *Journal Expo Sci Environ Epidemiology* 17(5): 433-444.
- Beckerman B, Jerrett M, Brook JR, Verma DK, Arain MA, Finkelstein MM, 2008. Correlation of nitrogen dioxide with other traffic pollutants near a major expressway. *Atmospheric Environment* 42: 275-290
- Bell ML, O'Neill MS, Cifuentes LA, Braga ALF, Green C, Nweke A, Rogat J, Sibold K, 2005. Challenges and recommendations for the study of socioeconomic factors and air pollution health effects. *Environmental Science & Policy* 8: 525-533.
- Berube KA, Sexton KJ, Jones TP, Moreno T, Anderson S, Richards RJ, 2004. The spatial and temporal variations in PM<sub>10</sub> mass from six UK homes. *Science of the Total Environment* 324:41-53.
- Blackman A, Newbold S, Shih JS, Evans D, Cook J, Batz M, 2006. The benefits and costs of informal sector pollution control: Mexican brick kilns. *Environment and Development Economics* 11(5):603-627.

- Blackman A, 2004. Maquiladoras, Air Pollution and Human Health in Ciudad Juarez and El Paso. In K.Kopinak (ed.) Social Costs of Industrial Growth in Northern Mexico. University of California San Diego Center for U.S.-Mexican Studies, San Diego. 179-203.
- Blackman A, Bannister GJ, 1997. Pollution Control in the Informal Sector: The Ciudad Juárez Brickmakers Project. *Natural Resources Journal* 37(4): 829-856.
- Blondeau P, Iordache V, Poupard O, Genin D, Allard F, 2005. Relationship between outdoor and indoor air quality in eight French schools. *Indoor Air* 15: 2-12.
- Braníš M, Šafránek J, Hytychová A, 2009. Exposure of children to airborne particulate matter of different size fractions during indoor physical education at school. *Building and Environment* 44: 1246-1252.
- Branis M, Rezacova P, Domasova M, 2005. The effect of outdoor air and indoor human activity on mass concentrations of PM<sub>10</sub>, PM<sub>2.5</sub>, and PM<sub>1</sub> in a classroom. *Environmental Research* 99: 143-149.
- Brasseur GP, Orlando JJ, Tyndall GS, 1999. *Atmospheric Chemistry and Global Change*, Oxford University Press, New York.
- Briggs J, Health OW, 2000. *Environmental Health Indicators: Development of a Methodology for the WHO European Region*: Bilthoven.
- Briggs DJ, Collins S, Elliott P, Ficher P, Kingham S, Lebrete E, et.al, 1997. Mapping urban air pollution using GIS: A regression-based approach. *International Journal of Geographic Information Sciences* 11: 699-718.
- Brook RD, Franklin B, Cascio W, et al. 2004. Air Pollution and Cardiovascular Disease: A Statement for Healthcare Professionals from the Expert Panel on Population and Prevention Science of the American Heart Association. *Circulation- Journal of the American Heart Association* 109: 2655-2671.
- BTS (Bureau of Transportation Statistics), 2009. Research and Innovative Technology Administration, Bureau of Transportation Statistics: Data and Statistics – Border Crossing/entry data. Available: <http://www.transtats.bts.gov/BorderCrossing.aspx>. (Accessed April 01, 2011).
- Cape JN, Tang YS, van Dijk N, Love L, Sutton MA, Palmer SCF, 2004. Concentrations of ammonia and nitrogen dioxide at roadside verges, and their contribution to nitrogen deposition. *Environ Pollution* 132: 469-478.

- CDC, 2008. National Health and Nutrition Examination Survey (NHANES), Respiratory Health ENO Procedures Manual.
- Chaloulakou A, Kassomenos P, Grivas G, Spyrellis N, 2005. Particulate matter and black smoke concentrations levels in central Athens, Greece, *Environment International*, 31: 651-659.
- Chauhan AJ, Inskip HM, Linaker CH, Smith S, Schreiber J, Johnston S, Holgate ST, 2003. Personal exposure to nitrogen dioxide (NO<sub>2</sub>) and the severity of virus induced asthma in children. *Lancet* 361: 1939-1944.
- Chow JC, Watson JG, Louie PKK, Anthony Chen LW, Sin D, 2005. Comparison of PM<sub>2.5</sub> carbon measurement methods in Hong Kong, China. *Environmental Pollution* 137:334-344.
- Chow JC, Watson JG, Lowenthal DH, 1996. Sources and chemistry of PM<sub>10</sub> aerosol in Santa Barbara County, CA. *Atmospheric Environment* 30:1489-1499.
- Chow JC, 1995. Measurement methods to determine compliance with ambient air quality standards for suspended particles. *Journal of Air & Waste Management Association* 45: 320-382.
- Cowherd Jr C, Donaldson J, 2005. Analysis of the fine fraction of particulate matter in fugitive dust' Final Report prepared for the Western Governors' Association, Western Regional Air Partnership (WRAP).
- Cox WM, Chu SH, 1995. Assessment of interannual ozone variation in urban areas from a climatological perspective. *Atmospheric Environment* 30: 2615-2625.
- Currey RC, Kelly KE, Meuzelaar, HLC, Sarofim, AF, 2005. The U.S. Mexican border environment: Integrated approach to defining particulate matter issues in the Paso del Norte region, Vol.12, San Diego State University Press, San Diego, CA.
- Cyrus J, Pitz M, Bischof W, Wichmann HE, Heinrich J, 2004. Relationship between indoor and outdoor levels of fine particle mass, particle number concentrations and black smoke under different ventilation conditions. *Journal of Exposure Analysis and Environmental Epidemiology* 14: 275-283.
- Cyrus J, Heinrich J, Hoek G, Meliefste K, Lewne M, Gehring U, Bellander T, Fischer P, Van Vliet P, Brauer M, Wichmann HE, and Brunekreef B, 2003. Comparison between different traffic-related particle indicators: Elemental carbon (EC) PM<sub>2.5</sub> mass and absorbance. *Journal of Exposure Analysis and Environmental Epidemiology* 13(2): 134-143.

- da Silva AS, Cardoso MR, Meliefste K, Brunekreef B, 2006. Use of passive diffusion sampling method for defining NO<sub>2</sub> concentrations gradient in Sao Paulo, Brazil, *Environmental Health* 5:19.
- Daniels MJ, Lee YD, Kaiser M, 2001. Assessing sources of variability in measurement of ambient particulate matter. *Environmetrics* 12: 547-558.
- Dawson JP, Adams PJ, Pandis SN, 2007. Sensitivity of ozone to summertime climate in the Eastern USA: a modeling case study. *Atmospheric Environment* 41: 1494-1511.
- De Hartog JJ, van Vliet PH, Brunekreef B, Knape MC, Janssen NA, Harssema H, 1997. Relationship between air pollution due to traffic, decreased lung function and airway symptoms in children. *Ned Tijdschr Geneesk* 141(38):1814-1818.
- Delfino RJ, Staimer N, Gillen D, Tjoa T, Sioutas C, Fung K, et al. 2006. Personal and ambient air pollution is associated with increased exhaled nitric oxide in children with asthma. *Environmental Health Perspectives* 114(11): 1736-1743.
- Demokritou P, Gupta T, Ferguson S, Koutrakis P, 2002. Development and laboratory performance evaluation of a personal cascade impactor. *Journal of the Air & Waste Management Association* 52(10): 1230-1237.
- Diapouli E, Chaloulakou A, Mihalopoulos N, Spyrellis N, 2008. Indoor and outdoor PM mass and number concentrations at schools in the Athens area. *Environmental Monitoring Assessment* 136: 13-20.
- Diette GB, Hansel NN, Buckley TJ, Curtin-Brosnan J, Eggleston PA, Matsui EC, 2007. Home indoor pollutant exposures among inner-city children with and without asthma. *Environmental Health Perspectives* 115(11): 1665-1669
- Dimitroulopoulou C, Ashmore MR, Byrne MA, Kinnersley RP, 2001. Modelling of indoor exposure to nitrogen dioxide in the UK. *Atmospheric Environment* 35: 269-279.
- Dockery DW, Pope CA, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BG, Speizer FE, 1993. An association between air pollution and mortality in six US cities. *The New England Journal of Medicine* 329:1753-1759.
- Dominici F, Sheppard L, Clyde M, 2003. Health effects of air pollution: A statistical review. *International Statistical Review* 71: 243-276.

- Dorevitch S, Demirtas H, Scheff PA, Persky VW, 2007. Bias and confounding in longitudinal measures of exhaled monoxides. *Journal of Exposure Science and Environmental Epidemiology* 17 (6): 583-590.
- Duan N, 1982. Models for human exposure to air pollution, *Environmental International* 8:305.
- Dupont LJ, Demedts MG, and Verleden GM, 2003. Prospective evaluation of the validity of exhaled nitric oxide for the diagnosis of asthma. *Chest* 123(3): 751-756.
- Einfield W, Church H, 1995. Short-term winter season PM<sub>10</sub> study: Winter season air pollution in El Paso-Ciudad Juarez, EPA-906-R-95-001.
- Ekmekcioglu D, Keskin SS, 2007. Characterization of indoor air particulate matter in selected elementary schools in Istanbul, Turkey. *Indoor Built Environment* 16:169-176.
- Elminir HK, 2005. Dependence of urban air pollutants on meteorology. *Science of the Total Environment* 350(1-3): 225-237.
- El Paso Metropolitan Planning Organization (MPO), 2007. TransBorder 2035: The Transportation Conformity Report for the El Paso MPO Study Area, 185 pages, El Paso MPO, El Paso, Texas.
- Finkelstein MM, Jerrett M, Sears MR, 2004. Traffic air pollution and mortality rate advancement periods. *American Journal of Epidemiology* 160(2): 173-177.
- Fischer PH, Hoek G, van Reeuwijk H, Briggs DJ, Lebret E, van Wijnen JH, Kingham S, Elliott PE, 2000. Traffic-related differences in outdoor and indoor concentrations of particles and volatile organic compounds in Amsterdam. *Journal of Atmospheric Environment* 34: 3713-3722.
- Fischer PH, Steerenberg PA, Snelder JD, van Loveren H, van Amsterdam JGC, 2002. Association between exhaled nitric oxide, ambient air pollution and respiratory health in school children. *International Archives of Occupational and Environmental Health* 75(5): 348-353.
- Frey RS, 2003. The transfer of core-based hazardous production processes to the export processing zones of the periphery: The Maquiladora centers of Northern Mexico. *Journal of World Systems Research*, IX (2): 317-354.
- Fromme H, Diemer J, Dietrich S, Cyrus J, Heinrich J, Lang W, Kiranoglu M, Twardella D, 2008. Chemical and morphological properties of particulate matter (PM<sub>10</sub>, PM<sub>2.5</sub>) in school classrooms and outdoor air. *Journal of Atmospheric Environment* 42: 6597- 6605.

- Fromme H, Lahrz T, Hainsch A, Oddoy A, Piloty M, Ruden H, 2005. Elemental carbon and respirable particulate matter in the indoor air of apartments and nursery schools and ambient air in Berlin (Germany). *Indoor Air* 15(5): 335-341.
- García JH, Li WW, Walton J, Arimoto R, Schloeeesslin C, Sage S, Okrasinski R, Greenlee J, 2004. Characterization and implication of potential fugitive dust sources in the Paso del Norte region, JI. *Science of the Total Environment*, 325:95-112.
- Gauderman WJ, Avol E, Gilliland F, Vora H, Thomas D, Berhane K, McConnell R, Kuenzli N, Lurmann F, Rappaport E, Margolis H, Bates D, Peters J, 2004. The effects of air pollution on lung development from 10 to 18 years of age. *New England Journal of Medicine* 351: 1057-1067.
- Gilbert NL, Woodhouse S, Stieb DM, Brook JR, 2003. Ambient nitrogen dioxide and distance from a major highway. *The Science of the Total Environment* 312: 43-46.
- Gillies JA, Gertler AW, Sagebiel JC, Dippel WA, 2001. On-road particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>) emissions in the Sepulveda Tunnel, Los Angeles, California. *Environmental Science & Technology* 35: 1054-1063.
- Gomez B, Palacios MA, Gomez M, Sanchez JL, Morrison G, Rauch S, McLeod C, Ma R, Caroli S, Alimonti A, Petrucci F, Bocca B, Schramel P, Zischka M, Petterson C, Wass U, 2002. Levels and risk assessment for humans and ecosystems of platinum-group elements in the airborne particles and road dust of some European cities. *Science of the Total Environment* 299:1-19
- Gonzalez-Ayala S, 2006. Scenario Planning Peer Workshop: Midwest Transportation Planners Conference, Federal Highway Administration, Kansas Division Office Mid-America Regional Council, Kansas City, MO.
- Gonzales M, Qualls C, Hudgens E, Neas L, 2005. Characterization of spatial gradient of nitrogen dioxide across a United States-Mexico border city during winter. *Science of the Total Environment* 337: 163-173.
- Götschi T, Oglesby L, Mathys P, Monn C, Manalis N, Koistinen K, Jantunen M, Hanninen O, Polanska L, Kunzli N, 2002. Comparison of black smoke and PM<sub>2.5</sub> levels in indoor and outdoor environments of four European cities. *Environmental science & Technology* 36: 1191-1197.

- Götschi T, Hazenkamp-von Arx M, Heinrich J, Bono R, Burney P, Forsberg B, 2005. Elemental composition and reflectance of ambient fine particles at 21 European locations. *Atmospheric Environment* 39: 5947-5958.
- Goyal R, Khare M, 2009. Indoor-outdoor concentrations of RSPM in classroom of a naturally ventilated school building near an urban traffic roadway. *Atmospheric Environment* 43: 6026-6038.
- Green RS, Smorodinsky S, Kim JJ, McLaughlin R, Ostro B, 2004. Proximity of California public schools to busy roads. *Environmental Health Perspectives* 112: 61-66.
- Grineski SE, Collins TW, 2008. Exploring patterns of environmental justice in the Global South: Maquiladoras in Ciudad Juárez, Mexico. *Population Environment* 29: 247-270.
- Grivas G, Chaloulakou A, Samara C, Spyrellis N, 2004. Spatial and Temporal variation of PM<sub>10</sub> mass concentrations within the greater area of Athens, Greece. *Water, Air, and Soil Pollution* 158: 357-371.
- Gunier RB, Hertz A, von Behren J, Reynolds P, 2003. Traffic density in California: Socioeconomic and ethnic differences among potentially exposed children. *Journal of Exposure Analysis and Environmental Epidemiology* 13: 240-246.
- Guo H, Morawska L, He C, Gilbert D, 2008. Impact of ventilation scenario on air exchange rates and on indoor particle number concentrations in an air-conditioned classroom. *Atmospheric Environment* 42: 757-768.
- Gwilliam K, 2003. Urban transport in developing countries. *Transp Rev* 23(2): 197-216.
- Harbour RL, 1972. Franklin Mountains, Texas and New Mexico. USGS Bulletin 1298. U.S. Government Printing Office, Washington, D.C.
- Hart R, VanDerslice J, Vera B, Crawford CG, Kieszak S, Philen R, and McGeehin M, 1999. Ambient air quality and acute pediatric respiratory illness in the Paso del Norte airshed. CDC/UTEP/ PSR
- Hazenkamp-von Arx ME, Gotschi T, Ackermann-Liebrich U, Bono R, Burney P, Cyrus J, Jarvis D, et.al., 2004. PM<sub>2.5</sub> and NO<sub>2</sub> assessment in 21 European study centers of ECRHS II: Annual means and seasonal differences. *Atmospheric Environment* 38 (13): 1943-1953.
- He C, Morawska L, Gilbert D, 2005. Particle deposition rates in residential houses. *Atmospheric Environment* 39: 3891-3899.

- HEI, 2010. Traffic-related air pollution: A critical review of the literature on emissions, exposure and health effects – Special Report 17. Health Effects Institute (HEI), Boston, Massachusetts.
- Hemmingsson T, Linnarsson D, Gambert R, 2004. Novel hand-held device for exhaled nitric oxide-analysis in research and clinical applications. *Journal of Clinical Monitoring and Computing* 18(5-6): 379-387.
- Hernandez-Cadena L, Tellez-Rojo MM, Sanin-Aguirre LH, Lacasana-Navarro M, Campos A, Romieu I. 2000. Relationship between emergency consultations for respiratory diseases and air pollution in Juarez City, Chihuahua. *Salud Publica Mex* 42(4): 288-297.
- Hinds WC, 1999. *Aerosol Technology: Properties, behavior & measurement of airborne particles*, New York, John Wiley & Sons, Inc.
- Hitchins J, Morawska L, Wolff R, Gilbert D, 2000. Concentrations of submicrometer particles from vehicle emissions a major road. *Atmospheric Environment* 34: 51-59.
- Hoek G, Meliefste K, Cyrys J, Lewne M, Bellander T, Brauer M, et al., 2002. Spatial variability of fine particle concentrations in three European areas. *Atmospheric Environment* 36: 4077-4088.
- Hoek G, Brunekreef B, Goldbohm S, Fischer P, van den Brandt PA, 2002. Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. *Lancet* 360: 1203-1209.
- Hoek G and Brunekreef B, 1994. Effects of low-level winter air pollution concentrations on respiratory health of Dutch children. *Environ Research* 64(2): 136-50.
- Holguin F, Flores S, Ross Z, Molina M, Molina L, Granados A, Rincon C, Cortez M, Bernhave K, Jerret M, Romieu I, 2007. Traffic-related exposures, airway function, inflammation and respiratory symptoms in children. *American Journal of Respiratory and Critical Care Medicine* 176: 1236-1242.
- Ito K, Xue N, Thurston G, 2004. Spatial variation of PM<sub>2.5</sub> chemical species and source apportioned mass concentrations in New York City. *Atmospheric Environment* 38:5269-5282.
- Jacob DJ, Winner DA, 2009. Effect of climate change on air quality. *Atmospheric Environment* 43: 51-63.



- Jansen KL, Larson TV, Koenig JQ, Mar TF, Fields C, Stewart J, Lippmann M, 2005. Associations between health effects and particulate matter and black carbon in subjects with respiratory disease. *Environmental Health Perspectives* 113(12): 1741-1746.
- Janssen NA, de Hartog JJ, Hoek G, Brunekreef B, Lanki T, Timonen KL, Pekkanen J, 2000. Personal exposure to fine particulate matter in elderly subjects: relation between personal, indoor, and outdoor concentrations. *Journal of the Air and Waste Management Association* 50: 1133-1143.
- Janssen NCH, Van Vliet PHN, Aarts F, Harssema H, Brunekreef B, 2001. Assessment of exposure to traffic related air pollution of children attending schools near motorways. *Atmospheric Environment* 35: 3875-3884.
- Jantunen E, Hanninen O, Koistinen K, Hashim JH, 2002. Fine PM measurements: Personal and indoor air monitoring. *Chemosphere* 49(9):993-1007.
- Jeon SJ, Meuzelaar HL, Sheya SA, Lighty JS, Jarman WM, Kasteler C, et.al, 2001. Exploratory studies of PM<sub>10</sub> receptor source profiling by GC/MS and principal component analysis of temporally and spatially resolved ambient samples. *Journal of Air and Waste Management Association* 51: 766-84.
- Johnson CE, Collins WJ, Stevenson DS, Derwent RG, 1999. The relative roles of climate and emissions changes on future oxidant concentrations. *J.Geophys.Res.* 104:18631-18645.
- ISO, 1993. Ambient Air-Determination of a black smoke index. International Organization for Standardization. International Standard 9835-1993 (E).
- Keeler GJ, Dvonch T., et al, 2002. Assessment of personal and community-level exposures to particulate matter among children with asthma in Detroit, Michigan, as part of Community Action Against Asthma (CAAA). *Environmental Health Perspectives* 110 (Suppl.2): 173-181
- Khalili B, Boggs PB, Bahna SL, 2007. Reliability of a new hand-held device for the measurement of exhaled nitric oxide. *Allergy* 62:1171-1174.
- Kharitonov SA, and Barnes PJ, 2002. Biomarkers of some pulmonary diseases in exhaled breath. *Biomarkers* 7(1): 1-32.
- Kim E, Hopke PK, 2004. Source apportionment of fine particles in Washington, DC, utilizing temperature-resolved carbon fractions. *Journal of the Air and Waste Management Association* 54: 773-785.

- Kim E, Hopke PK, Pinto JP, Wilson WE, 2005. Spatial variability of fine particle mass, components, and source contributions during the regional air pollution study in St. Louis. *Environmental Science & Technology* 39: 4172-4179.
- Kinney PL, Aggarwal M, Northridge ME, Janssen NAH, Shepard P, 2000. Airborne concentrations of PM<sub>2.5</sub> and diesel exhaust particles on Harlem sidewalks: A community-based pilot study. *Environmental Health Perspectives* 108(3): 213-218.
- Kleeman MJ, Eldering A, Hall JR, Cass GR, 2001. Effect of emissions control programs on visibility in Southern California. *Environmental Science and Technology* 35(23): 4668-4674.
- Klepeis NE, Nelson WC, Ott WR, Robinson JP, Tsang AM, Switzer P, Behar JV, Hern SC, Engelmann WH, 2001. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. *Journal of Exposure Analysis and Environmental Epidemiology* 11(3):231-252.
- Koenig JQ, Mar TF, Allen RW, Jansen K, Lumley T, Sullivan JH, Trenga CA, Larson TV, Liu LJS, 2005. Pulmonary effects of indoor- and outdoor-generated particles in children with asthma. *Environmental Health Perspectives* 113(4): 499-503.
- Kousa A, Oglesby L, Koistinen K, Kunzli N, Jantunen M, 2002. Exposure chain of urban air PM<sub>2.5</sub>- associations between ambient fixed site, residential outdoor, indoor, workplace and personal exposures in four European cities in the EXPOLIS-study. *Atmospheric Environment* 36:3031-3039.
- Krudysz M.A., Froines J.R, Fine P.M, Sioutas C, 2008. Intra-community spatial variation of size-fractioned PM mass, OC, EC, and trace elements in the Long Beach, CA area. *Atmospheric Environment* 42: 5374-5389.
- Kulkarni N, Grigg J, 2008. Effects of Air Pollution on Children. *Pediatrics and Child Health* 18(5): 238-242.
- Lam GCK, Leung DY, Niewiadomski M, Pang SW, 1999. Street-level concentrations of nitrogen dioxide and suspended particulate matter in Hong Kong. *Atmospheric Environment* 33:1-11.
- Laden F, Neas LM, Dockery DW, Schwartz J, 2000. Association of fine particulate matter from different sources with daily mortality in six US cities. *Environment Health Perspectives* 108: 941-947.

- Lebret E, Briggs D, van Reeuwijk H, Fischer P, Smallbone K, Harssema H, Kriz B, Gorynski P, Elliott P, 2000. Small area variations in ambient NO<sub>2</sub> concentrations in four European areas. *Atmospheric Environment* 34(9): 117-185.
- Lee SC, Chang M, 2000. Indoor and outdoor air quality investigation at schools in Hong Kong. *Chemosphere* 41: 109-113.
- Levy JI, Lee K, Spengler JD, Yanagisawa Y, Bischof W, Braathen O, Chung Y, Coward S, Gutschmidt K, Jin K, Korenaga T, Ohkoda Y, Meneses F, Pastuszka J, Patil RS, Qing X, Raizenne M, Salonen MO, Sega K, Seifert B, Shah S, Torres E, Yoon D, Zhang X, 1998. Impact of residential nitrogen dioxide exposure on personal exposure: An International Study. *Journal of Air and Waste Management Association* 48: 553-560.
- Lewne M, Cyrus J, Meliefste K, Hoek G, Brauer M, Fischer P, 2004. Spatial variation in nitrogen dioxide in three European areas. *Science of the Total Environment* 332: 217-230.
- Li WW, Sarnat JA, Stock TH, 2010. Characterization of traffic related air pollution in elementary schools and its Impact on asthmatic children in El Paso, Texas: Quality assurance plan, NUATRC, Houston, Texas, 114p.
- Li WW, Bang JJ, Chianelli RR, Yacaman MJ, Ortiz R, 2005. Characterization of Airborne Particulate matter in the Paso del Norte Air Quality Basin: Morphology and Chemistry. Ed (Currey RC) in *The U.S.-Mexican border environment: An integrated approach to defining particulate matter issues in the Paso del Norte Region*, SCERP Monograph 12: 113-129.
- Li WW, Paschold H, Morale H, Chianelli J, 2003. Correlations between short-term indoor and outdoor PM concentrations at residences with evaporative coolers. *Journal of Atmospheric Environment* 37: 2691-2703.
- Li WW, Orquiz R, Pingitore Jr. NE, Garcia JH, Espino TT, Gardea-Torresdey J, Chow J, Watson JG, 2001. Analysis of temporal and spatial dichotomous PM air samples in the El Paso-Cd. Juarez air quality basin. *Journal of Air and Waste Management Association* 51: 1511-1560.
- Linaker CH, Chauhan AJ, Inskip H, Holgate ST, Coggon D, 2000. Personal exposure of children to nitrogen dioxide relative to concentrations in outdoor air. *Occupational Environ Med* 57: 472-476.
- Linaker CH, Chauhan AJ, Inskip H, Frew AJ, Sillence A, Coggon D, Holgate ST, 1996. Distribution and determinants of personal exposure to nitrogen dioxide in school children. *Occupational Environ Med*, 53: 200-203.

- Liu L, Poon R, Chen L, Frescura AM, Montuschi P, Ciabattini G, et al. 2009. Acute effects of air pollution on pulmonary function, airway inflammation, and oxidative stress in asthmatic children. *Environmental Health Perspectives* 117(4): 668-674.
- Long CH, Suh P, Catalano KP, 2001. Using time-and size-resolved particulate data to quantify indoor penetration and deposition behavior. *Environmental Science and Technology* 35 (10): 2089-2099.
- Luoma M, Batterman A, 2001. Characterization of particulate emissions from occupant activities in offices. *Indoor Air* 11: 35-48.
- McConnell R, Berhane K, Gilliland F, London SJ, Vora H, Avol E, Gauderman WJ, Margolis, HG, Lurmann F, Thomas DC, Peters JM, 1999. Air pollution and bronchitic symptoms in Southern California children with asthma. *Environmental Health Perspectives* 107(9): 757-60.
- Medina-Ramon M, Goldberg R, Melly S, Mittleman MA, Schwartz J, 2008. Residential exposure to traffic-related air pollution and survival after heart failure. *Environmental Health Perspectives* 116 (4): 481-485.
- Melia RJW, Chinn S, Rona RJ, 1990. Indoor levels of NO<sub>2</sub> associated with gas cookers and kerosene heaters in inner city areas of England. *Atmospheric Environment* 24B: 177-180.
- Mi YH, Norback D, Tao J, Mi YI, Fern M., 2006. Current asthma and respiratory symptoms among pupils in Shanghai, China: influence of building ventilation, nitrogen dioxide, ozone, and formaldehyde in classrooms. *Indoor Air* 16: 454 - 464.
- Miller L, Lemke LD, Xu X, Molaroni SM, You H, Wheeler A, et.al., 2010. Intra-urban correlation and spatial variability of air toxics across an international airshed in Detroit, Michigan (USA) and Windsor, Ontario (Canada). *Atmospheric Environment* 44: 1162-1174.
- Mitra AP, Morawska L, Sharma C, Zhang J, 2002. Chapter two: Methodologies for characterization of combustion sources and for quantification of their emissions. *Chemosphere* 49: 903-922.
- Monn C, 2001. Exposure assessment of air pollutants: A review on spatial heterogeneity and indoor/outdoor/personal exposure to suspended particulate matter, nitrogen dioxide and ozone. *Journal of Atmospheric Environment* 35:1-32.
- Monn C, Fuchs A, Hogger D, Junker M, Kogelschatz D, Roth N, Wanner HU, 1997. Particulate matter less than 10  $\mu\text{m}$  (PM<sub>10</sub>) and fine particle less than 2.5  $\mu\text{m}$  (PM<sub>2.5</sub>): Relationships

- between indoor, outdoor and personal concentrations. *Science of the Total Environment* 208: 15-21.
- Mukerjee S, Smith LA, Norris GA, Morandi MT, Gonzales M, Noble CA, Neas LM, Ozkaynak AH, 2004. Field method comparison between passive air samplers and continuous monitors for VOCs and NO<sub>2</sub> in El Paso, Texas, *Journal of the Air and Waste Management Association* 54: 307-319.
- Nevin BJ, and Broadley KJ, 2002. Nitric Oxide in respiratory disease. *Pharmacology & Therapeutics*, 95(3): 259-293.
- NAAQS, 2006. National Ambient Air Quality Standards for Particulate Matter, Proposed Rule, *Fed. Register* 71(100: 2620-2708.
- Noble C, Mukherjee S, Gonzales M, Rodes C, Lawless P, Natarajan S, et.al, 2003. Continuous measurements of and relationship between fine and ultrafine particulate matter, criteria air pollutants and meteorological conditions in El Paso, Texas. *Atmospheric Environment*, 37: 827-40.
- Noullett M, Jackson PL, Brauer M, 2006. Winter measurements of children's personal exposure and ambient fine particle mass, sulphate and light absorbing components in a northern community', *Atmospheric Environment* 40: 1971-1990.
- Nunes TV, Pio CA, 1993. Carbonaceous aerosols in industrial and coastal atmospheres', *Atmospheric Environment* 27: 1339-1346.
- Ogawa, 1997. NO, NO<sub>2</sub>, NO<sub>x</sub> and SO<sub>2</sub> Sampling Protocol Using the Ogawa Sampler. Ogawa & Company, Pompano Beach, FL. <http://www.ogawausa.com/pdfs/prono-noxno2so206.pdf> (Accessed on September 12, 2010).
- Oglesby L, Kunzli N, Roosli M, Braun-Fahrlander M, Mathys P, Stern W, Jantunen M, Kousa A, 2000. Validity of ambient levels of fine particles as surrogate for personal exposure to outdoor air pollution- Results of the European EXPOLIS-EAS study (Swiss Center Basel). *Journal of the Air & Waste Management Association* 50: 1251-1261.
- Orion Research, 1997. Cahn Model C-33 Microbalance Instruction Manual, Orion Research Inc., Beverly, MA.
- Orquiz R, 2001. Gravimetric and elemental analysis of particulate matter in the El Paso-Cd. Juarez air basin. MS Thesis, Department of Civil Engineering, The University of Texas at El Paso, El Paso, Texas, 143p.

- Parker JL, Larson RR, Eskelson E, Wood EM, Veranth JM, 2008. Particle size distribution and composition in a mechanically ventilated school building during air pollution episodes. *Indoor Air* 18: 386-393.
- Paschold H, Li WW, Morale H, Pingitore NE, Maciejewska B, 2003a. Elemental analysis of airborne particulate matter and cooling water in west Texas residences. *Journal of Atmospheric Environment* 37: 2681-2690.
- Paschold H, Li WW, Morale H, Walton JW, 2003b. Laboratory study of the impacts of evaporative cooler on PM concentrations. *Journal of Atmospheric Environment* 37: 1075-1086.
- Patel MM, Chillrud SN, Correa JC, Feinberg M, Hazi Y, Deepti KC, 2009. Spatial and temporal variations in traffic-related particulate matter at New York City high schools. *Atmospheric Environment* 43: 4975- 4981.
- Peach J and Williams J, 2004. *Population Projects for the U.S. Mexican Border Region*. San Diego State University Press, San Diego.
- Peacock J, Symonds P, Jackson P, Bremmer SA, Scarlett JF, Strachan DP, 2003. Acute effects of winter air pollution on respiratory function in schoolchildren in Southern England. *Occupational and Environmental Medicine* 60: 82-89.
- Pennington DW, Pottingb J, and Finnveden G, 2004. Life cycle assessment Part 2: Current impact assessment practice. *Environmental International*, 30(5): 721-739.
- Penttinen P, Alm S, Ruuskanen J, Pekkanen J, 2000. Measuring reflectance of TSP-filters for retrospective health studies. *Atmospheric Environment* 34: 2581-2586.
- Peters A, von Klot S, Heier M, Trentinaglia I, Hormann A, Wichmann HE, Lowel H, 2004. Exposure to traffic and the onset of myocardial infarction. *New England Journal of Medicine* 351(17): 1721-1730.
- Pinto JP, Lefohn AS, Shadwick DS, 2004. Spatial variability of PM<sub>2.5</sub> in urban areas in the United States. *Journal of the Air & Waste Management Association* 54: 440-449.
- Pleijel H, Pihl Karlsson G, Binsell Gerdin E, 2004. On the logarithmic relationship between NO<sub>2</sub> concentration and the distance from a highroad. *Science of the Total Environment*. 332 (1-3): 261-264.
- Pope CA, Dockery DW, 2006. Health effects of fine particulate air pollution: Lines that connect. *The Journal of the Air & Waste Management Association* 56:709-742.

- Pope III CA, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K, Thurson GD, 2002. Lung Cancer, cardiopulmonary mortality and long-term exposure to fine particulate air pollution. *The Journal of Air & Waste Management Association* 287:1132-1141.
- Poupard O, Blondeau P, Iordache V, Allard F, 2005. Statistical Analysis of parameters influencing the relationship between outdoor and indoor air quality in schools. *Atmospheric Environment* 39: 2071-2080.
- Rijnders E, Janssen NAH, van Vliet PHN, Brunekreef B, 2001. Personal and outdoor nitrogen dioxide concentrations in relation to degree of urbanization and traffic density. *Environmental Health Perspectives* 109 (Supplement 3): 411-417.
- Rincon CA, Anderson JR, Bang JJ, Greenlee JC, Kelly KE, Li WW, 2005. Chapter I: Background and Recent Research on Particulate Matter in the Paso del Norte Border Region, in *The U.S. – Mexican Border Environment: An Integrated Approach to Defining Particulate Matter Issues in the Paso del Norte Region*, ed. R.C. Curry, K. Kelly, H. Meuzelaar, A. Sarofim, San Diego State University Press, San Diego, CA. SCERP Monograph Series 12:1-26.
- Roemer WH, van Wijnen JH, 2001. Differences among black smoke, PM<sub>10</sub> and PM<sub>1.0</sub> levels at urban measurement sites. *Environmental Health Perspectives* 109 (2): 151-154.
- Rogge WF, Hildemann LM, Mazurek MA, Cass GR, Simoneit BRT, 1993. Sources of fine organic aerosol- Road dust, tire debris, and organometallic brake lining dust: Roads as sources and sinks. *Environment Science Technology* 27: 1892-1904.
- Rojas-Bracho L, Suh HH, Koutrakis P, 2000. Relationship among personal, indoor and outdoor fine and coarse particle concentrations for individuals with COPD. *Journal of Exposure Analysis and Environmental Epidemiology* 10(3): 294-306.
- Romieu I, Aguilar MR, Macias HM, Villareal AB, Cadena LH, Arroyo LC, 2003. Health Impacts of Air Pollution on Morbidity and Mortality among children of Ciudad Juarez, Chihuahua, Mexico. Commission for Environmental Cooperation, Montreal.
- Roorda-Knape MC, Janssen NAH, de Hartog JJ, van Klijet PHN, Harssema H, Brunekreef B, 1998. Air pollution from traffic in city districts near major roadways. *Journal of Atmospheric Environment* 32: 1921-1930.
- Salvi S, 2007. Health effects of ambient air pollution in children. *Pediatric Respiratory Reviews* 8:275-280.

- Sanchez RA, 1990. Health and environmental risks of the Maquiladora in Mexicali. *Natural Resources Journal* 130:163-186.
- Samet JM, Dominici F, Curriero FC, Coursac I, Zeger SL, 2000. Fine Particulate air pollution and mortality in 20 US cities, 1987-1994. *The New England Journal of Medicine* 343:1742-1749.
- Schwartz J, 2004. Air Pollution and children's health. *Pediatrics* 113(4): 1037-1043.
- Seinfeld JH, Pandis SN, 1993. *Atmospheric Chemistry & Physics: From Air Pollution to Climate Change*, Wiley-Interscience.
- Sarnat JA, Moise T, Shpund J, Liu Y, Pachon JE, Qasrawi R, Abdeen Z, Brenner S, Nassar K, Schauer JJ, 2010. Assessing the spatial and temporal variability of fine particulate matter components in Israeli, Jordanian, and Palestinian cities. *Atmospheric Environment* 44: 2383-2392.
- Sarnat JA, Koutrakis P, Suh HH, 2000. Assessing the relationship between personal particulate and gaseous exposures of senior citizens living in Baltimore, MD. *Journal of Air and Waste Management Association*, 50: 1184-1198.
- Sarnat SE, Raysoni AU, Li WW, Holguin F, Johnson B, Luevano SF, Garcia JH, Sarnat JA, 2011. Impact of traffic-related air pollution on exhaled nitric oxide in asthmatic children along the US-Mexico border. *Environmental Health Perspectives*, (In review).
- Sarnat SE, Coull BA, Ruiz PA, Koutrakis P, Suh HH, 2006. The influences of ambient particle composition and size on particle infiltration in Los Angeles, CA, residences. *Journal of the Air and Waste Management Association* 56: 186-196.
- Sawant AA, Na K, Zhu X, Cocker K, Butt S, Song C, Cocker III DR, 2004. Characterization of PM<sub>2.5</sub> and selected gas-phase compounds at multiple indoor and outdoor sites in Mira Loma, California. *Atmospheric Environment*, 38(37): 6269-6278.
- Schwartz J, Litonjua A, Suh H, Verrier M, Zanobetti A, Syring M, Nearing B, Verrier R, Stone P, MacCallum G, Speizer E, Gold DR, 2005. Traffic related pollution and heart rate variability in a panel of elderly subjects. *Thorax* 60(6): 455-461.
- Schwartz J, Litonjua A, Suh H, Verrier M, Zanobetti A, Syring M, Nearing B, Verrier R, Stone P, MacCallum G, Speizer FE, and Gold DR, 2005. Traffic related pollution and heart rate variability in a panel of elderly subjects. *Thorax* 60(6): 455-461.



- Schwartz J, 2000. Assessing confounding, effect modification, and thresholds in the association between ambient particles and daily deaths. *Environmental Health Perspectives* 108: 563-568.
- SEMARNAT, 2006. Programa de gestión de la calidad del aire de Ciudad Juárez (PROAIRE) 2006-2012.
- Silkoff PE, McClean PA, Slutsky AS, Suguru Wakita HG, Chapman KR, Szalai JP, Zam N, 1997. Marked flow-dependence of exhaled nitric oxide using a new technique to exclude nasal nitric oxide. *American Journal of Respiratory Critical Care Medicine* 155: 260-267.
- Singer BC, Hodgson AT, Hotchi T, Kim JJ, 2004. Passive measurement of nitrogen oxides to assess traffic-related pollutant exposure for the East Bay Children's Respiratory Health Study. *Atmospheric Environment* 38: 393-403.
- Smargiassi A, Baldwin M, Pilger C, Dugandzic R, Brauer M. 2005. Small-scale spatial variability of particle concentrations and traffic levels in Montreal: A pilot study. *Science Total Environment* 338: 243-251.
- Steenenbergh PA, Janssen NAH, de Meer G, Fischer PH, Nierkens S, van Loveren H, et al. 2003. Relationship between exhaled NO, respiratory symptoms, lung function, bronchial hyperresponsiveness, and blood eosinophilia in school children. *Thorax* 58(3): 242-245.
- Southwest Weather Bulletin. (n.d.). Retrieved June 23, 2010, from NOAA: <http://www.srh.noaa.gov/images/epz/swwww/swwb2010a.pdf>.
- Tippayawong N, Khuntong P, Nitatwichit C, Khunatorn Y, Tantakitti C, 2009. Indoor/outdoor relationships of size-resolved particle concentrations in naturally ventilated school environments. *Building and Environment* 44: 188-197.
- Tiitta P, Raunemaa T, Tissari J, Yli-Tuomi T, Leskinen A, Kukkonen J, Harkonen J, Karppinen A, 2002. Measurements and modeling of PM<sub>2.5</sub> concentrations near a major road in Kuopio, Finland. *Atmospheric Environment* 36: 4057-4068.
- Traynor GW, Apte MG, Carruthers AR, Dillworth JF, Grimsrud DT, Thompson WT, 1987. Indoor air pollution and inter-room pollutant transport due to unvented kerosene-fired space heaters. *Environ International* 13: 159-166.
- Turpin BJ, Huntzicker JJ, 1991. Secondary formation of organic aerosol in the Los Angeles Basin: A descriptive analysis of organic and elemental carbon concentrations. *Atmospheric Environment* 25A:207-215.

- U.S. Environmental Protection Agency (EPA). 2010. Online. Available: <http://www.epa.gov/air/criteria.html> (accessed February 20, 2011).
- U.S.EPA., 2005. Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information, EPA-452/R-05-005a., U.S. Environment Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC.
- USEPA, U.S. EPA, 2002. Health Assessment Document for Diesel Engine Exhaust (Final 2002). U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington Office, Washington, DC, EPA/600/8-90/057F, 2002.
- U.S.EPA., 2002. <http://www.epa.gov/usmexicoborder/> (Accessed on August 10, 2010).
- U.S.EPA, 2001. EPA requirements for quality assurance project plans: EPA/240/B-01/003. U.S. Environmental Protection Agency, Washington, D.C
- Van Amsterdam JGC, Nierkens S, Vos SG, Oppenhuizen A, van Loveren H, Steerenberg PA, 2000. Exhaled nitric oxide: A novel biomarker of adverse respiratory health effects in epidemiological studies. *Archives of Environmental Health*, 55(6): 418-423.
- Van Roosbroeck S, Wichmann J, Janssen NAH, Hoek G, van Wijnen JH, Lebret E, Brunekreef B, 2006. Long-term personal exposure to traffic-related air pollution among school children- a validation study. *Science of the Total Environment* 368: 565-573.
- Von Schneidmesser E, Zhou J, Stone EA, Schauer JJ, Qasrawi R, Abdeen Z, Shpund J, Vanger A, Sarnat JA, 2010. Temporal and Spatial Trends in the Sources of Fine Particle Organic Carbon in Israel, Jordan, and Palestine. *Atmospheric Environment* 44: 3669-3678.
- Wadden RA and Scheff PA, 1983. Indoor air pollution: characterization, prediction, and control, John Wiley & Sons, Inc, New York.
- Wallace, L.A., 1996. Indoor Particles: a review. *Journal of the Air Pollution Control Association* 46: 98-127.
- Wang G, Wang H, Yu Y, Gao S, Feng J, Gao S et al., 2003. Chemical characterization of water-soluble components of PM<sub>10</sub> and PM<sub>2.5</sub> atmospheric aerosols in five locations of Nanjing, China. *Atmospheric Environment* 37: 2893-902.

- Ward TJ, Noonan C, Hooper K, 2007. Results of an indoor size fractionated PM school sampling program in Libby, Montana. *Environment Monitoring Assessment* 130: 163-171.
- Watson JG, 2002. Visibility: Science and regulation. *Journal of the Air & Waste Management Association* 52(6): 628-713.
- Watson JG, Turpin BJ, Chow JC, 2001. The measurement process: Precision, accuracy, and validity. In *Air Sampling Instruments for Evaluation of Atmospheric Contaminants, Ninth Edition*, Cohen, B., Ed. American Conference of Governmental Industrial Hygienists, Cincinnati, OH.
- Weschler CJ, 2009. Changes in indoor pollutants since the 1950s. *Atmospheric Environment* 43: 153-169.
- Wheeler A, Xu X, Smith-Doiron M, Gilbert N, Brook J, 2006. Intra-urban variability of air pollution: Monitoring and modeling of PM<sub>2.5</sub>, PM<sub>10-2.5</sub>, and NO<sub>2</sub>. *Epidemiology* 17: S243.
- Whitley and Murray, 2003. Autocatalyst- derived platinum, palladium, and rhodium (PGE) in infiltration basin and wetland sediments receiving urban runoff. *Science of the Total Environment* 341(1-3): 199-209.
- William DM and Homedes N, 2001. The impact of the Maquiladoras on health and health policy along the US-Mexico Border. *Journal of Public Health Policy* 22 (3): 320-337.
- Wilson JG, Kingham S, Sturman AP, 2006. Intraurban variations of PM<sub>10</sub> air pollution in Christchurch, New Zealand: implications for epidemiological studies. *Science of the Total Environment* 367: 559-572.
- Wilson JG, Kingham S, Pearce J, Sturman AP, 2005. A review of intraurban variations in particulate air pollution: Implications for epidemiologic research. *Atmospheric Environment* 39: 6444-6462.
- Wilson R, Spengler J, 1996. *Particles in Our Air: Concentrations and Health Effects*, Harvard University Press, Boston.
- Wilson WE, Suh HH, 1997. Fine Particles and Coarse Particles: Concentration relationships relevant to epidemiologic studies. *Journal of the Air and Waste Management Association* 47: 1238-1249.
- Wise EK, Comrie AC, 2005. Meteorologically adjusted urban air quality trends in the Southwestern United States, *Atmospheric Environment* 39: 2969-2980.

- WHO, 2006. Who Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide, and Sulfur Dioxide – Global Update 2005 – Summary of Risk Assessment. Geneva, World Health Organization.
- Wolf ME, Fields PG, and González-Ayala S. 2003. Developing a National Emissions Inventory for Mexico: On-Road Mobile Source Emissions Inventory. Presented at the 12th Annual U.S. EPA International Emissions Inventory Conference, San Diego, CA, April 29-May 1, 2003.
- Wong CM, Ma S, Hedley AJ, Lam TH, 2001. Effect of air pollution on daily mortality in Hong Kong. *Environmental Health Perspectives* 109:335-340.
- World Health Organization, 1997. Nitrogen Oxides (2<sup>nd</sup> edition), Environmental Health Criteria 188. Geneva, Switzerland: World Health Organization, International Program on Chemical Safety.
- Wongphatarakul V, Friedlander SK, Pinto JP, 1998. A comparative study of PM<sub>2.5</sub> ambient aerosol chemical databases. *Environmental Science & Technology* 32: 3926-3934.
- Wrobel A, Rokita E, Maenhaut W, 2000. Transport of traffic-related aerosols in urban areas. *Science of the Total Environment*, 257: 199-211.
- Yue W, Li X, Liu J, Li Y, Yu X, et.al., 2006. Characterization of PM<sub>2.5</sub> in the ambient air of Shanghai city by analyzing individual particles. *Science of the Total Environment* 368: 916-925.
- Zanobetti A, Schwartz J, Samoli E, Gryparis A, Touloumi G, et.al, 2003. The temporal pattern of respiratory and heart disease mortality in response to air pollution. *Environmental Health Perspectives* 111: 1188-1193.
- Zegar SL, Thomas D, Dominici F, Samet JM, Schwartz J, Dockery D, Cohen A, 2000. Exposure measurements error in time-series studies of air pollution: concepts and consequences. *Environmental Health Perspectives* 108: 419-426.
- Zhu Y, Hinds WC, Kim S, Sioutas C, 2002. Concentration and size distribution of ultrafine particles near a major highway. *Journal of the Air and Waste Management Association* 52: 1032-1042.

## Glossary

1) BC	Black Carbon
2) BOA	Bridge of the Americas
3) CAMS	Continuous Ambient Monitoring Sites
4) CO	Carbon Monoxide
5) COD	Coefficient of Divergence
6) $D_p$	Particle Size
7) EC	Elemental Carbon
8) eNO	Exhaled nitric oxide, ppb
9) $F_{ENO}$	Fractional Exhaled Nitric Oxide
10) ETS	Environmental Tobacco Smoke
11) $FEF_{25-75}$	Forced expiratory flow during the two interior quartiles of exhalation
12) $FEV_1$	Forced expiratory volume in one second
13) FENO	Fractional Exhaled Nitric Oxide
14) FVC	Forced Vital Capacity
15) GC/MS	Gas chromatography/mass spectrometry
16) GEE	Generalized estimating equations
17) HIPAA	Health Insurance Portability and Accountability Act
18) ICS	Inhaled Corticosteroids
19) IQR	Inter-Quartile Range
20) LABA	Long-acting bronchodilators
21) LB	Leukotriene blockers
22) LIBAIC	Combination of long-acting bronchodilators and inhaled corticosteroids

23) LOD	Limit of Detection
24) LT	Leukotriene Blocker
25) NC	Nasal Corticosteroids
26) NUATRC	Mickey Leland National Urban Air Toxics Research Center
27) NO <sub>2</sub>	Nitrogen Dioxide
28) O <sub>3</sub>	Ozone
29) PE	Physical exercise
30) PEF	Peak Expiratory Flow
31) PM <sub>2.5</sub>	Particle with aerodynamic diameters of less than 2.5 μm
32) PM <sub>10-2.5</sub>	Particle with aerodynamic diameters between 10 and 2.5 μm
33) PM <sub>10</sub>	Particle with aerodynamic diameters of less than 10 μm
34) PUF	Polyurethane foam
35) PTFE	Polytetrafluoroethylene
36) SABA	Short-acting bronchodilators
37) SC	Systemic Corticosteroids
38) TAKS	Texas Assessment of Knowledge and Skills Test
39) TCEQ	Texas Commission on Environmental Quality
40) TEOM	Tapered Elemental Oscillating Microbalance
41) UTEP	University of Texas at El Paso
42) nm	nano meter, 10 <sup>-9</sup> m
43) μm	micro meter, 10 <sup>-6</sup> m
44) ppm	parts per million (in volume)
45) ppb	parts per billion (in volume)

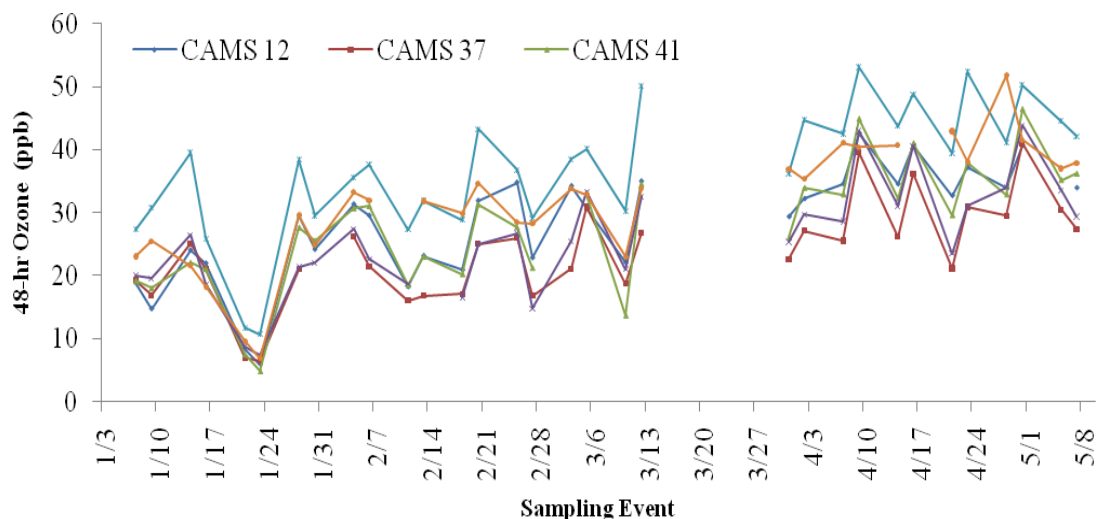
## Appendices

## Appendix A

### Association between Pollutant Variables and Meteorological Parameters at the Schools and TCEQ CAMS Sites

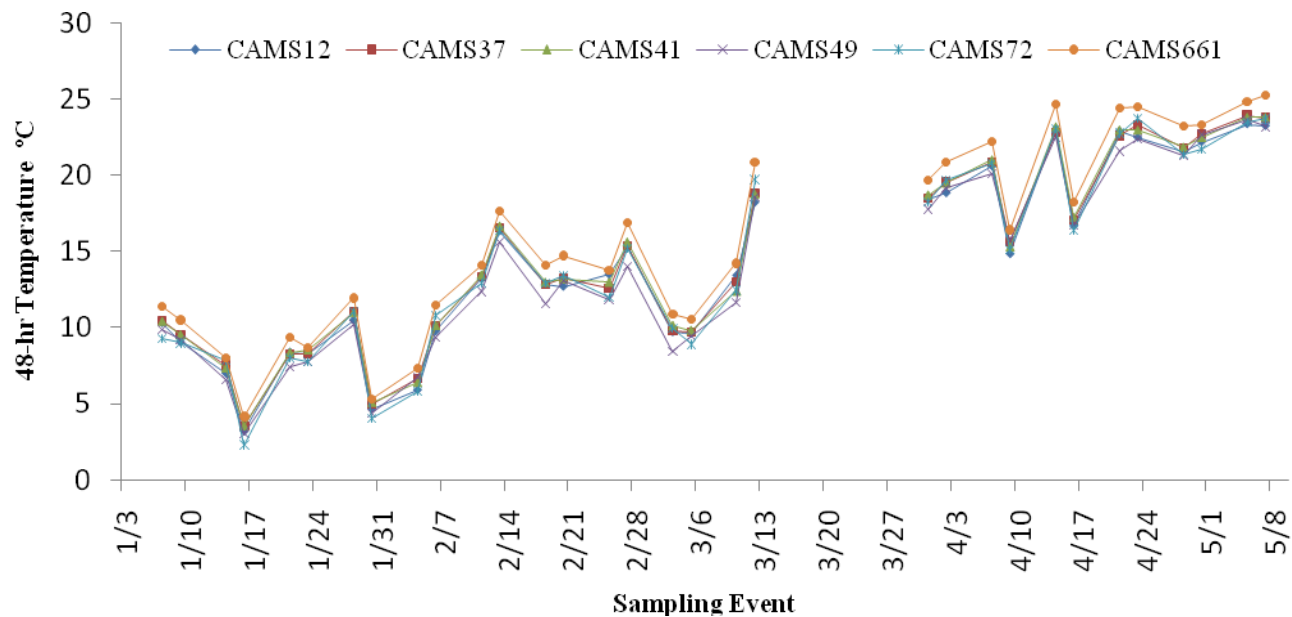
#### A.1 Temporal variations of the pollutant and meteorological parameters from TCEQ CAMS sites

Hourly and daily averaged data from central monitoring sites help reflect temporal and spatial variability in pollutant concentrations. Pollutant (ozone) and meteorological data (temperature, relative humidity, and resultant wind speed) from six TCEQ CAMS stations were obtained from the TCEQ website. The hourly averaged data was pooled into 48-hr averages to correlate with the 48-hr integrated PM data obtained from the four schools. Integrated pollutant measurements obtained from indoor and outdoor locations at the four schools might show spatial variations, but exhibit temporal variability similar to central monitoring sites. Figures A-1, A-2, A-3, and A-4 are the temporal variations for ozone, temperature, relative humidity, and resultant wind speed, respectively, for the study period.

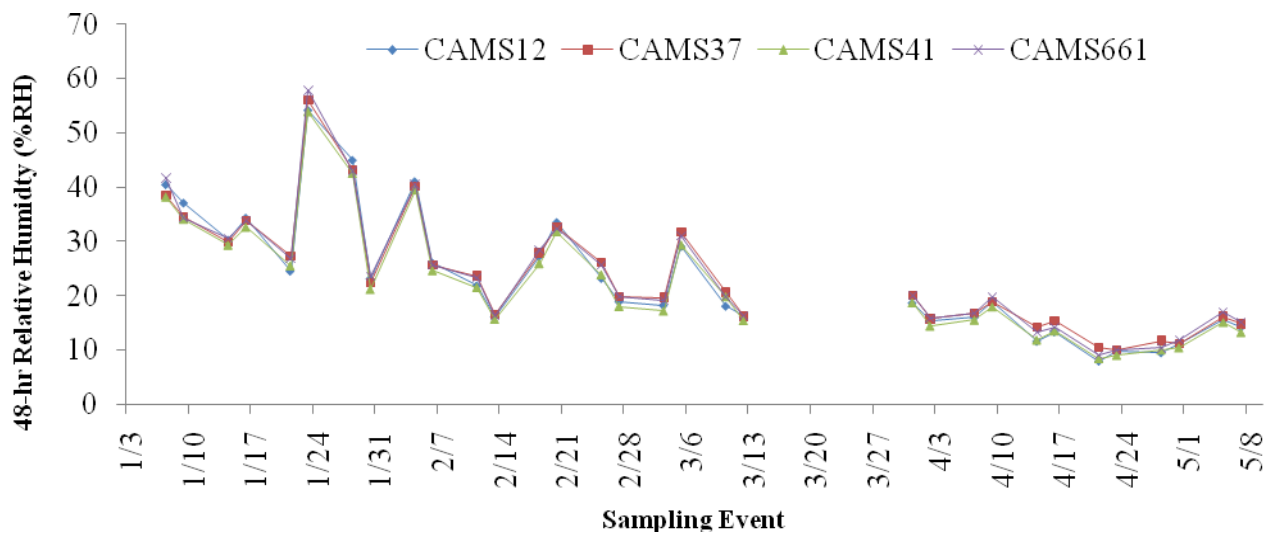


**Figure A-1: Temporal variation for 48-hr ozone at TCEQ CAMS sites**

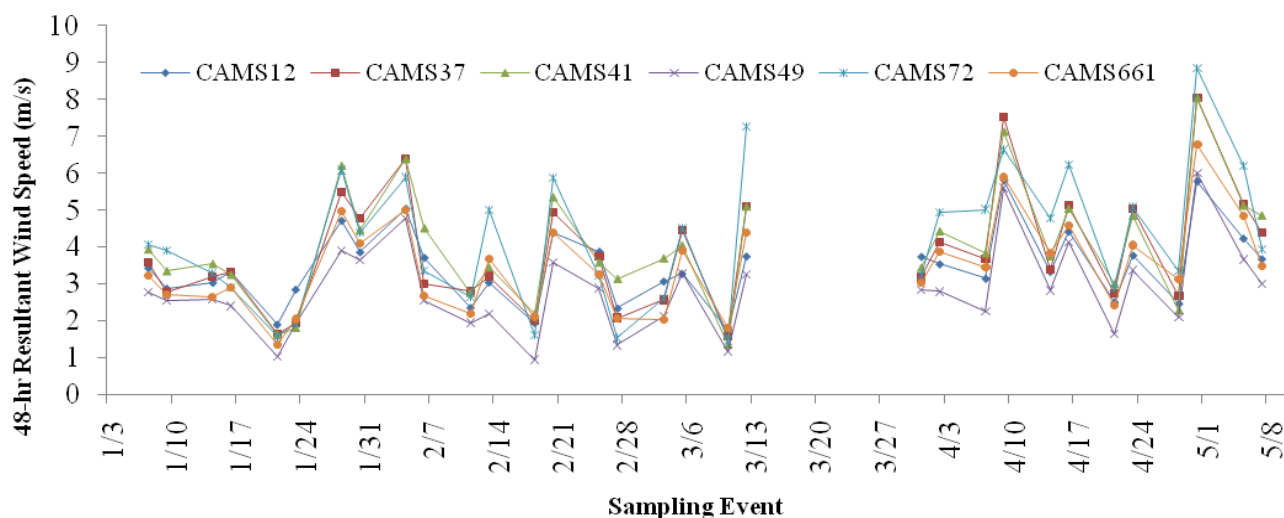




**Figure A-2: Temporal variation for 48-hr Temperature at TCEQ CAMS sites**



**Figure A-3: Temporal variation for 48-hr Relative Humidity at TCEQ CAMS sites**



**Figure A-4: Temporal variation for 48-hr Relative Humidity at TCEQ CAMS sites**

## A.2 Inter-site Pearson Correlation Coefficients for Meteorological Parameters

Pearson correlation coefficients were calculated for ozone, humidity, and temperature from the six TCEQ CAMS stations. The p-value for all the correlations is less than 0.001.

**Table A-1: Correlations of 48-hr average TCEQ CAMS O<sub>3</sub> Data (Jan01- May 30, 2008),  
p< 0.001**

Sites	CAMS 12	CAMS 37	CAMS 41	CAMS 49	CAMS 72	CAMS 661
CAMS 12 (n=63)	1	0.916	0.966	0.921	0.932	0.856
CAMS 37 (n=64)		1	0.955	0.976	0.911	0.787
CAMS 41 (n=64)			1	0.948	0.947	0.863
CAMS 49 (n=64)				1	0.918	0.828
CAMS 72 (n=65)					1	0.877
CAMS 661 (n=59)						1

Table A-1 presents the Pearson's correlations for the ozone data from the six TCEQ CAMS stations. As expected, for ozone, which is a regional pollutant, the data among the various CAMS stations is highly correlated. The Pearson's Correlation Coefficients were higher than 0.78 across all the CAMS stations. The highest coefficient of 0.976 was observed between CAMS 37 and CAMS 49. The p-value was less than 0.001 for all the cases.

**Table A-2: Correlations of 48-hr average TCEQ CAMS Temperature Data (Jan01- May 30, 2008),  $p < 0.001$**

Sites	CAMS 12	CAMS 37	CAMS 41	CAMS 49	CAMS 72	CAMS 661
CAMS 12 (n =65)	1	0.998	0.999	0.996	0.995	0.998
CAMS 37 (n=65)		1	0.999	0.998	0.997	0.999
CAMS 41 (n=65)			1	0.998	0.997	0.998
CAMS 49 (n=65)				1	0.994	0.996
CAMS 72 (n=65)					1	0.998
CAMS 661 (n=65)						1

**Table A-3: Correlations of 48-hr average TCEQ CAMS RH Data (Jan01- May 30, 2008),  $p < 0.001$**

Sites	CAMS 12	CAMS 37	CAMS 41	CAMS 661
CAMS 12 (n =65)	1	0.992	0.997	0.995
CAMS 37 (n=65)		1	0.998	0.996
CAMS 41 (n=65)			1	0.997
CAMS 661 (n=65)				1

As expected, both the temperature and the relative humidity data are highly correlated, with values greater than 0.99 ( $p < 0.001$ ). Table A-2 and A-3 show the correlations of the 48-hr average data for both these parameters.

### **A.3 Pearson's Correlation Coefficients between pollutants and meteorological parameters across TCEQ CAMS sites**

Pearson's Correlation Coefficients were computed among various meteorological parameters across the six CAMS sites. CAMS 12 (UTEP) and CAMS 41 (Chamizal) monitored the maximum parameters across the six CAMS sites. Table A-4 presents the correlation coefficients among various parameters and the associated 'p' values.

Table A-4 shows a strong negative correlation between nitrogen dioxide and ozone. The relationship between these two parameters is very significant ( $p < 0.001$ ). For CAMS 12, the r-value is -0.705, and for CAMS 41, the r-value is -0.818. A negative correlation exists between nitrogen dioxide and  $PM_{10}$ . However, these values are not significant because of high 'p' values. A negative but significant correlation was observed between nitrogen dioxide and resultant wind

speed. The 'r' values ranged from -0.702 to -0.824 across the three CAMS stations (p-value <0.001). Moderately significant correlations were observed between nitrogen dioxide and temperature, but not between nitrogen dioxide and relative humidity.

Significantly moderate correlations were observed between ozone and relative wind speed (p<0.001). The Pearson's r ranged from 0.545 to 0.669 for the six CAMS stations. Ozone was also moderately correlated with temperature for all the CAMS stations (p<0.001). A negative but moderate correlation was observed between ozone and relative humidity. The 'r' values ranged from -0.451 to -0.631 (p<0.001).

**Table A-4: Pearson Correlation Coefficients between the various meteorological parameters and pollutant variables across the six CAMS sites**

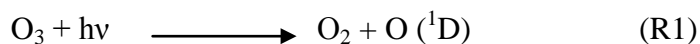
Parameter	CAMS 12		CAMS 37		CAMS 41		CAMS 49		CAMS 72		CAMS 661	
	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
NO <sub>2</sub> -O <sub>3</sub>	-0.705	<0.001	-0.757	<0.001	-0.818	<0.001	-	-	-	-	-	-
NO <sub>2</sub> -PM <sub>2.5</sub>	0.241	0.057	-	-	0.044	0.738	-	-	-	-	-	-
NO <sub>2</sub> -PM <sub>10</sub>	-0.131	0.301	-	-	-0.139	0.291	-	-	-	-	-	-
NO <sub>2</sub> -RWS	-0.824	<0.001	-0.702	<0.001	-0.777	<0.001	-	-	-	-	-	-
NO <sub>2</sub> -T	-0.379	0.002	-0.265	0.033	-0.413	0.001	-	-	-	-	-	-
NO <sub>2</sub> -RH	0.095	0.449	0.030	0.813	0.180	0.168	-	-	-	-	-	-
O <sub>3</sub> -P <sub>2.5</sub>	0.036	0.782	-	-	0.189	0.135	-	-	-	-	-	-
O <sub>3</sub> -PM <sub>10</sub>	0.243	0.057	-	-	0.336	0.007	0.391	0.001	-	-	-	-
O <sub>3</sub> -RWS	0.642	<0.001	0.663	<0.001	0.669	<0.001	0.634	<0.001	0.599	<0.001	0.545	<0.001
O <sub>3</sub> -T	0.597	<0.001	0.500	<0.001	0.580	<0.001	0.570	<0.001	0.613	<0.001	0.655	<0.001
O <sub>3</sub> -RH	-0.505	<0.001	-0.451	<0.001	-0.504	<0.001	-	-	-	-	-0.631	<0.001
PM <sub>2.5</sub> -PM <sub>10</sub>	0.776	<0.001	-	-	0.748	<0.001	-	-	-	-	-	-
PM <sub>2.5</sub> -RWS	0.008	0.949	-	-	-0.035	0.780	-	-	-	-	-	-
PM <sub>2.5</sub> -T	0.247	0.051	-	-	0.407	0.001	-	-	-	-	-	-
PM <sub>2.5</sub> -RH	-0.279	0.027	-	-	-0.327	0.008	-	-	-	-	-	-
PM <sub>10</sub> -RWS	0.419	0.001	-	-	0.377	0.002	0.468	<0.001	-	-	-	-
PM <sub>10</sub> -T	0.196	0.120	-	-	0.272	0.028	0.393	0.001	-	-	-	-
PM <sub>10</sub> -RH	-0.219	0.082	-	-	-0.301	0.015	-	-	-	-	-	-
RWS-T	0.235	0.060	0.244	0.050	0.216	0.084	0.217	0.083	0.340	0.006	0.325	0.008
RWS-RH	-0.079	0.534	-0.177	0.159	-0.143	0.254	-	-	-	-	-0.170	0.175
T-RH	-0.587	<0.001	-0.568	<0.001	-0.573	<0.001	-	-	-	-	-0.577	<0.001

Fine particulate matter was strongly correlated with PM<sub>10</sub> for CAMS 12, and CAMS 41 (p<0.001). PM<sub>2.5</sub> and relative humidity were negatively but significantly correlated at the 0.05 level. The r value of -0.279 and -0.327 were obtained for these two parameters at CAMS 12 and CAMS 41 respectively. For PM<sub>10</sub> and relative wind speed, a significant but weak correlation was observed (r = 0.419, p=0.0001 for CAMS 12; r = 0.377, p=0.002 for CAMS 41; r = 0.468,

p<0.001). Temperature and relative humidity had a negatively moderate correlation. The association was significant with p<0.001. The 'r' value of -0.587 was observed between these two parameters at CAMS 12.

#### **A.4 Spearman's Correlation Coefficients between meteorological parameters across the four schools and their respective CAMS sites (96-hr averages)**

Spearman's Correlation Coefficients were also computed between the pollutant metrics monitored the four school sites and their corresponding TCEQ CAMS sites. The values were averaged over a 96-hr period to correspond with the 96-hr NO<sub>2</sub> data. Both indoor and outdoor pollutant variables were involved in this analysis. Pollutant metrics from school EP-A were correlated with the meteorological and pollutant parameters from CAMS72. The correlations are shown in Table 8-5. Similarly, school EP-B was correlated with CAMS 37 (Table A-6), school CJ-A with CAMS 49 (Table A-7), and school CJ-B with CAMS 661 (Table A-8). The CAMS sites were selected on the basis of their proximity to their respective schools. Correlations with single asterisk are significant at the 0.05 level and correlations significant at 0.01 level are in double asterisk. Correlations were statistically robust but negative between ozone and nitrogen dioxide ( $r = -0.6$ ,  $p < 0.01$ ), for both indoor and outdoor microenvironments. Ozone was also negatively correlated with relative humidity ( $r = -0.8$ ). Relative humidity has an offsetting effect on ozone (Johnson et al., 1999; Jacob et al., 2009). Increasing relative humidity increases ozone loss as per the following reaction:



where (R2) competes with reaction of the excited oxygen atom O (<sup>1</sup>D) with N<sub>2</sub> or O<sub>2</sub> stabilizing O (<sup>1</sup>D) to the ground-state atom O (<sup>3</sup>P), which eventually reacts with O<sub>2</sub> to return ozone. Ozone decreases with increasing water vapor due to (R2).

Correlations between ozone and resultant wind speed were significantly strong and positive at 0.01 level. These correlations varied from  $r = 0.69$  to  $0.90$  across the CAMS sites. This could be attributed to weak wind speeds that may increase ozone concentrations due to longer reaction time and increased aerodynamic resistance to dry deposition (Baertsch-Ritter et al., 2004; Dawson et al., 2007; Jacob et al., 2009).

Significantly robust ( $r > 0.65$ ) and positive association was observed between ozone and temperature and is in line with observations made by Cox and Chu, (1995). An increase in temperature results in higher ozone concentrations due to photochemical reactions. These correlations were statistically significant too at the 0.01 level. Wise and Comrie, (2005) have reported strong correlations or elevated ozone levels and temperature in the polluted metropolitan areas of the southwest US. Black carbon was moderately but negatively correlated with resultant wind speed ( $-0.5$ ). This suggests that black carbon concentrations may not be influenced by wind speed.

Statistically significant and positive correlations between the PM species and temperature were observed across the two El Paso schools and their corresponding CAMS sites ( $r > 0.5$ ). One of the factors influencing this observation may be the increased formation of the secondary aerosol with increased solar intensity during daylight (Grivas et al., 2004). However, caution should be exercised while interpreting these results as these correlations are based on 96-hr averages. Weak and non-significant correlations were observed for the CJ-A – CAMS 49 and CJ-B – CAMS 661 site pairs. Negative but statistically significant correlations were observed between the PM species and relative humidity across all the four schools and their corresponding CAMS sites. This could be attributed to the efficient scavenging of the PM species by precipitation as the wet deposition provides the main PM sink (Jacob et al., 2009). Another

plausible explanation for this observation could be the importance of dust as a substantial PM source in this region. This observation has been documented by other researchers as well in the southwestern US (Wise and Comrie, 2005).

**Table A-5: Spearman's correlation coefficients for the pollutant and meteorological parameters between school EP-A and CAMS 72**

Parameters	P2.5 IN	PM2.5 OUT	PMC IN	PMC OUT	PM10 IN	PM10 OUT	BC IN	BC OUT	NO2 IN	NO2 OUT	CAMS72 O3	CAMS72 RWS	CAMS72 T
CAMS72 O3	.665*	.824**	.789**	.775**	.789**	.808**	-.315	-.670**	-.693**	-.662**	1		
	.013	.000	.000	.001	.001	.001	.253	.006	.003	.005	.		
	13	16	15	15	14	13	15	15	16	16	16		
CAMS72 RWS	.505	.647**	.464	.575*	.521	.648*	-.131	-.436	-.580*	-.756**	.697**	1	
	.078	.007	.081	.025	.056	.017	.643	.104	.019	.001	.003	.	
	13	16	15	15	14	13	15	15	16	16	16	16	
CAMS72 T	.423	.871**	.775**	.718**	.767**	.736**	-.140	-.447	-.372	-.385	.771**	.485	1
	.150	.000	.001	.003	.001	.004	.620	.095	.156	.141	.000	.057	.
	13	16	15	15	14	13	15	15	16	16	16	16	16

**Table A-6: Spearman's correlation coefficients for the pollutant and meteorological parameters between school EP-B and CAMS 37**

Parameters	PM2.5 IN	PM2.5 OUT	PM10-2.5 IN	PM10-2.5 OUT	PM10 IN	PM10 OUT	BC IN	BC OUT	NO2 IN	NO2 OUT	CAMS37 NO2	CAMS37 O3	CAMS37 RWS	CAMS37 T	CAMS37 RH
CAMS37 O3	.780**	.666**	.886**	.305	.736**	.521	-.508	-.678**	.350	-.682**	-.846**	1			
	.002	.009	.000	.288	.004	.056	.063	.008	.201	.007	.000	.			
	13	14	14	14	13	14	14	14	15	14	15	15			
CAMS37 RWS	.776**	.600*	.650**	.089	.596*	.386	-.672**	-.690**	.221	-.617*	-.838**	.907**	1		
	.001	.018	.009	.752	.025	.156	.006	.004	.412	.014	.000	.000	.		
	14	15	15	15	14	15	15	15	16	15	16	15	16		
CAMS37 T	.771**	.707**	.761**	.696**	.701**	.771**	.120	-.127	.485	-.434	-.309	.646**	.409	1	
	.001	.003	.001	.004	.005	.001	.671	.652	.057	.106	.244	.009	.116	.	
	14	15	15	15	14	15	15	15	16	15	16	15	16	16	
CAMS37 RH	-.736**	-.736**	-.804**	-.693**	-.679**	-.796**	-.114	.206	-.391	.572*	.382	-.771**	-.500*	-.912**	1
	.003	.002	.000	.004	.008	.000	.685	.462	.134	.026	.144	.001	.049	.000	.
	14	15	15	15	14	15	15	15	16	15	16	15	16	16	16



**Table A-7: Spearman's correlation coefficients for the pollutant and meteorological parameters between school CJ-A and CAMS 49**

Parameters	PM2.5 IN	PM2.5 OUT	PMC IN	PMC OUT	PM10 IN	PM10 OUT	BC IN	BC OUT	NO2 IN	NO2 OUT	PM10 CAMS49	CAMS49 O3	CAMS49 RWS	CAMS49 T
CAMS49 O3	.098	-.203	.364	-.073	.145	-.118	-.888**	-.874**	-.686**	-.829**	.525*	1		
	.762	.527	.272	.832	.670	.729	.000	.000	.005	.000	.044	.		
	12	12	11	11	11	11	12	12	15	15	15	15		
CAMS49 RWS	-.143	-.110	.098	-.503	-.084	-.413	-.456	-.522	-.362	-.462	.215	.689**	1	
	.642	.721	.762	.095	.795	.183	.117	.067	.169	.072	.425	.004	.	
	13	13	12	12	12	12	13	13	16	16	16	15	16	
CAMS49 T	.462	.330	.483	.455	.392	.427	-.747**	-.615*	-.882**	-.717**	.727**	.679**	.275	1
	.112	.271	.112	.138	.208	.167	.003	.025	.000	.002	.001	.005	.302	.
	13	13	12	12	12	12	13	13	16	16	16	15	16	16

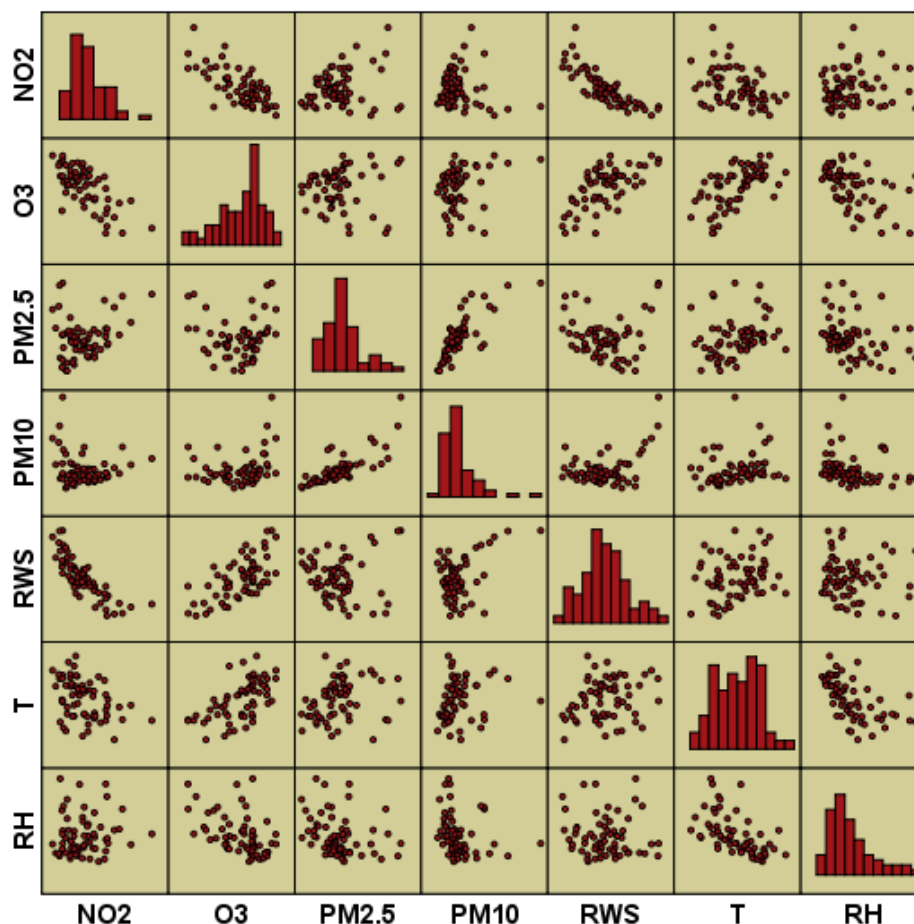
**Table A-8: Spearman's correlation coefficients for the pollutant and meteorological parameters between school CJ-B and CAMS 661**

Parameters	PM2.5 IN	PM2.5 OUT	PMC IN	PMC OUT	PM10 IN	PM10 OUT	BC IN	BC OUT	NO2 IN	NO2 OUT	CAMS661 O3	CAMS661 RWS	CAMS661 T	CAMS661 RH
CAMS661O3	.030	.030	.067	.050	-.200	-.067	-.855**	-.709*	-.771**	-.345	1			
	.934	.934	.865	.898	.606	.865	.002	.022	.001	.227	.			
	10	10	9	9	9	9	10	10	14	14	14			
CAMS661RWS	.056	.042	.300	-.345	-.009	-.291	-.545	-.517	-.471	-.603*	.705**	1		
	.863	.897	.370	.298	.979	.385	.067	.085	.066	.013	.005	.		
	12	12	11	11	11	11	12	12	16	16	14	16		
CAMS661T	.385	.427	.518	.409	.318	.345	-.559	-.343	-.844**	-.118	.798**	.465	1	
	.217	.167	.102	.212	.340	.298	.059	.276	.000	.664	.001	.070	.	
	12	12	11	11	11	11	12	12	16	16	14	16	16	
CAMS661RH	-.182	-.238	-.409	-.209	-.100	-.155	.692*	.573	.850**	.126	-.824**	-.447	-.918**	1
	.572	.457	.212	.537	.770	.650	.013	.051	.000	.641	.000	.083	.000	.
	12	12	11	11	11	11	12	12	16	16	14	16	16	16

### **A.5 Scatter Plot Matrix for 48-hr Pollutant and Meteorological Parameters**

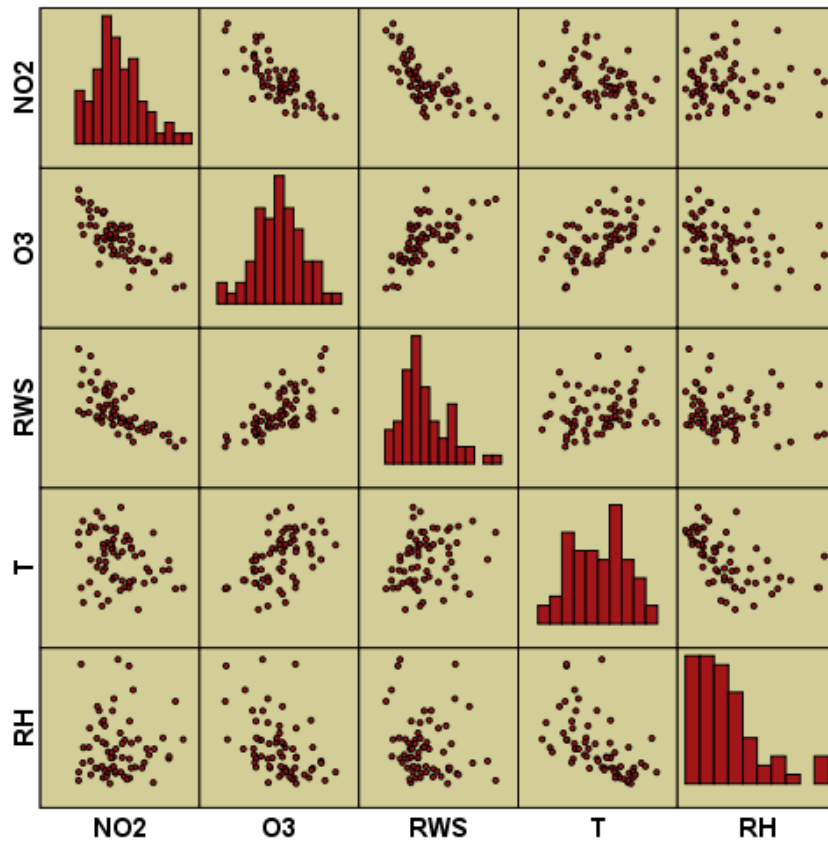
Scatter plot matrices were plotted for various meteorological and pollutant parameters obtained from the six CAMS stations. These matrices show two-parameter relative scatter plots between the various parameters. The relative distribution for each parameter is also shown as a bar chart. Data from these sites was pooled to a 48-hour average- Monday to Wednesday and Wednesday to Friday. The averaging was done to reflect the time frame of the actual sampling schedule for PM and NO<sub>2</sub> monitoring at the four schools. Nitrogen dioxide and ozone concentrations are in ppb. PM<sub>2.5</sub> and PM<sub>10</sub> concentrations are in µg/m<sup>3</sup>. Temperature and relative humidity are in °C and %, respectively. Resultant wind speed is in m/s. Some of the relationships are in a linear fashion, some are non-linear and others appear to be totally unrelated.

Figure A-5 is the scatter plot matrix for the various parameters from TCEQ CAMS Site for the time period spanning from January 01 to May 30 2008. From the figure it is obvious that there exists a negative correlation between ozone and nitrogen dioxide, which was expected during winter and spring season. Ozone pollution in any urban area is mostly a summer problem because of the photochemical nature of the source (Jacob et al., 2009). A negative correlation was also observed between temperature and relative humidity ( $r = -0.587$ ,  $p < 0.001$ ). Ozone was moderately correlated with resultant wind speed, and temperature but negatively correlated with relative humidity ( $p < 0.001$ ).



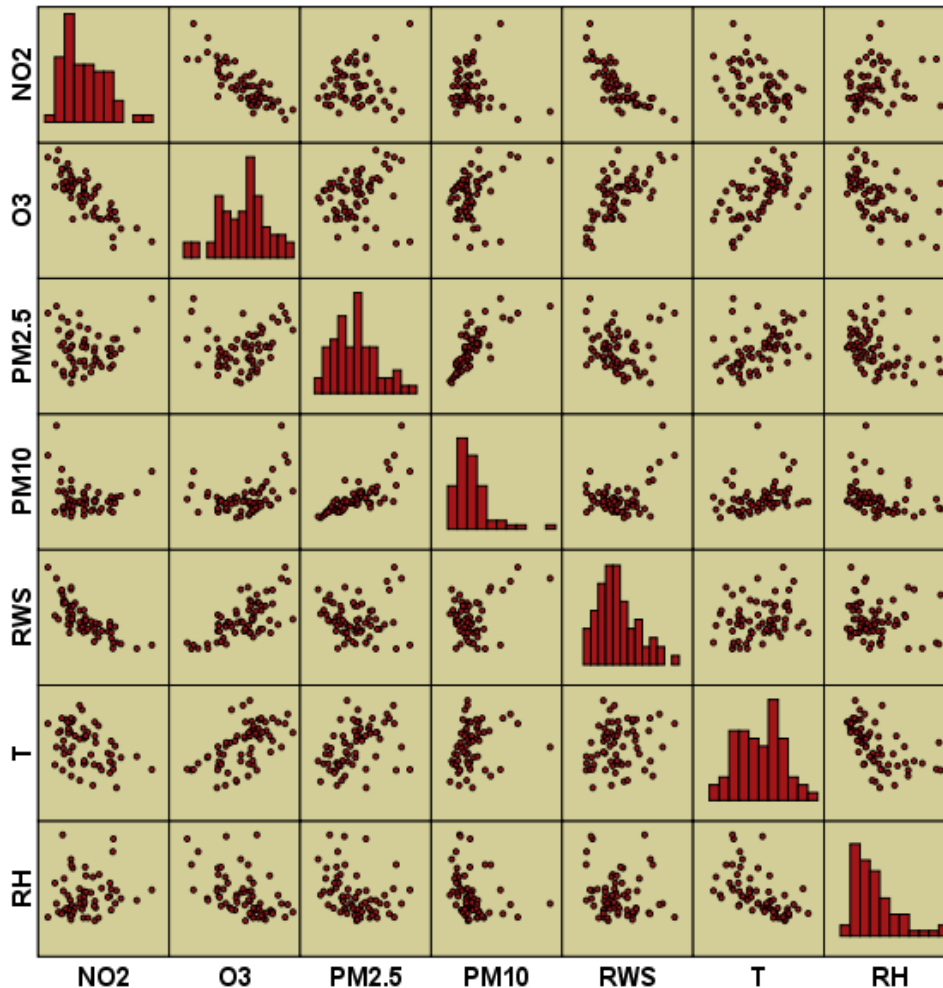
**Figure A-5: Scatter plot Matrix of 48-hr meteorological parameters and other pollutants from TCEQ CAMS 12 site.**

Figures A-6 and A-7 are the scatter plot matrices for the meteorological parameters from CAMS 37 and CAMS 41 respectively. For CAMS 37 site, we see almost a linear negative correlation between nitrogen dioxide and ozone ( $r = -0.757$ ,  $p < 0.001$ ). Similarly a moderately negative correlation, as it evident from the figure was observed between temperature and relative humidity. Ozone was moderately correlated with resultant wind speed and temperature ( $p < 0.001$ ). But a negative correlation was obtained between ozone and relative humidity ( $r = -0.451$ ,  $p < 0.001$ ). A fair amount of scatter was observed between relative humidity and nitrogen dioxide signifying that there is hardly any correlation between these two parameters.



**Figure A-6: Scatter plot of 48-hr meteorological parameters and other pollutants from TCEQ CAMS 37 site.**

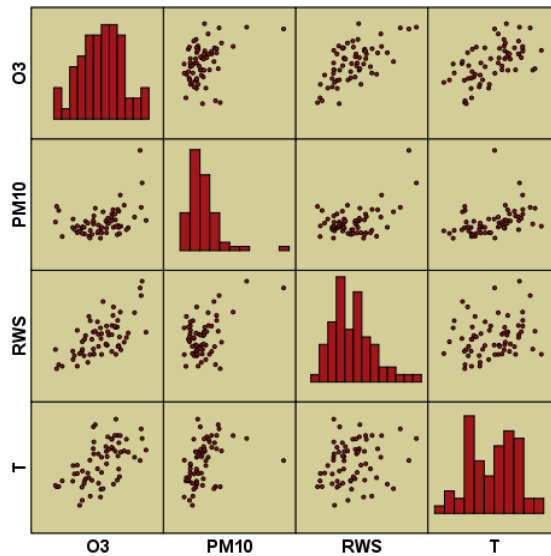
As is evident from a visual analysis of Figure A-6, there exists a tight linear relationship between ozone and nitrogen dioxide ( $r = -0.818$ ,  $p < 0.001$ ). Ozone being a regional pollutant is homogeneous in the Paso del Norte air shed.  $PM_{10}$  seems to be more correlated with the resultant wind speed than  $PM_{2.5}$ . Similar to the other CAMS sites, ozone is moderately correlated with temperature and resultant wind speed. These relationships are statistically significant ( $p < 0.001$ ). Temperature and nitrogen dioxide are negatively correlated ( $r = -0.413$ ,  $p = 0.001$ ). Also, a significant scatter is seen between nitrogen dioxide and relative humidity.



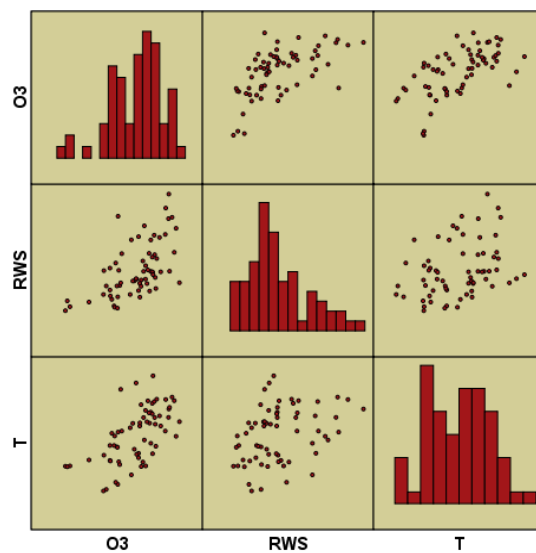
**Figure A-7: Scatter plot of 48-hr meteorological parameters and other pollutants from TCEQ CAMS 41 site.**

The scatter plots for meteorological and pollutant parameters from CAMS 49, 72 and CAMS 661 are shown in Figure A-8, A-9, and A-10, respectively. As is evident from Figure A-8, a moderate positive correlation exists between  $PM_{10}$  and resultant wind speed ( $r = 0.468$ ,  $p < 0.001$ ). A statistically significant but weak correlation was observed between ozone and  $PM_{10}$  at CAMS 49 ( $r = 0.391$ ,  $p = 0.001$ ). Figure A-9 is the scatter plot for the three parameters from CAMS 72 station. Ozone is moderately and positively correlated with temperature and relative humidity. Resultant wind speed and temperature are weakly correlated ( $r = 0.340$ ,  $p = 0.006$ ). Figure A-10 is the scatter plot matrix for the three meteorological and one pollutant parameter

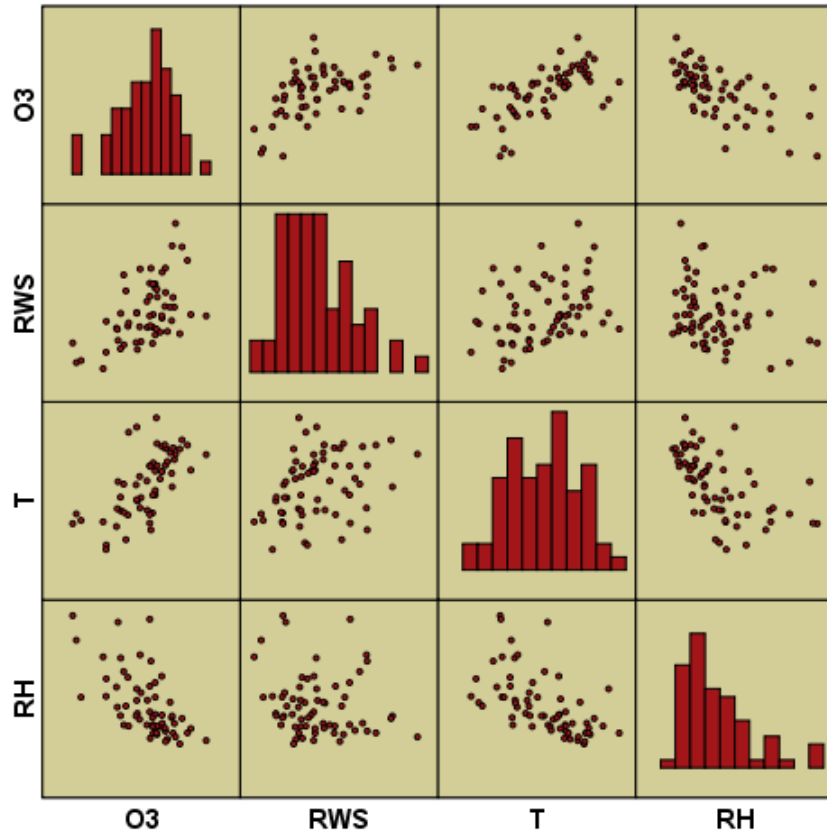
from CAMS661. A moderate but negative correlation was observed between temperature and relative humidity ( $r = -0.577$ ,  $p < 0.001$ ). There exists a moderate linear relationship between ozone and temperature ( $r = 0.655$ ,  $p < 0.001$ ) and ozone and resultant wind speed ( $r = 0.545$ ,  $p < 0.001$ ).



**Figure A-8: Scatter plot of 48-hr meteorological parameters and other pollutants from TCEQ CAMS 49 site**



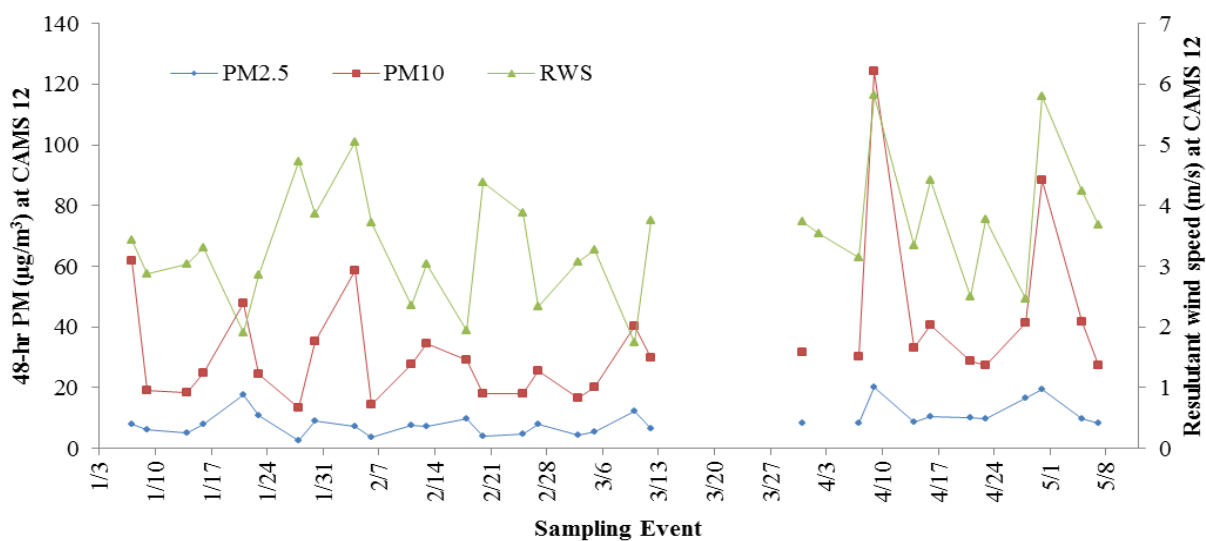
**Figure A-9: Scatter plot of 48-hr meteorological parameters and other pollutants from TCEQ CAMS 72 site.**



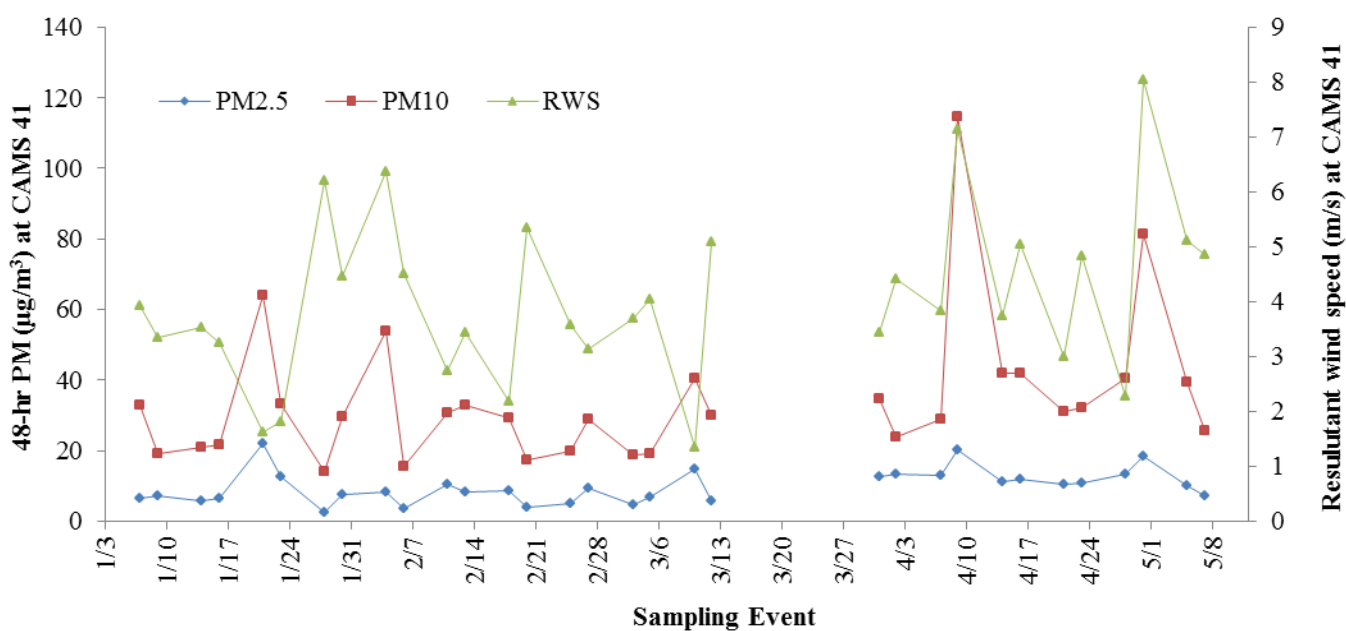
**Figure A-10: Scatter plot of 48-hr meteorological parameters and other pollutants from TCEQ CAMS 661 site.**

#### **A.6 Temporal variations of Outdoor PM and resultant wind speed at the four schools and CAMS sites**

Temporal variations of PM ( $PM_{2.5}$  and  $PM_{10}$ ) and the resultant wind speed for the four schools and two CAMS sites (CAMS 12 and CAMS 41) are plotted in Figures A-11 to A-16. These graphs reflect the concentration profile for particulate matter corresponding to the resultant wind speed for specific sampling event. High concentrations of PM in the Paso del Norte region is more pronounced during episodes of both low (stagnant) and high wind speeds. This is in line with previous studies conducted by Li et al. (2001) in this region.

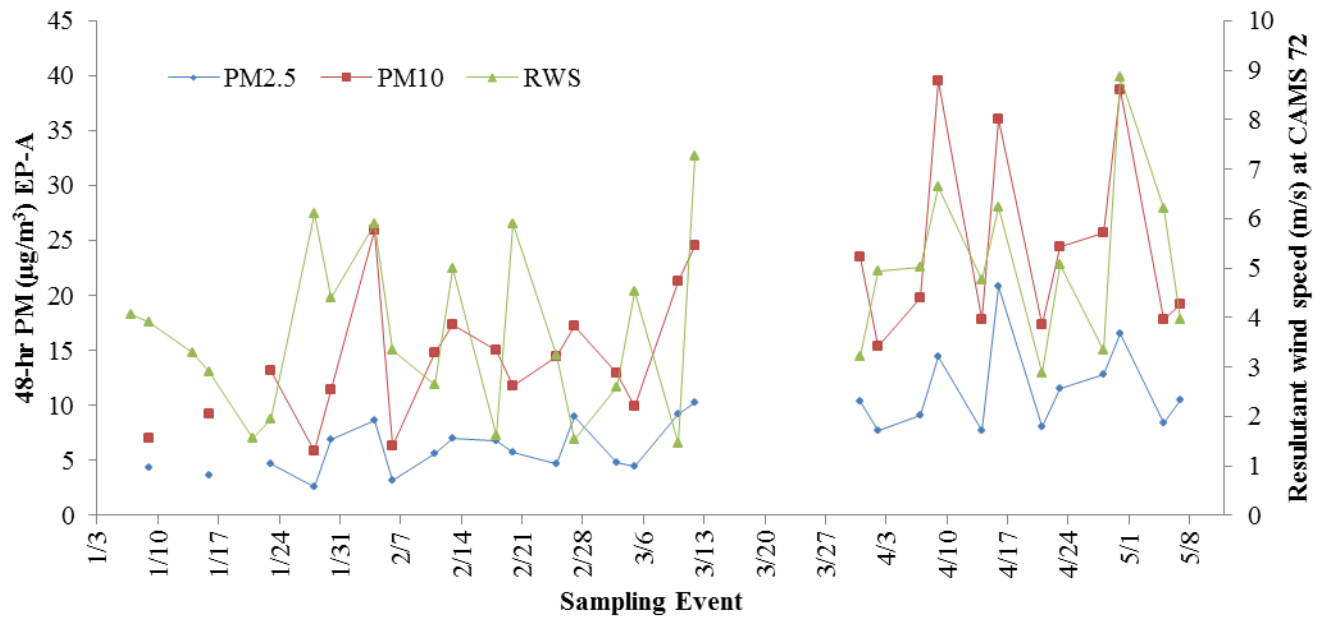


**Figure A-11: Temporal variations of PM and resultant wind speed at CAMS 12 for the sampling period.**

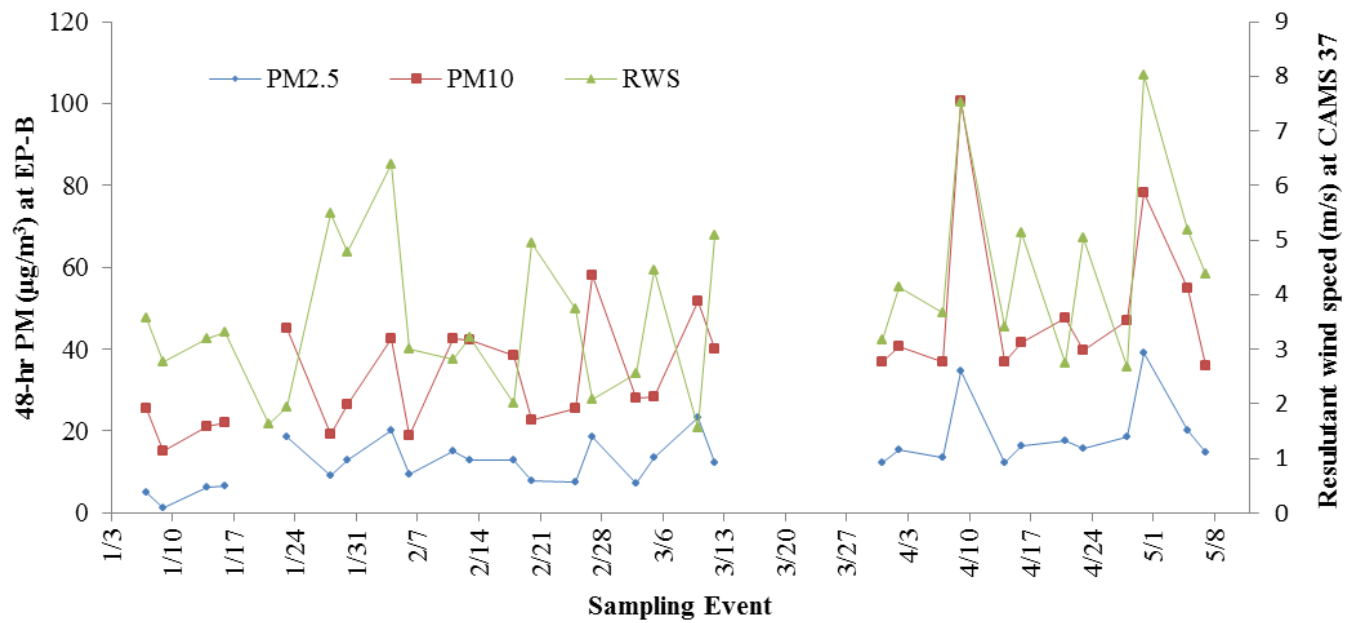


**Figure A-12: Temporal variations of PM and resultant wind speed at CAMS 41 for the sampling period.**

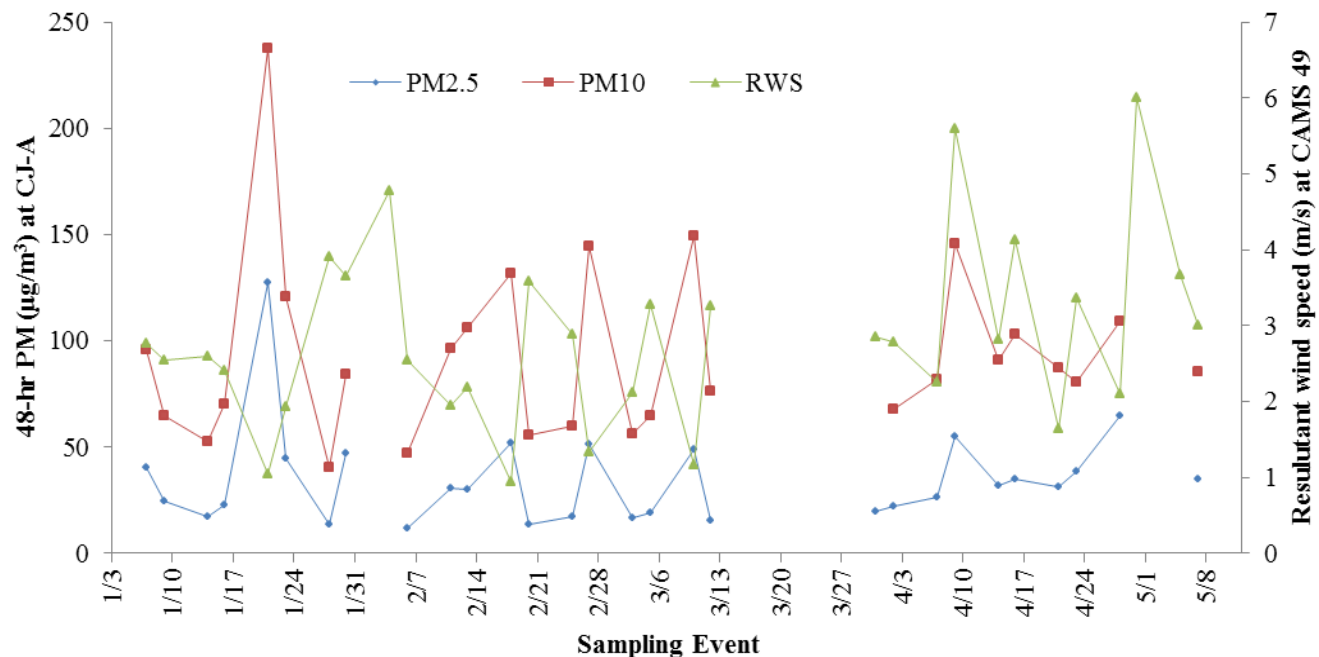




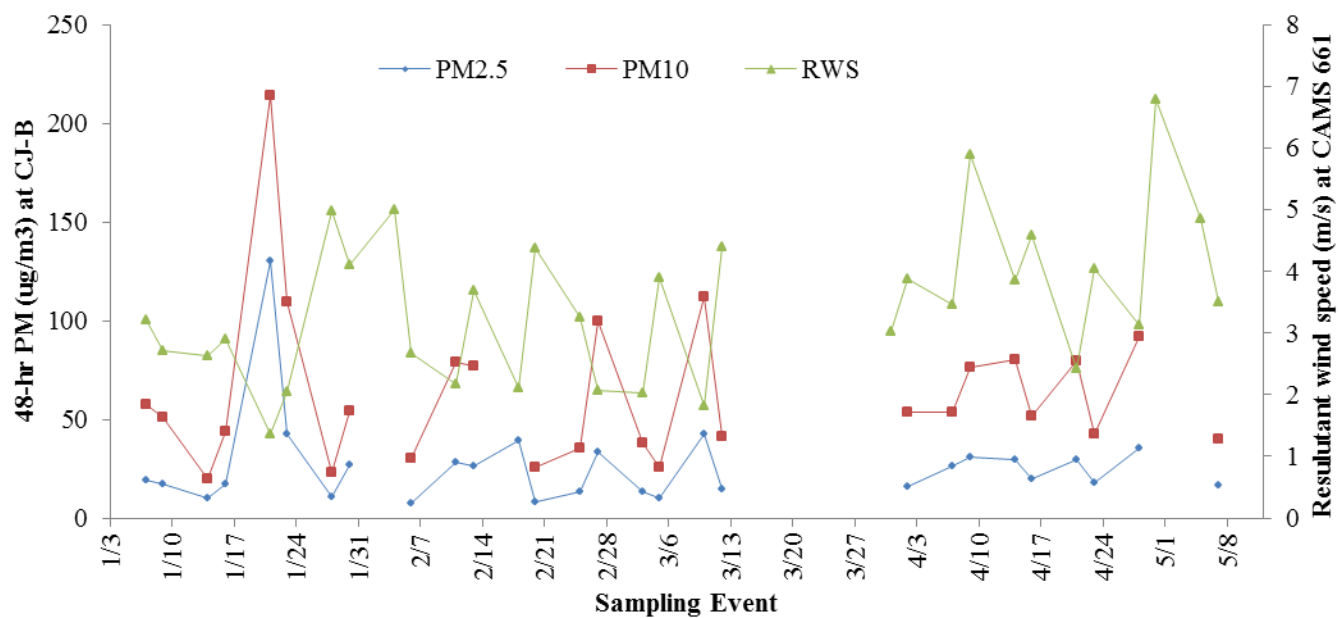
**Figure A-13: Temporal variations of PM and resultant wind speed at EP-A for the sampling period.**



**Figure A-14: Temporal variations of PM and resultant wind speed at EP-B for the sampling period.**



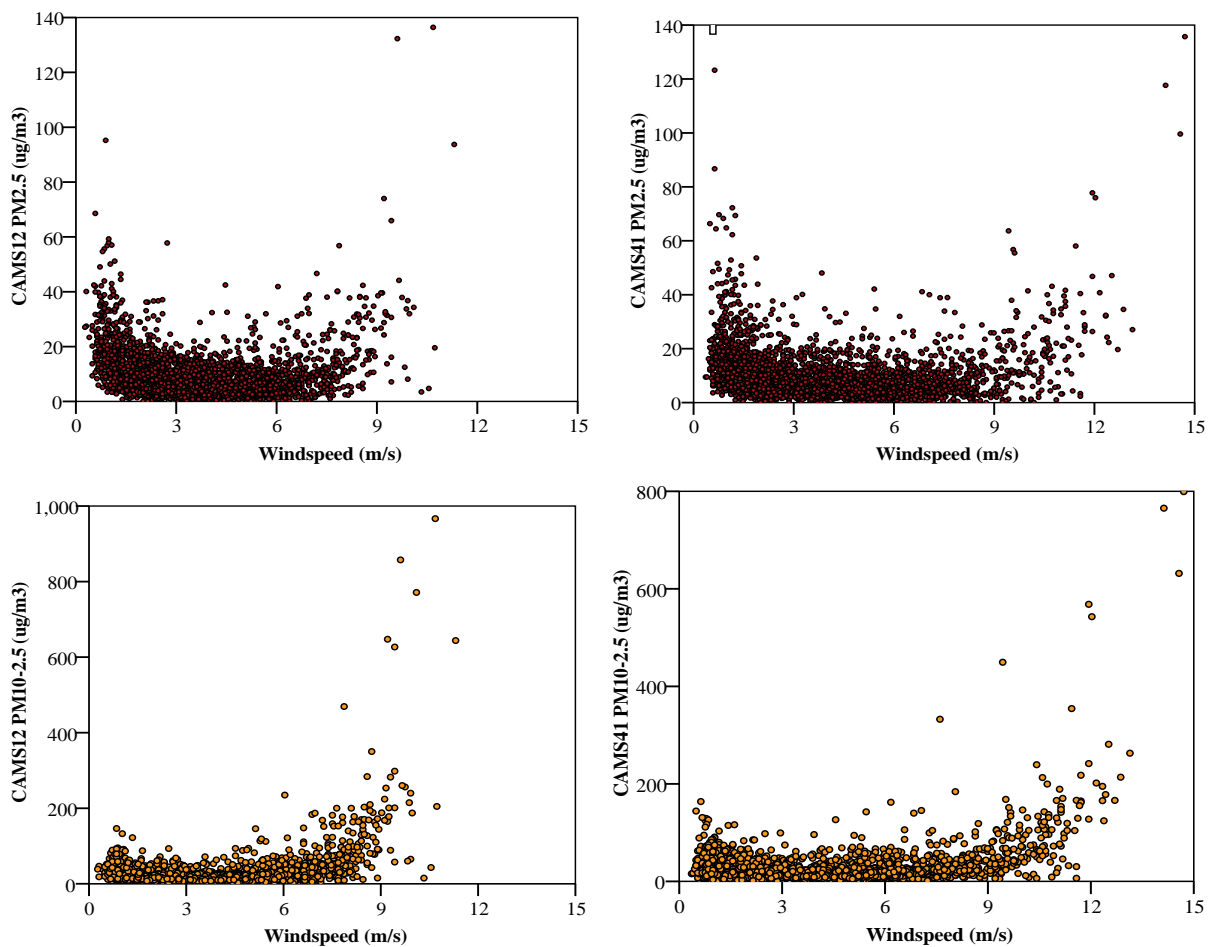
**Figure A-15: Temporal variations of PM and resultant wind speed at CJ-A for the sampling period.**

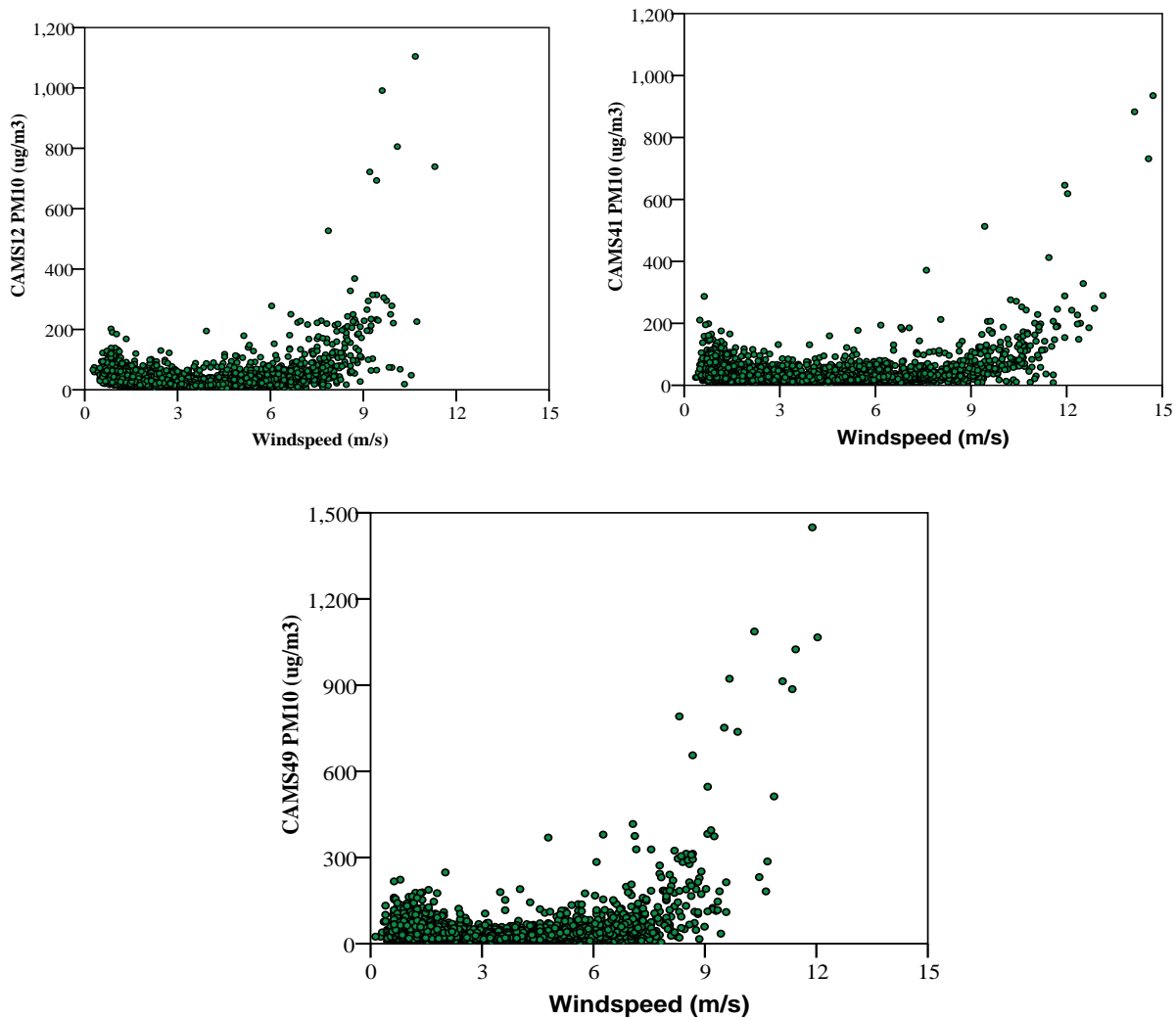


**Figure A-16: Temporal variations of PM and resultant wind speed at CJ-B for the sampling period.**

In addition to the temporal variations, scatter plots between the PM species and resultant wind speed were plotted to elucidate the role of windspeed in the transport or gravitational

settling of the PM particles. The scatter plots were based on the hourly PM and resultant wind speed data from the CAMS sites. Figure A-17 shows the various scatter plots between the PM species and the wind speed from the CAMS sites. It is obvious that for  $PM_{2.5}$ , high concentrations are observed during episodes of low (less than 2 m/s) and high (greater than 7 m/s) wind speed. For the coarse fraction of  $PM_{10}$ , high concentrations are observed at wind speed greater than 7 m/s.





**Figure A-17: Scatter plots for the PM and the wind speed at the CAMS Sites.**

## **Appendix B**

### **Morphological Properties of Particulate Matter Particles**

After the reflectance analysis, a few filters were subjected to SEM analysis in Dr. Larry Murr's laboratory in the Department of Metallurgical & Materials Engineering at UTEP. This analysis helped characterize the morphology, chemical and elemental composition of the PM<sub>2.5</sub> Teflon (Berube et al., 2004; Yue et al., 2006). This method also helps attribute the various sources from which such particles may originate. This chapter describes the details of the SEM analysis conducted on the sampled filters. The size range of the particles examined was from 0.2 to 20  $\mu\text{m}$ .

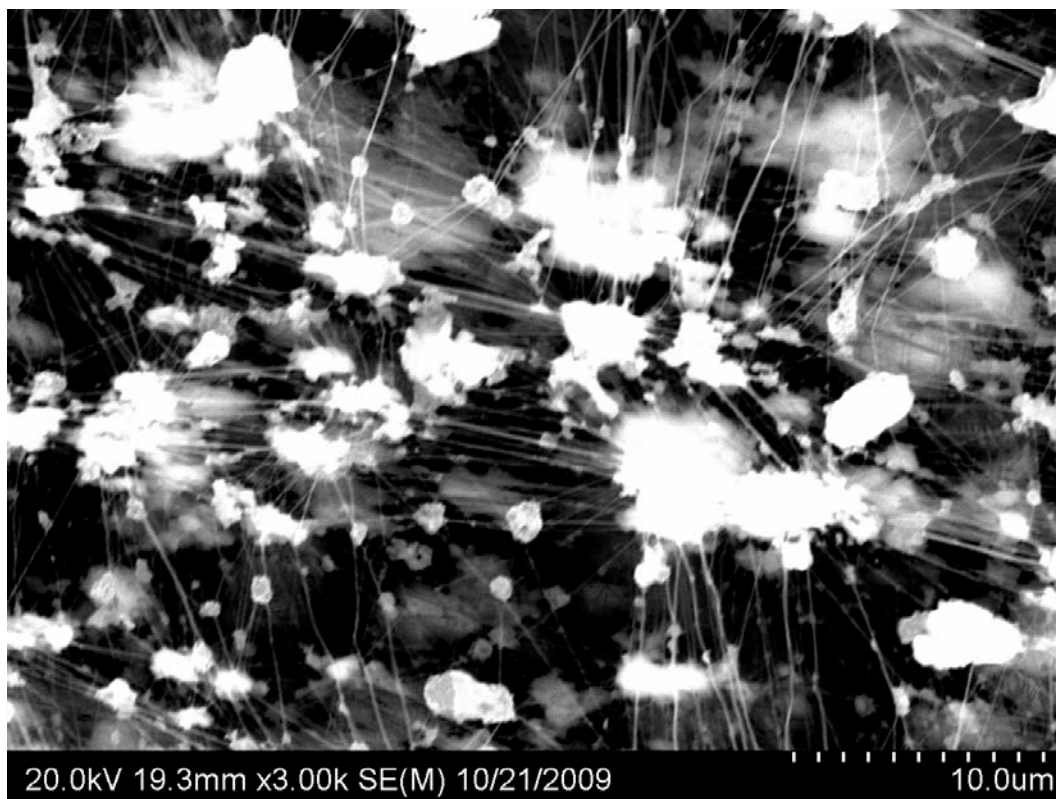
The analysis was conducted using Hitachi S4800 Scanning Electron Microscope with Energy Dispersive X-ray Spectroscopy (SEM/EDAx). The Teflon ring around each filter was cut using a blade and the filter was affixed to aluminum SEM stubs. The samples were coated with noble metals, either Gold or Palladium, using a Gatan Model 682 Precision Etching Coating System to achieve conductivity and vacuum durability and then scanned with the electron beam. In the EDAx, the signals were displayed according to the mean energy.

Some of the microphotographs generated with the SEM/EDX analysis are shown below. A visual analysis of the images suggests that the particles have diverse shapes. Some particles are present laminar or spherical shapers where some are in aggregated or cumulus forms.



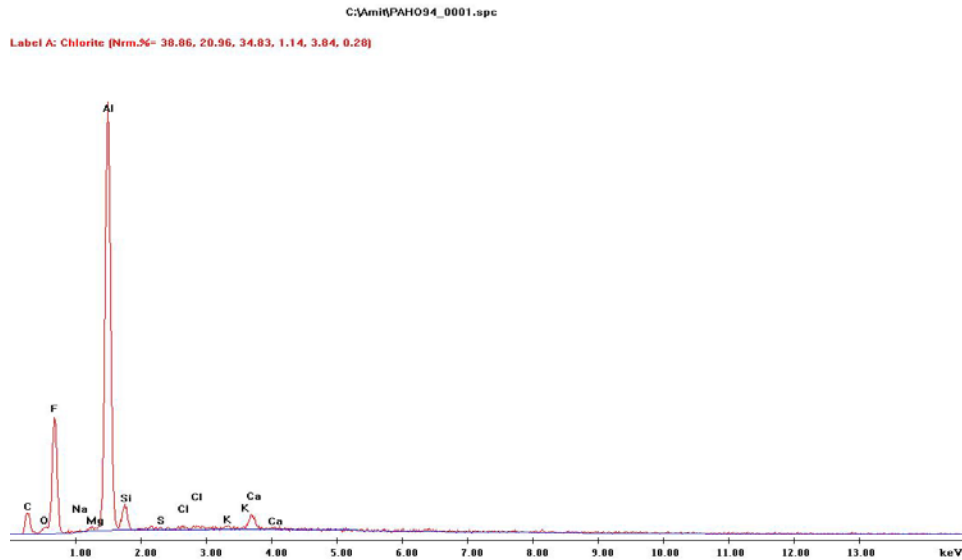
**Figure B-1: SEM Microphotographs of the PM<sub>2.5</sub> filter deployed at School EP-A (Outdoor) from 23<sup>rd</sup> – 25<sup>th</sup> January, 2008**

Figure B-1 shows the SEM image of the filter deployed at school EP-A (outdoor microenvironment) from 23<sup>rd</sup> – 25<sup>th</sup> January, 2008. Peaks of Aluminum and Platinum were observed in the EDX spectral profile of a single particle on the filter (not shown here). Energy in keV is on the X-axis of a graph, and the Y-axis denotes the number of signals per unit time. The concentration of an element is, thus, denoted by the length of each line. The filter collected 68  $\mu\text{g}$  of PM<sub>2.5</sub> and the PM<sub>2.5</sub> mass concentration was 4.67  $\mu\text{g}/\text{m}^3$ . The filter was showered with Palladium before the SEM analysis.

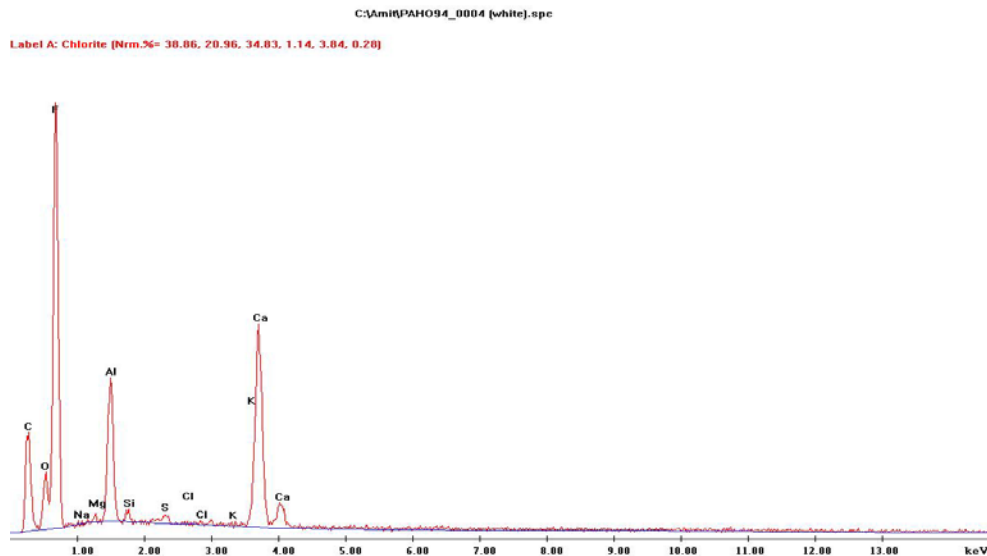


**Figure B-2: SEM Microphotographs of the PM<sub>2.5</sub> filter deployed at School EP-B (Outdoor) from 30<sup>th</sup> January - 1<sup>st</sup> February 2008.**

Figure B-2 is the SEM image of the filter deployed at school EP-B (outdoor microenvironment) from 30<sup>th</sup> January – 1<sup>st</sup> February 2008. The mass collected on the filter was 187.67  $\mu\text{g}$  with a concentration of 12.81  $\mu\text{g}/\text{m}^3$ . The filter was showered with Gold before the SEM analysis. Three EDX profiles of this filter are shown in Figures B-3 to B-5. These three profiles correspond to three different parts of the image in Figure B-2. The high peaks of aluminum (Al) observed in the EDX profiles, perhaps, may have a geological source.

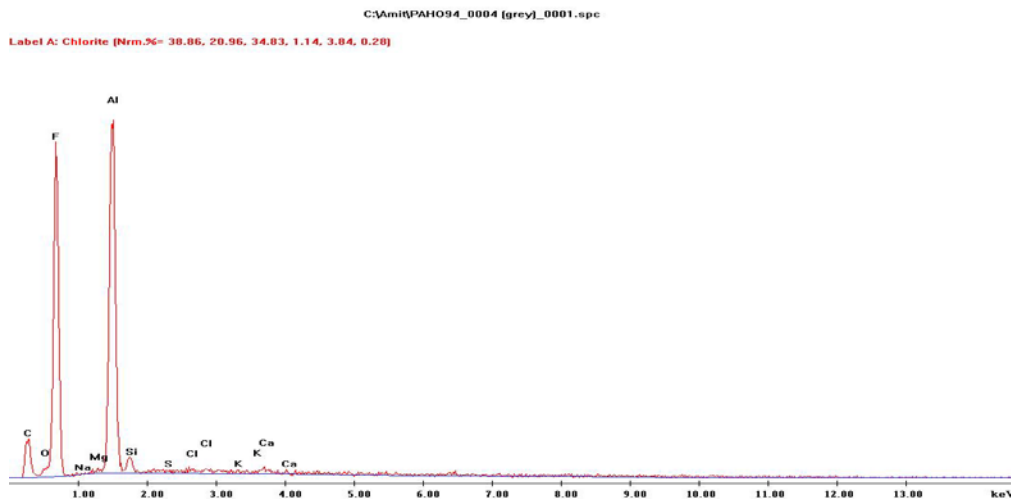


**Figure B-3: EDX Profile (corresponding to the black part of image) of the PM<sub>2.5</sub> filter deployed at School EP-B (Outdoor) from 30<sup>th</sup> January - 1<sup>st</sup> February 2008**

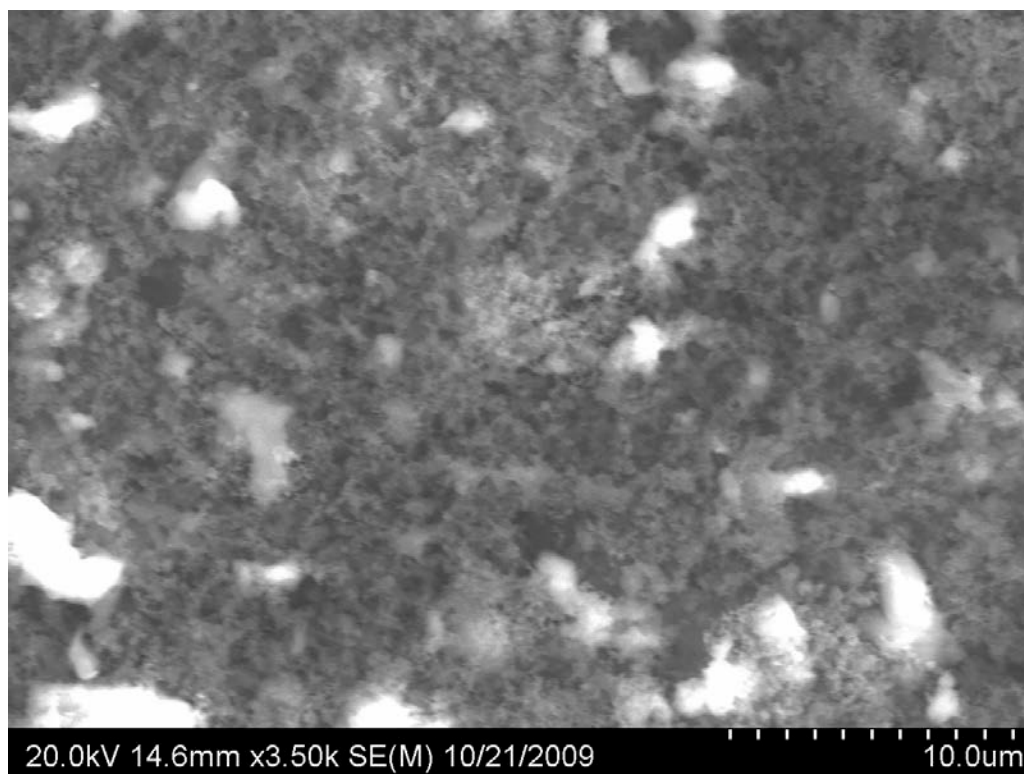


**Figure B-4: EDX Profile (corresponding to the white part of the image) of the PM<sub>2.5</sub> filter deployed at School EP-B (Outdoor) from 30<sup>th</sup> January – 1<sup>st</sup> February 2008**



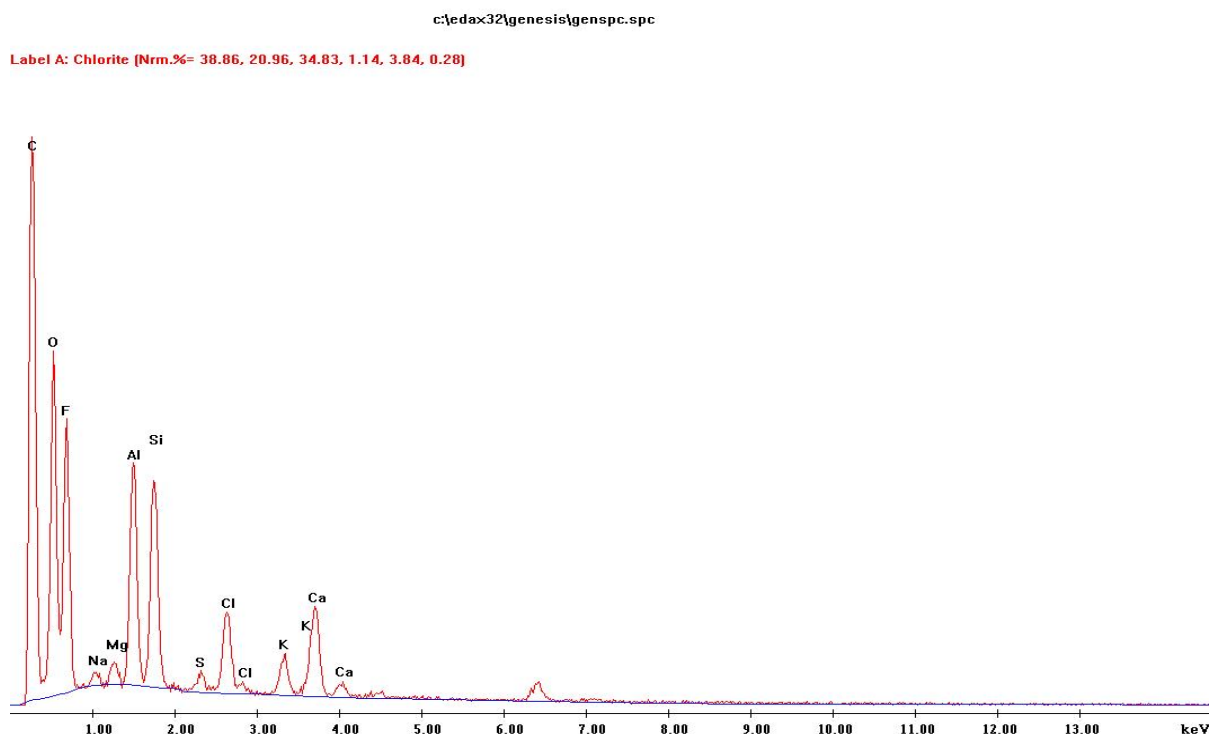


**Figure B-5: EDX Profile (corresponding to the grey part of the image) of the PM<sub>2.5</sub> filter deployed at School EP-B (Outdoor) from 30<sup>th</sup> January – 1<sup>ST</sup> February 2008**

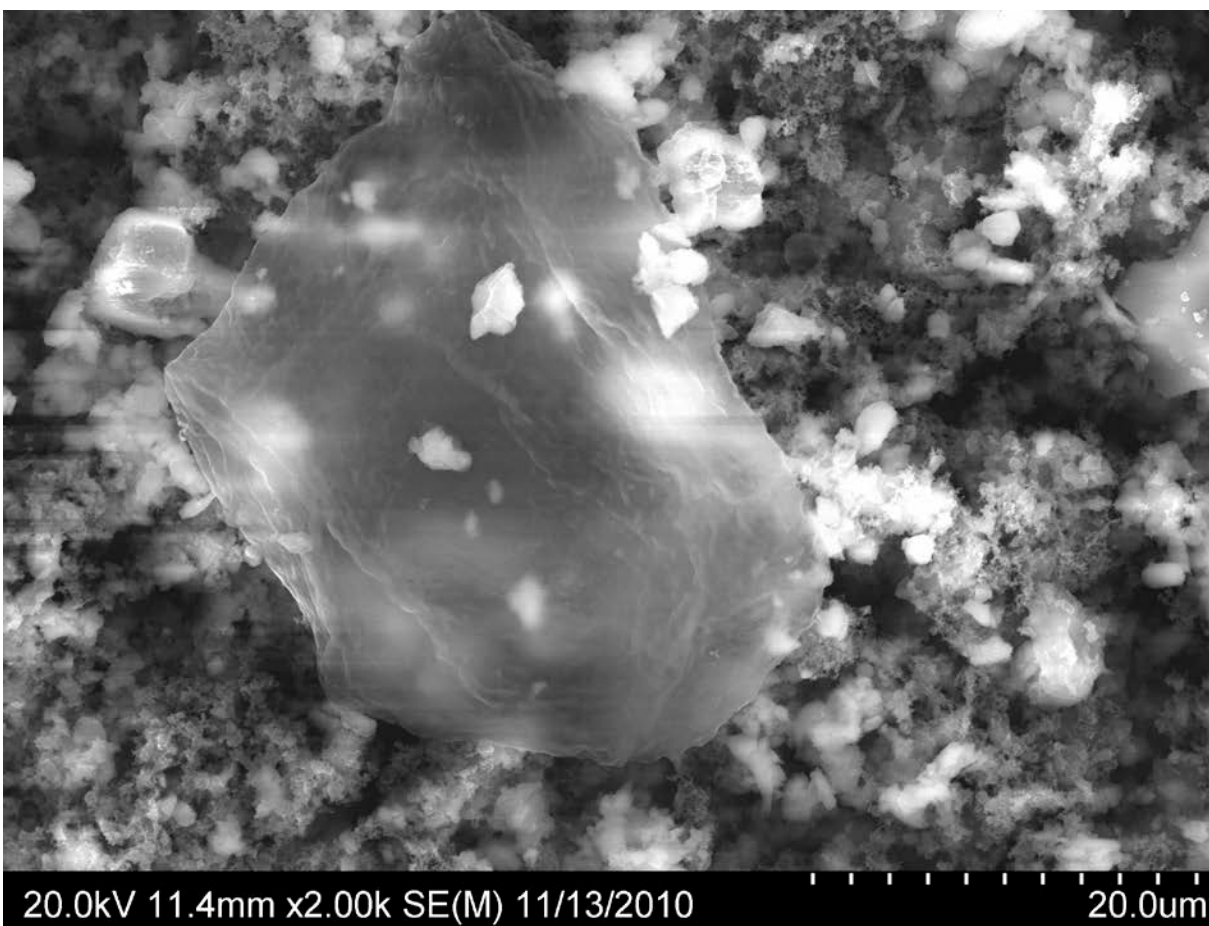


**Figure B-6: SEM Microphotographs of the PM<sub>2.5</sub> filter deployed at School CJ-B (Indoor) from 21<sup>st</sup> -23<sup>rd</sup> January 2008**

Figure B-6 and B-7 respectively are the SEM image and EDX profile of a filter deployed in the indoor microenvironment at school CJ-B in Ciudad Juarez from 21<sup>st</sup>-23<sup>rd</sup> January 2008. The filter was **not** showered with the noble metal before the SEM analysis. The mass collected on this filter was 864  $\mu\text{g}$  with a  $\text{PM}_{2.5}$  mass concentration of  $59.78 \mu\text{g}/\text{m}^3$ . The EDX profile shows high peaks of carbon, which can be attributed to incomplete diesel combustion. The filter for this specific run was jet black in color. The EDX profile indicates that the  $\text{PM}_{2.5}$  particles collected at this location comprise primarily of carbon, oxygen, and silica.



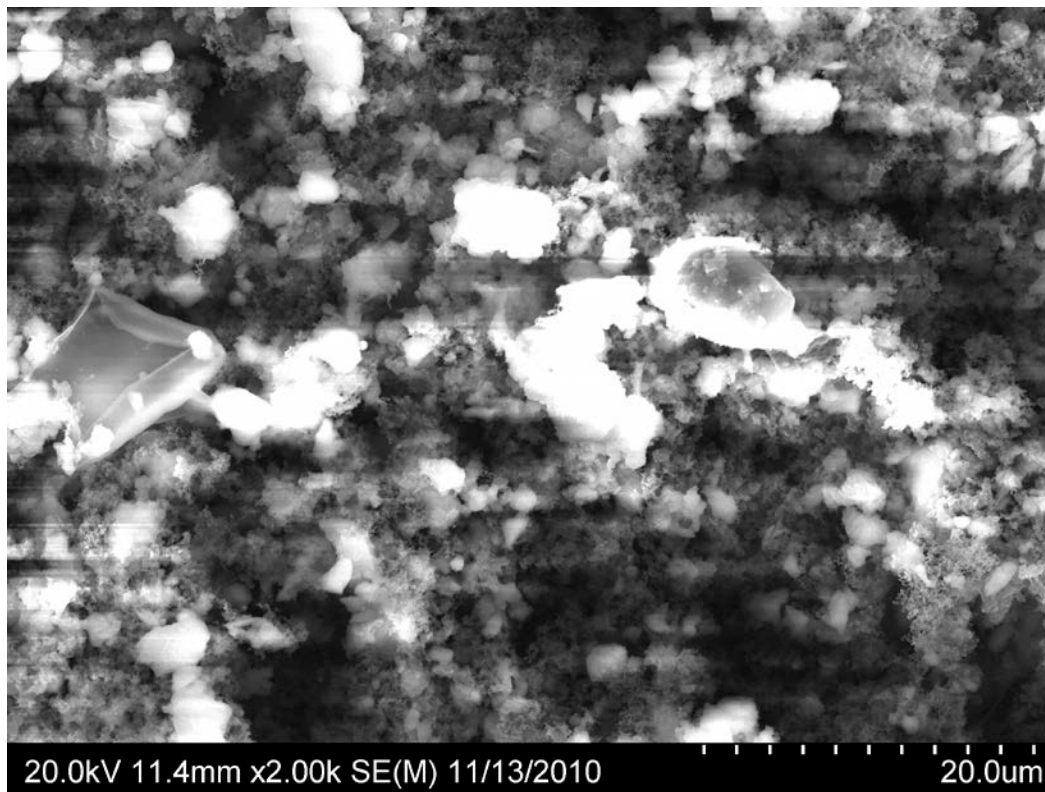
**Figure B-7: EDX Profile of the  $\text{PM}_{2.5}$  filter deployed at School CJ-B (Indoor) from 21<sup>st</sup>-23<sup>rd</sup> January 2008**



**Figure B-8: SEM Microphotograph of the PM<sub>2.5</sub> filter deployed at School CJ-B (Outdoor) from 21<sup>st</sup>-23<sup>rd</sup> January 2008**

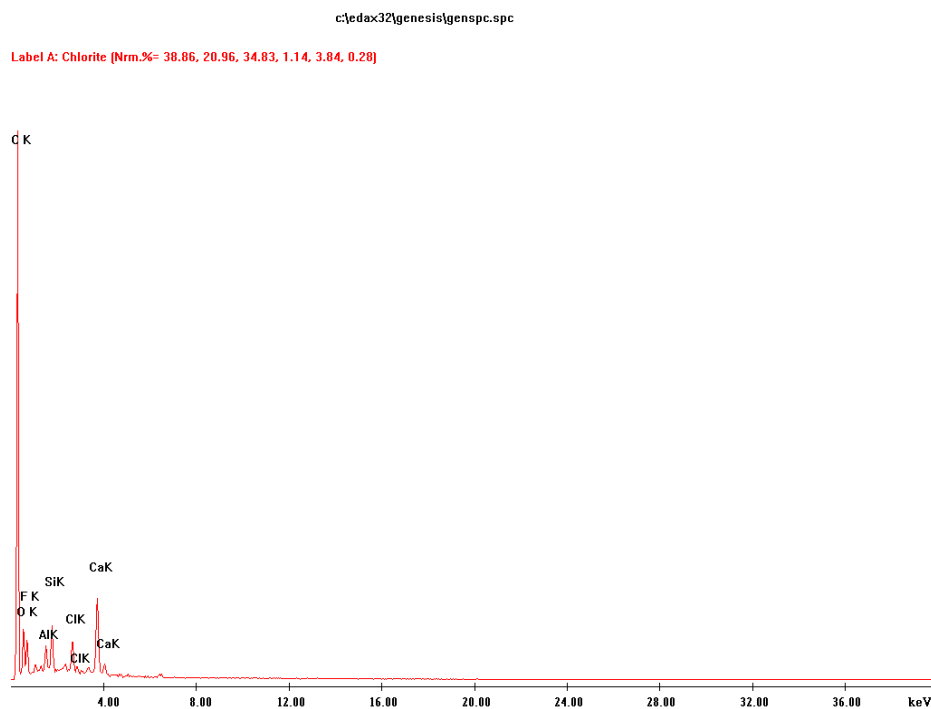
Figure B-8 and B-9 are the SEM images of the Teflon filter from the outdoor microenvironment of school CJ-B, which was deployed on January 21 and retrieved on January 28, 2008. The mass collected on the filter was 1867.67  $\mu\text{g}$  and the PM<sub>2.5</sub> concentration was 130.4  $\mu\text{g}/\text{m}^3$ . The sample was showered with noble metal: palladium before the SEM analysis. The EDX profiles (Figures B-10 and B-11) show high peaks of carbon suggesting the influence of soot particles emanating from incomplete diesel emissions. Moderate peaks of calcium (Ca) are also observed in the profile. In the Paso del Norte region, the coarse fraction of PM essentially consists of particles of geological origin. It is possible that the Teflon filters collected some

particles in the higher cut-off range ( $> PM_{2.5}$ , which is consistent with the aerodynamic sizing cutoff of the Harvard cascade impactors.

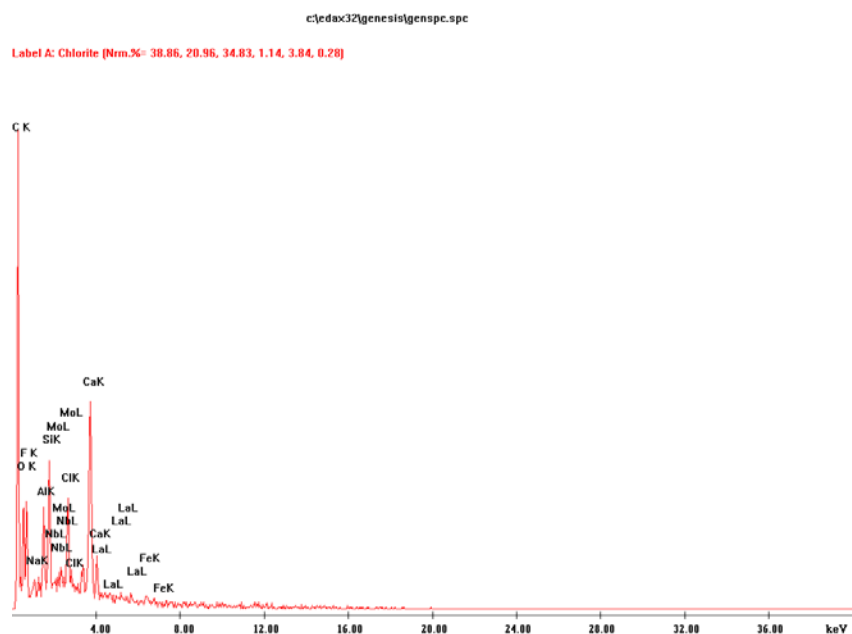


**Figure B-9: SEM Microphotographs of the  $PM_{2.5}$  filter deployed at School CJ-B (Outdoor) from 21<sup>st</sup>-23<sup>rd</sup> January 2008**

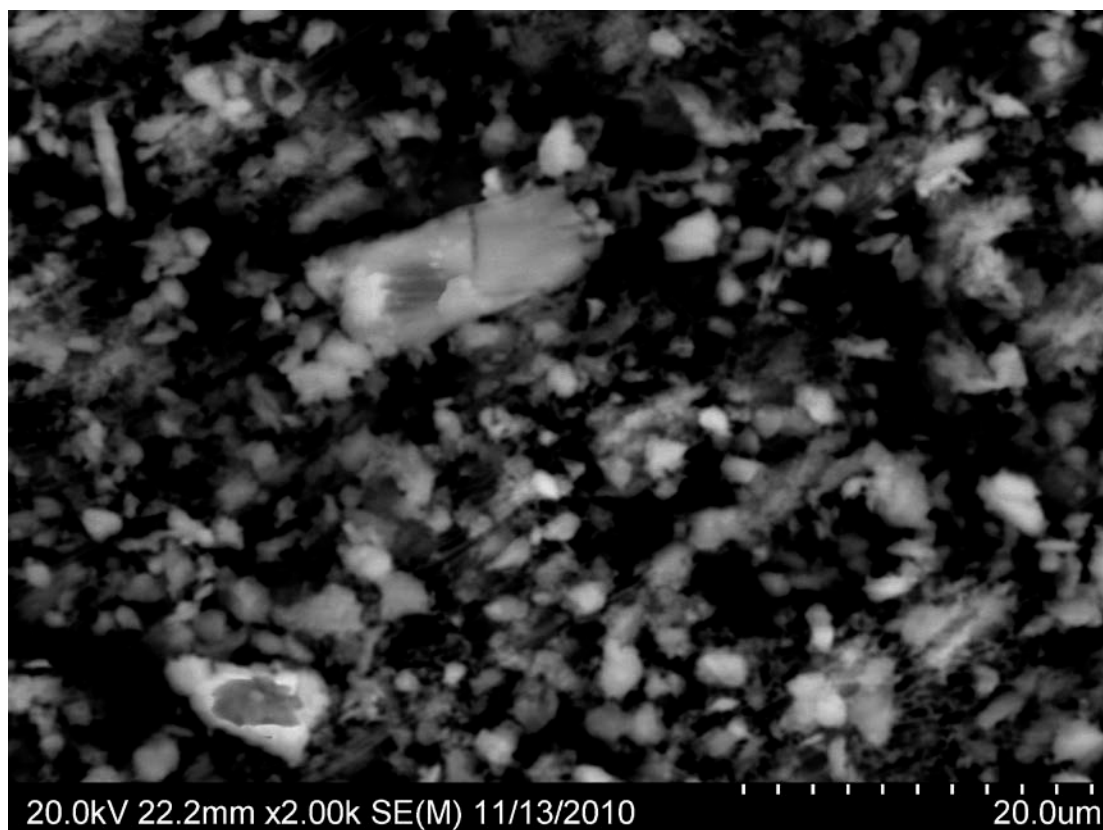
Figure B-9 also indicates that most of the soot particles occur in clusters. In addition, Bang and Murr, 2003, have documented that more than 70 % of the particles collected from ambient air in the Paso del Norte region are clusters of small particles. SEM analysis conducted on  $PM_{2.5}$  and  $PM_{10-2.5}$  by Li et al., 2005 have shown that smaller particles generally adhere to larger particles, and some larger particles are an agglomeration of these smaller particles.



**Figure B-10: EDX Profile of the PM<sub>2.5</sub> filter deployed at School CJ-B (Outdoor) from 21<sup>st</sup>-23<sup>rd</sup> January 2008**

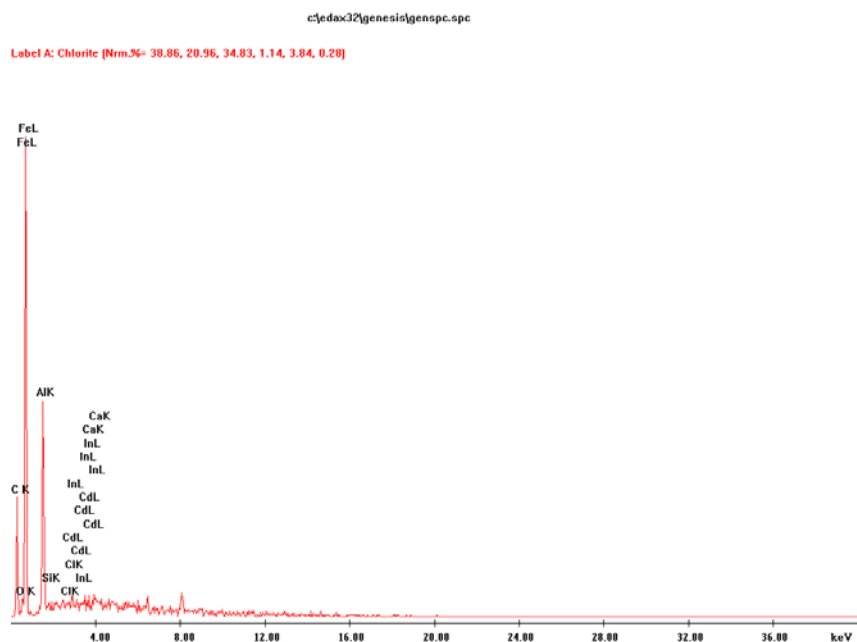


**Figure B-11: EDX Profile of the PM<sub>2.5</sub> filter deployed at School CJ-B (Indoor) from 21<sup>st</sup>-23<sup>rd</sup> January 2008**

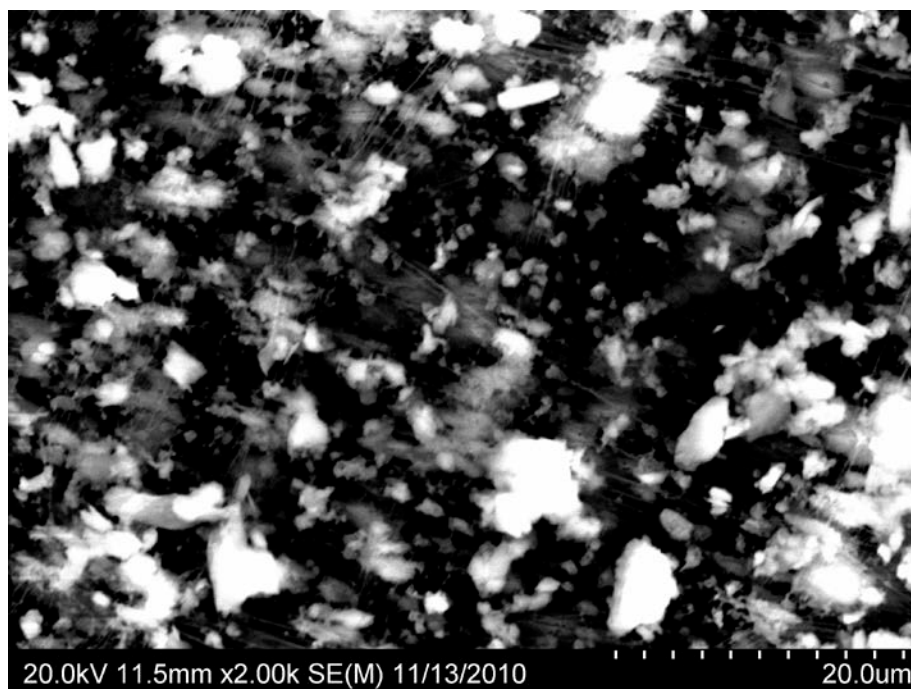


**Figure B-12: SEM Microphotographs of the PM<sub>2.5</sub> filter deployed at School CJ-B (Indoor) from 16<sup>th</sup> -18<sup>th</sup> April 2008**

Figure B-12 is an SEM image of the PM<sub>2.5</sub> filter from CJ-B which was deployed in the indoor microenvironment from 16<sup>th</sup>-18<sup>th</sup> April 2008. The mass collected on this filter was 354.67  $\mu\text{g}$  and the corresponding concentration was 25.94  $\mu\text{g}/\text{m}^3$ . The sample was showered with a noble metal before the SEM analysis. High peak of iron (Fe) and aluminum (Al) were observed as is obvious from the EDX profiles (Figure B-13). This suggests the influence of possible industrial sources around this school in addition to sources from traffic emissions. It is prudent to mention here that particles containing transition metals like Fe have been associated with respiratory health effects (Aust et al., 2002). The high peak observed in the indoor microenvironment of this school posits typical respiratory health challenges for young elementary schools children, both asthmatic and non-asthmatic.

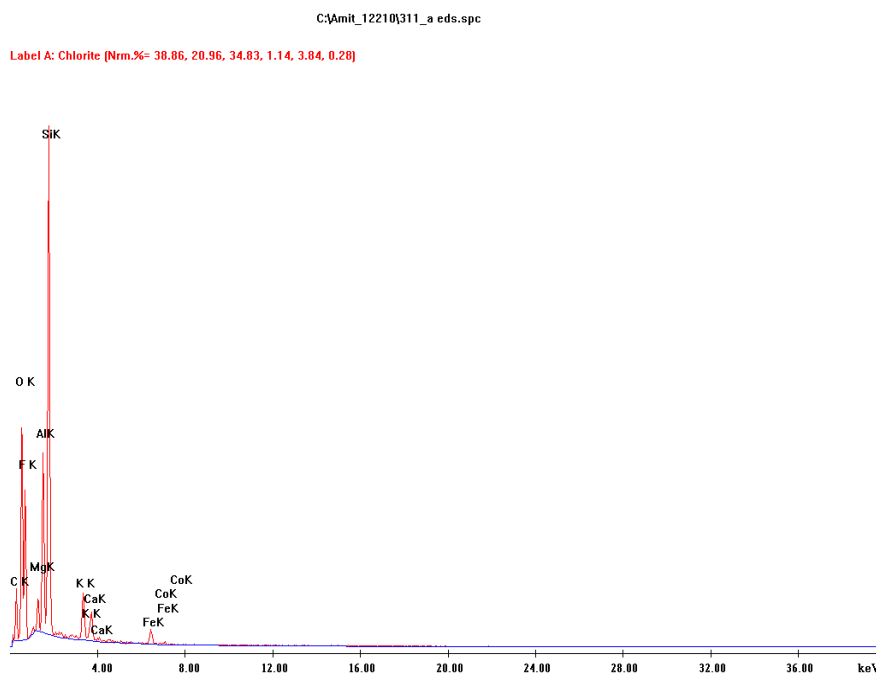


**Figure B-13: EDX Profile of the PM<sub>2.5</sub> filter deployed at School CJ-B (Indoor) from 16<sup>th</sup> - 18<sup>th</sup> April 2008**



**Figure B-14: SEM Microphotographs of the PM<sub>2.5</sub> filter deployed at School CJ-A (Outdoor) from 23<sup>rd</sup>-25<sup>th</sup> April 2008**

The SEM image of the PM<sub>2.5</sub> filter deployed at school CJ-A in the outdoor microenvironment from 23<sup>rd</sup> – 25<sup>th</sup> April 2008 is shown in Figure B-14. The mass collected on the filter was 537.33 µg and the PM<sub>2.5</sub> concentration was 38.25 µg/m<sup>3</sup>. This sample was showered with a noble metal before the SEM analysis too. As has been mentioned in the previous chapters, school CJ-A is surrounded by unpaved roads and streets and the location of a park in the north-western part of the school led to high geological crustal elements on the filter. This observation is corroborated by the high peaks of silica and aluminum obtained in the EDX profiles as shown in Figure B-15. The SEM results obtained from this study are in line with and consistent with the results in the literature. Abu-Allaban et al., 2007 documented that the fine fraction in the Paso del Norte region is rich in carbon and the coarse fraction of PM is chiefly geologic in origin.



**Figure B-15: EDX Profile of the PM<sub>2.5</sub> filter deployed at School CJ-A (Outdoor) from 16<sup>th</sup> - 18<sup>th</sup> April 2008**



There is very limited data on SEM/EDX analysis on particulate matter samplers collected from classrooms. A study conducted by Fromme and colleagues in Germany documented high coarse particulate matter in the indoor microenvironment and the indoor particles were composed of various constituents of silicon (Si), oxygen (O), calcium (Ca), and carbon (Fromme et al., 2008). The authors also found high levels of Fe indoors as compared to outdoors.

In sum, the SEM analysis conducted on the filters obtained from this study suggests that the fine and coarse fraction of particulate matter in the Paso del Norte region is characterized by traffic emissions, fugitive sources like dust emanating from unpaved roads and streets and industrial sources. Characterization of the physical properties of particulate matter is crucial in to understand the toxicological health effects of particulate matter and would also aid in pollution abatement strategies in this region.

## **Appendix C**

**Recruitment Flyer – El Paso (English)**

**Recruitment Flyer – El Paso (Spanish)**

**Recruitment Flyer – Ciudad Juarez (Spanish)**

## El Paso Children's Asthma and Traffic Pollution Study



**Does your child have physician-diagnosed asthma?**

**Are you interested in the effects of pollution from traffic on your child's asthma symptoms?**

Researchers from the Emory University School of Public Health in Atlanta, Georgia and the University of Texas at El Paso (UTEP) are currently enrolling children between the ages of 6 and 12 living in El Paso in a research study to examine the impact of air pollution levels measured at your child's school on asthma symptoms.

Your child may be eligible to participate in this study if he/she has **physician-diagnosed asthma**; is willing and able to complete (with the help of field staff) **weekly questionnaires** about their asthma symptoms and to provide **weekly breath samples**, which will be tested for exhaled nitric oxide, a measure of lung inflammation. The study will last for 12 weeks during the winter of 2006-07 and the weekly questionnaires and breath sampling will take approximately 10-15 minutes per week, during the school day. In addition, you must also be willing and able to complete an initial questionnaire (which will take approximately 30 minutes) and answer questions over the phone about your child's symptoms and medication usage once a week (which will take 10 minutes).

Children completing this study will receive a \$50 gift certificate to a local bookstore for their participation.

**For more information, please contact either:**

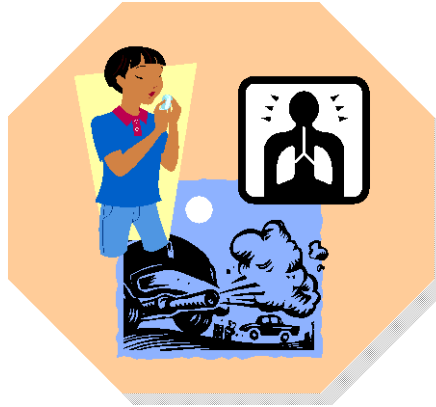
Dr. Fernando Holguin  
(404) 498-1027  
Emory University  
80 Jesse Hill Jr. Drive  
Atlanta, GA 30322

Dr. Jeremy Sarnat  
(404) 712 9725  
Emory University  
1518 Clifton Road NE  
Atlanta, GA 30322

Dr. Wen-Whai Li  
(915) 747-8755  
UTEP  
500 W. University Ave.  
El Paso, TX 79968



## Estudio Binacional de Contaminación vial y Asma Infantil



### A su niño le han diagnosticado ASMA?

### Esta Ud Interesado en los efectos que la contaminación del aire puede tener en los síntomas de asma ?

Investigadores de la Escuela de Salud Pública Emory en Atlanta , la Universidad de Texas en el Paso (UTEP) están invitando a estudiantes de Ciudad Juárez de 6 a 12 años para participar en un estudio de investigación para evaluar el impacto de los contaminantes del aire en los síntomas de asma.

Su niño podría calificar para ser elegido y participar en el estudio, si el o (ella) ha sido diagnosticado por un Médico con asma, acepta contestar un cuestionario acerca de la condición de salud de su hijo con la ayuda de personal que labora en el estudio y realizar una prueba de aliento exhalado para medir óxido nítrico, (soplar a través de un tubo) el cual se utiliza para detectar inflamación de las vías respiratorias.

Este estudio durará 12 semanas. El cuestionario junto con las muestras de aliento tomará aproximadamente 10 a 15 minutos y se harán una vez por semana durante el horario de clases, para lo cual se solicitará el permiso de las autoridades de la escuela. Además se le llamará por teléfono una vez por semana para saber si su hijo tiene algún síntoma o ha requerido utilizar medicamentos.

Los niños que completen el estudio recibirán un certificado de regalo por 50 dólares para compensar su participación.

Dr. Fernando Holguin  
(404) 498-1027

Dr. Jeremy Sarnat  
(404) 712 9725

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## Estudio Binacional de Contaminación vial y Asma Infantil



### A su niño le han diagnosticado ASMA?

### Esta Ud Interesado en los efectos que la contaminación del aire puede tener en los síntomas de asma?

Investigadores de la Escuela de Salud Pública Emory en Atlanta, la Universidad de Texas en El Paso (UTEP) y el Instituto Mexicano del Seguro Social, están invitando a estudiantes de El Paso de 6 a 12 años para participar en un estudio de investigación para evaluar el impacto de los contaminantes del aire en los síntomas de asma.

Su niño podría calificar para ser elegido para participar en el estudio, si el o (ella) ha sido diagnosticado por un Médico con asma, si acepta contestar un cuestionario acerca de la condición de salud de su hijo con la ayuda de personal que labora en el estudio y realizar una prueba de aliento exhalado para medir óxido nítrico (soplar a través de un tubo) el cual se utiliza para detectar inflamación de las vías respiratorias.

Este estudio durará 12 semanas y el cuestionario, las muestras de aliento tomarán aproximadamente 10 a 15 minutos una vez por semana durante el horario de clases, para lo cual se solicitará el permiso de las autoridades de la escuela. Además se le llamará por teléfono una vez por semana para saber si su hijo tiene algún síntoma o ha requerido utilizar medicamentos.

Los niños que completen el estudio recibirán un certificado de regalo por su participación.

---

#### FAVOR DE DESPRENDER Y ENTREGAR ESTE CUPÓN A LA MAESTRA

Esta Ud interesado en que su hijo participe? Si \_\_\_\_\_ No \_\_\_\_\_

Le gustaría recibir más información del estudio Si \_\_\_\_\_ No \_\_\_\_\_

Nombre del niño \_\_\_\_\_ Edad \_\_\_\_\_

Dirección \_\_\_\_\_

Teléfono \_\_\_\_\_ Su hijo(a) tiene asma? Si \_\_\_\_\_ No \_\_\_\_\_ No se \_\_\_\_\_

Nombre del Padre, Madre o Tutor \_\_\_\_\_

Nombre de la Escuela \_\_\_\_\_ Grado \_\_\_\_\_

Si tiene dudas favor comunicarse con Dra Silvia Flores L. Tel 6 49 72 00 ext 41307

Dr. Fernando Holguin  
(404) 498-1027  
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80 Jesse Hill Jr. Drive  
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## **Appendix D**

**Screening Questionnaire (English)**

**Screening Questionnaire (Spanish)**

## **SCREENING QUESTIONNAIRE**

Emory/UTEP – Winter 2007-2008

Date: \_\_\_\_\_ Screened By: \_\_\_\_\_

Parent/Guardian's Name: \_\_\_\_\_

Child's Name: \_\_\_\_\_

Home Phone: \_\_\_\_\_ Other Phone: \_\_\_\_\_

Address (include zip code): \_\_\_\_\_

Date Called: \_\_\_\_\_ Date Called Back: \_\_\_\_\_

1) Does another member in your household have asthma? Yes ☐ No ☐

2) Has your child ever been diagnosed with asthma? Yes ☐ No ☐

If yes, when: \_\_\_\_\_

3) Does your child have any allergies? Yes ☐ No ☐

If yes, to what?: \_\_\_\_\_

4) What is your child's age? \_\_\_\_\_ Date of Birth: \_\_\_\_\_

5) a. What medications is your child currently taking for their asthma?

\_\_\_\_\_

b. Other medications? \_\_\_\_\_

6) Does your child have an active lung disease other than asthma (e.g. chronic bronchitis, emphysema, cystic fibrosis, chronic obstructive pulmonary disease, chronic heart failure)? Yes ☐ No ☐

7) Does anyone in your household smoke? Yes ☐ No ☐

8) Has your child used oral steroid medication to treat asthma in the last 4 months (Inhaled Steroids > 500  $\mu$ g/Day BDP)? Yes ☐ No ☐

9) Does your child take more than 8 puffs/day of an inhaler? Yes ☐ No ☐

How many puffs/day? \_\_\_\_\_

What is the name of the medication (e.g., Albuterol)? \_\_\_\_\_

10) Other information: \_\_\_\_\_

<b>Inclusion Criteria: To be completed by field staff only</b>	<b>YES</b>	<b>NO</b>	<b>Comments</b>
Age 6-12 yrs?	<input type="checkbox"/>	<input type="checkbox"/>	
Diagnosed asthmatic?	<input type="checkbox"/>	<input type="checkbox"/>	
No other lung disease or major illness?	<input type="checkbox"/>	<input type="checkbox"/>	
Lives in non-smoking household?	<input type="checkbox"/>	<input type="checkbox"/>	
Approximate distance (km) between residence and school: _____			
Residence near school?	<input type="checkbox"/>	<input type="checkbox"/>	
<b>Subject eligible for study?</b>	<input type="checkbox"/>	<input type="checkbox"/>	

## **ENTREVISTA**

Emory/UTEP – Invierno 2007-2008

Fecha: \_\_\_\_\_ Realizada por: \_\_\_\_\_

Padre o guardián legal: \_\_\_\_\_

Nombre del Niño(a): \_\_\_\_\_

Teléfono de casa: \_\_\_\_\_ Otro: \_\_\_\_\_

Dirección: \_\_\_\_\_ Código postal \_\_\_\_\_

Fecha de la llamada telefónica: \_\_\_\_\_ Fecha para volver a llamar \_\_\_\_\_

.....

1) ¿Hay algún miembro de la familia que tenga asma? Si ☐ No ☐

2) ¿Su hijo(a) ha sido diagnosticado con asma? Si ☐ No ☐  
Si la respuesta es Si, ¿cuando?: \_\_\_\_\_

3) ¿Su hijo(a) tiene algún tipo de alergia? Si ☐ No ☐  
Si la respuesta es Si, ¿a que es alérgico?: \_\_\_\_\_

4) ¿Cual es la edad de su hijo(a)? \_\_\_\_\_ Fecha de Nac: \_\_\_\_\_

5) a ¿Que medicamentos recibe actualmente su hijo para el asma?

\_\_\_\_\_

b. ¿Aalgún otro medicamento que esté tomando? \_\_\_\_\_

6) Su hijo(a) tiene alguna otra enfermedad de los pulmones o el Corazón? (Bronquitis crónica, fibrosis quística, etc)? Si ☐ No ☐

7) Alguna persona en su casa fuma? Si ☐ No ☐

8) Su hijo(a) ha utilizado esteroides orales para tratar el asma en los últimos 4 meses? (prednisona, prednisolona)? Si ☐ No ☐

9) Su hijo utiliza mas de 8 veces al día los inhaladores para el asma? Si ☐ No ☐

Cuántas veces al día los usa? \_\_\_\_\_ Como se llama el medicamento? \_\_\_\_\_

10) Otra información: \_\_\_\_\_

<b>Criterios de Inclusión : Completar solo por personal del estudio</b>	<b>SI</b>	<b>NO</b>	<b>Comentarios</b>
¿Edad 6 a 12 años?	<input type="checkbox"/>	<input type="checkbox"/>	
¿Ha sido diagnosticado con asma?	<input type="checkbox"/>	<input type="checkbox"/>	
¿NO tiene otras enfermedades graves del pulmón o el corazón?	<input type="checkbox"/>	<input type="checkbox"/>	
¿Vive en una casa donde nadie fuma?	<input type="checkbox"/>	<input type="checkbox"/>	
Distancia aproximada (mts ) entre la casa y la escuela :			
La casa se encuentra cerca de la escuela?	<input type="checkbox"/>	<input type="checkbox"/>	
<b>Es el niño(a) elegible para el estudio?</b>	<input type="checkbox"/>	<input type="checkbox"/>	



## **Appendix E**

**Baseline Questionnaire Form (English)**

**Baseline Questionnaire Form (Spanish)**

## CHILD BASELINE INTERVIEW

### ***SECTION A. GENERAL INFORMATION***

**A1. STUDY ID:** PAHO-Children`s Asthma and Traffic Emissions Study

**A2. SCREENING ID** \_\_\_\_ \_

**A3. COMPLETION DATE** \_\_\_\_ \_ / \_\_\_\_ \_ / \_\_\_\_ \_

**M M D D Y Y**

**A4. INTERVIEWER'S INITIALS** \_\_\_\_ \_

**A5. CHILD'S DATE OF BIRTH** \_\_\_\_ \_ / \_\_\_\_ \_ / \_\_\_\_ \_

**M M D D Y Y**

**A6. CARETAKER'S NAME**

**A6a.**\_\_\_\_\_**A6b.**\_\_\_\_\_

[FIRST]

[LAST]

**A7. CARETAKER'S RELATIONSHIP TO CHILD**

**Mother (bio or adoptive) . 1**

**Father (bio or adoptive) . . 2**

**Step-mother . . . . . 3**

**Step-father . . . . . 4**

**Foster parent . . . . . 5 [Not allowed]**

**Grandmother . . . . . 6**

**Grandfather . . . . . 7**

**Sibling . . . . . 8**

**Other family . . . . . 9 Specify: \_\_\_\_\_**

**Other non-family . . . . . 10 Specify: \_\_\_\_\_**

**Don't know . . . . . -2**

## **SECTION B. HEALTH OF THE CHILD**

The first questions are about [CHILD]'s health in general. Let's start with the time [CHILD] was born.

### **B1. How much did [CHILD] weigh at birth?**

[If caretaker responds with only pounds, prompt with "How many ounces?"]

If caretaker knows only lbs, enter the number of pounds in B1a and enter -2 for ounces in B1b.

If caretaker does not know either pounds or ounces, enter -2 in both spaces and answer B1c.

If caretaker reports 1/2 ounces, round to nearest ounce, e.g. 8 lbs 5.5 oz = 8 lbs 6 oz.]

**B1a. \_\_\_\_ lbs B1b. \_\_\_\_ ounces**

**B1c. [ONLY ANSWER IF B1a=-2.]**

**Did [CHILD] weigh greater than or less than 5 lbs at birth?**

**Greater than 5 lbs . 1**

**Less than 5 lbs . . . . 2**

**Don't know . . . . . -2**

**B2. When [CHILD] was first born, was he/she in an intensive care unit, premature nursery, or any type of special care facility?**

**Yes . . . . . 1**

**No . . . . . 0**

**Don't know . . . . . -2**

**B3. When [CHILD] was first born, was he/she on a respirator (breathing machine)?**

**Yes . . . . . 1**

**No . . . . . 0**

**Don't know . . . . . -2**

## **SECTION C. MEASURES OF MORBIDITY [To be asked at start of study]**

Now I want to talk with you about how asthma affects you and [CHILD] each day. The next few questions are about [CHILD]'s health in the last week, that is, the past 14 days, from [14 days ago] to today.

[USE CALENDAR and MARK DAYS.]

**C1. In the last two weeks, how many days did [CHILD] have wheezing or tightness in the chest or cough? \_\_\_\_Days**

**C2. In the last two weeks, how many days did [CHILD] have to slow down or stop his/her play or activities because of asthma, wheezing or tightness in the chest, or cough? \_\_\_\_Days**

**C3. In the last 14 nights, how many nights did [CHILD] wake up because of asthma, wheezing or tightness in the chest, or cough? \_\_\_\_Nights**

**C4. In the last two weeks, on how many days was [CHILD] limited in activity for more than half a day? \_\_\_\_Days**

**C5. In the past 14 nights, how many nights did you wake up or lose sleep because of [CHILD]'s asthma? \_\_\_\_Nights**

**C6. How many days during the past 14 days did you have to change your daytime or evening plans because of [CHILD]'s asthma? \_\_\_\_Days**

**C7. During the past 14 days, how many days did [CHILD] miss school for any reason?**

[Include only days school was in session.] \_\_\_\_ Days [IF 0, SKIP TO C8]

**C7a. How many of those days did [CHILD] miss school due to asthma? \_\_\_\_ Days**

**C8. During the past 2 months, did [CHILD] have to stay overnight in the hospital for any reason?**

[DO NOT INCLUDE OVERNIGHT WAITS IN THE ER]

Yes ..... 1

No ..... 0 [SKIP TO C9]

**C8a. How many times?**

[NUMBER OF DIFFERENT ADMISSIONS, NOT TOTAL NUMBER OF NIGHTS.] \_\_\_\_ Stays

[Start with the most recent hospitalization and complete the grid below. Use calendar. ]

**C8b. When was the last time [CHILD] was in the hospital overnight?**

**C8c. How many days was [CHILD] in the hospital then?**

**C8d. What was the main reason that [CHILD] was hospitalized that time?**

[USE THE FOLLOWING CODES, BUT DO NOT READ LIST.

1=ASTHMA, 2=OTHER, -2=DON'T KNOW]

**C8e. Was [CHILD] in the ICU?**

[1=Yes, 0=No]

	Date (mm/dd/yy)	Days	Reason	Intensive care
<b>MOST RECENT: 1.</b>	____/____/____	1. ____	1. ____	1. ____
<b>ADMISSION #2: 2.</b>	____/____/____	2. ____	2. ____	2. ____
<b>ADMISSION #3: 3.</b>	____/____/____	3. ____	3. ____	3. ____
<b>ADMISSION #4: 4.</b>	____/____/____	4. ____	4. ____	4. ____

**C9. Not counting hospitalizations, during the past 2 months did [CHILD] see a doctor or health care provider for any reason? Include visits to an emergency room, a doctor's office, or a clinic.**

Yes ..... 1

No ..... 0 [SKIP TO NEXT SECTION]

**C9a. How many times? \_\_\_\_ visits**

[Start with most recent visit and complete the grid below for up to 6 visits. Use calendar.]

**C9b. When was the (last) visit?**

**C9c. Was that visit for asthma or another reason?**

[1=Asthma, 2=Other]

**C9d. Was that an appointment that was scheduled at a clinic at least 24 hours ahead or was it an emergency visit at an ER or clinic?**

[1=Clinic, scheduled, 2=ER, 3=Clinic, unscheduled]

	C9b. Date (mm/dd/yy)	C9c	C9d
<b>MOST RECENT: 1.</b>	____/____/____	1. ____	1. ____

VISIT #2: 2. \_\_\_\_/\_\_\_\_/\_\_\_\_ 2. \_\_\_\_ 2. \_\_\_\_  
 VISIT #3: 3. \_\_\_\_/\_\_\_\_/\_\_\_\_ 3. \_\_\_\_ 3. \_\_\_\_  
 VISIT #4: 4. \_\_\_\_/\_\_\_\_/\_\_\_\_ 4. \_\_\_\_ 4. \_\_\_\_  
 VISIT #5: 5. \_\_\_\_/\_\_\_\_/\_\_\_\_ 5. \_\_\_\_ 5. \_\_\_\_  
 VISIT #6: 6. \_\_\_\_/\_\_\_\_/\_\_\_\_ 6. \_\_\_\_ 6. \_\_\_\_

#### **SECTION D. MEDICAL RISK ASSESSMENT**

Now I have a few questions about the medical care [CHILD] receives and the medicines that he/she takes.

**D1. During the past 12 months, when [CHILD] went to a doctor for asthma care, was it usually in an ER or clinic or doctor's office? [DO NOT READ LIST.]**

ER ..... **1**  
 Clinic/office ..... **2**  
 Both, mostly ER ..... **3**  
 Both, mostly clinic/office ..... **4**  
 Never had doctor's visit ..... **5**

**D2. During the past 2 months, did [CHILD] take any medicines for asthma?**

Yes ..... **1**  
 No ..... **0** [SKIP TO D3]

**D2a. Is your child currently taking any medicines prescribed for asthma every day, even when he/she is well, to prevent symptoms?**

Yes ..... **1** [SKIP TO D3a]  
 No ..... **0**

**D3. In the past 2 months, has your child been prescribed any medicines for asthma to use every day, even when he/she is well, to prevent symptoms?**

Yes ..... **1**  
 No ..... **0** [SKIP TO D4]  
 Don't know ..... **-2** [SKIP TO D4]

**D3a. What kind of medicines? What form was the medicine?**

[DO NOT READ LIST. In the chart below, enter 1 for all medicines that are named.  
 Enter 0 for all other medicines. Can use pictures of medicines.]

**D3b.** [For each medicine named in B3a, ask the following question and enter the code in the chart below. For those not named in B3a, enter -1 for 'Not Applicable.' ] **During the past two months, how often did [CHILD] use this medicine? Would you say...** [READ LIST.]

Never or rarely **0**  
 Sometimes **1**  
 Usually **2**  
 Almost always **3**

1. Liquid or tablets, can't remember name .....
2. Inhaled medicine(s), can't remember name .....
3. Nebulized medicine(s), can't remember name .....
4. Albuterol (Ventolin, Proventil) by mouth.....
5. Ipratropium (Atrovent).....
6. Albuterol (Ventolin, Proventil) by inhaler.....
7. Albuterol (Ventolin, Proventil) by nebulizer (electric machine).....
8. Cromolyn (Intal, Nasalcrom) by inhaler.....
9. Cromolyn (Intal) by nebulizer (electric machine).....
10. Nasalcrom by nasal spray.....
11. Prednisone or prednisolone (deltasone, medrol) by mouth.....
12. Beclomethasone (Qvar) by inhaler.....
13. Steroid by nasal spray (Nasonex, Rhinocort, Flonase).....
14. Triamcinolone (Azmacort) by inhaler.....
15. Flunisolide (Aerobid) by inhaler.....
16. Fluticasone (Flovent) by inhaler.....
17. Theophylline (Slo-phyllin, Slo-bid, Theo-dur) by mouth.....
18. Budesonide (Pulmacort) by diskhaler.....
19. Other (Specify): B3a20a. ....

**D4a. What medicines do you give [CHILD] when he/she is having asthma signs or symptoms?**

**What form is the medicine?** [DO NOT READ LIST. Can use pictures of medicines. If not volunteered, read options for form of medicine: liquid or oral, inhaled or nebulizer/electric machine. In the chart below, enter 1 for all medicines that are named. Enter 0 for all other medicines.]

**D4b. [Only ask for medicines named in B4a. For those not named in B4a, enter -1 for 'Not Applicable.'] During the past two months, did [CHILD] use this medicine because he/she was having asthma signs/symptoms?**

Yes ..... 1  
 No ..... 0  
 Don't know ..... -2

**D4c. [Only ask for medicines reported as used in B4b. For those not reported as used in D4b, enter -1 for 'Not Applicable.'] Is [CHILD] supposed to take this medicine more than once a day?**

Yes ..... 1  
 No ..... 0  
 Don't know ..... -2

	B4a	B4b	B4c
		Did Use?	More?
1. Liquid or tablets, can't remember name .....	_____	_____	_____
2. Inhaled medicine(s), can't remember name .....	_____	_____	_____
3. Nebulized medicine(s), can't remember name .....	_____	_____	_____
4. Albuterol (Ventolin, Proventil) by mouth.....	_____	_____	_____
5. Ipratropium (Atrovent).....	_____	_____	_____
6. Albuterol (Ventolin, Proventil) by inhaler.....	_____	_____	_____
7. Albuterol (Ventolin, Proventil) by nebulizer (electric machine).....	_____	_____	_____
8. Cromolyn (Intal, Nasalcrom) by inhaler.....	_____	_____	_____
9. Cromolyn (Intal) by nebulizer (electric machine).....	_____	_____	_____
10. Nasalcrom by nasal spray.....	_____	_____	_____

11. Prednisone or prednisolone (deltasone, medrol) by mouth..... \_\_\_\_\_
12. Beclomethasone (Qvar) by inhaler..... \_\_\_\_\_
13. Steroid by nasal spray (Nasonex, Rhinocort, Flonase)..... \_\_\_\_\_
14. Triamcinolone (Azmacort) by inhaler..... \_\_\_\_\_
15. Flunisolide (Aerobid) by inhaler..... \_\_\_\_\_
16. Fluticasone (Flovent) by inhaler..... \_\_\_\_\_
17. Theophylline (Slo-phyllin, Slo-bid, Theo-dur) by mouth..... \_\_\_\_\_
18. Budesonide (Pulmacort) by diskhaler..... \_\_\_\_\_
19. Other (Specify): B3a20a. \_\_\_\_\_

**D4d. How many different medicines does [CHILD] usually take in one day for asthma?**

\_\_\_\_\_ different medicines

**D5d. Have you had any problems in dealing with [CHILD]'s taking medications at school?**

Yes ..... 1

No ..... 0

[Doesn't Take Meds at School] ... -1

**D6. During the past 12 months, was [CHILD] covered at any time by Medicaid?**

Yes ..... 1

No ..... 0

Don't know ..... -2

**D7. Is [CHILD] now covered by a health insurance plan which pays any part of a hospital, doctor's or surgeon's bill?**

Yes ..... 1

No ..... 0 [SKIP TO E1]

Don't Know ..... -2 [SKIP TO E1]

**D7a. What is the name of your health insurance plan?** \_\_\_\_\_

[Do not ask for a category below. Each ASU will have a list of the plans and will code into the categories below after the baseline interview. If the caretaker does not know the name of the plan, then code as 'Don't know'. If the name of the plan is not enough to determine the type of plan, then code as 'Cannot be determined.']

Managed care ..... 1

Medicaid ..... 2

Medicaid Managed Care ..... 3

Private ..... 4

Cannot be determined ... ..... 5

Don't know ..... -2

## **SECTION E. DEMOGRAPHICS**

Most of the interview so far has asked about asthma. Now I have some more general questions about [CHILD], you and your family. First, I have a few questions about your family background, home, and so forth.

**E1. What grade is [CHILD] currently enrolled in?**

[If baseline occurs during the summer break, ask, "IN WHAT GRADE WILL [CHILD] BE ENROLLED IN SEPTEMBER?" Code as follows: P=preschool, K=kindergarten, 1-6= grades 1-6]

\_\_\_\_\_

**E2. How long has [CHILD] lived at his/her current address?**

**a. \_\_\_\_\_ years b. \_\_\_\_\_ months**

**E3. Do any of [CHILD]'s parents, brothers, sisters, or grandparents have asthma?**

[Include those who do and do not live in household.]

**Yes ..... 1**

**No ..... 0**

**Don't know ..... -2**

**E4. Do any of [CHILD]'s parents, brothers, or sisters have hay fever and/or eczema?**

[Include those who do and do not live in household.]

**Yes ..... 1**

**No ..... 0**

**Don't know ..... -2**

**E4a. Does [CHILD] have hay fever and/or eczema?**

**Yes ..... 1**

**No ..... 0**

**Don't know ..... -2**

**E5. What is the highest grade or school level that you have completed?**

\_\_\_\_\_ [Use education codes below.]

**E6. How many people live in [CHILD]'s home, including [CHILD] and you? \_\_\_\_\_**

[The respondent should be included, if appropriate.]

**E6a. How many of these household members are adults? (18 years and over) \_\_\_\_\_**

**E7. Thinking about where [CHILD] lives, who would you say is the head or heads of the household?**

[PROMPT: Who would you say is "in charge"?]

**E7a. How is \_\_\_\_\_ related to [CHILD]?**

**E7b. What is the highest grade or level of school that \_\_\_\_\_ has completed?**

	<b>a. Relation</b>	<b>b. Education</b>
<b>Name 1</b> _____	<b>1.</b> _____	<b>1.</b> _____

[Do not data enter this name.]

<b>Name 2</b> _____	<b>2.</b> _____	<b>2.</b> _____
---------------------	-----------------	-----------------

[Do not data enter this name.]

Relationship codes:

**1=Mother (bio or adoptive)**

**2=Father (bio or adoptive)**

**3=Step-mother**

**4=Step-father**

**5=Foster parent**

**6=Grandmother**

**7=Grandfather**

**8=Sibling**

Education codes:

**0 = Never attended school**

**1-11 = Specific grade completed for grades 1-11**

**12 = GED or 12th grade**

**13 = 1 or 2 years of college/technical/voc training**

**14 = 3 or 4 years of college/technical/voc training**

**15 = 5+ years of college/technical/voc training**

**16 = Other**



9=Other family  
10=Other non-family  
-2 = Don't know

-2 = Don't know

**E8. How would you describe [CHILD]'s race, nationality, or ethnic background?**

[ASK OPEN-ENDED AND USE CODES BELOW]

[PROMPT WITH: "WHAT IS [CHILD]'s RACE?"]

**Hispanic** [If necessary, prompt with 'WHICH ETHNIC GROUP OR NATIONALITY?']

**Puerto Rican** ..... 1  
**Dominican** ..... 2  
**Mexican** ..... 3  
**South American** ..... 4  
**Central American** ..... 5  
**Cuban** ..... 6  
**Other Hispanic** ..... 7

**Black**

**African American/Black American** .... 8  
**West Indian** ..... 9  
**Caribbean black** ..... 10  
**Other black** ..... 11

**White** ..... 12

**Asian** ..... 13

**Which ethnic group or nationality? a.** \_\_\_\_\_

**E9. And how would you describe your race, nationality, or ethnic background?**

[ASK OPEN-ENDED AND USE CODES BELOW]

**Hispanic** [If necessary, prompt with 'WHICH ETHNIC GROUP OR NATIONALITY?']

**Puerto Rican** ..... 1  
**Dominican** ..... 2  
**Mexican** ..... 3  
**South American** ..... 4  
**Central American** ..... 5  
**Cuban** ..... 6  
**Other Hispanic** ..... 7

**Black** [If necessary, prompt with 'WHICH ETHNIC GROUP OR NATIONALITY?']

**African American/Black American** .... 8  
**West Indian** ..... 9  
**Caribbean black** ..... 10  
**Other black** ..... 11

**White** ..... 12

**Which ethnic group or nationality? a.** \_\_\_\_\_

Asian ..... 13  
Which ethnic group or nationality? a. \_\_\_\_\_

**e10. What is your current marital status?**

[PROMPT IF NECESSARY.]

Married ..... 1  
Divorced ..... 2  
Single ..... 3  
Widowed ..... 4  
Separated ..... 5  
Other ..... 6 Specify: a. \_\_\_\_\_

### ***SECTION F. SMOKING***

Now I would like to ask you some questions about smoking.

**F1. How many people who live in [CHILD]'s home smoke? \_\_\_\_ people**

[Include respondent if smoker.]

**F2. Does anyone else who takes care of [CHILD], such as a babysitter or day care worker, smoke?**

Yes ..... 1

No ..... 0

**F3. Do you smoke cigarettes, even occasionally?**

Yes ..... 1

No ..... 0 [SKIP TO F4]

**F3a. About how many years have you been smoking? \_\_\_\_ years**

**F3b. About how many cigarettes a day do you smoke? \_\_\_\_ # cigarettes /day**

**F3b1. How many of these are smoked in the home? \_\_\_\_ # of daily cigarettes at home**

**F4. Does [CHILD] smoke cigarettes?**

Yes ..... 1

No ..... 0

Don't know ..... -2

**F5. Many people have difficulties keeping their children away from tobacco smoke. Do you have problems keeping [CHILD] away from people who are smoking?**

Yes ..... 1

No ..... 0

Don't know ..... -2

**F6. How frequently is your child around people who are smoking? Would you say...**

[READ LIST.]

Daily ..... 1

Several times a week ..... 2

Several times a month ..... 3  
Rarely ..... 4

***SECTION G. OTHER RISK FACTORS***

**G1 Does your home use gas or electric fuel for cooking?**

Gas.....1 [If gas, go to B1a.]

Electric.....2

Wood, other biofuel...3

**G1a. Does your gas stove have a constant pilot light?**

Yes.....1

No.....0

Don't know.....-2

## ENTREVISTA INICIAL

### SECCION A. INFORMACION GENERAL

A1. Nombre del Estudio: PAHO-Children`s Asthma and Traffic Emissions Study

A2. No. de Identificación \_\_\_\_\_

A3. Fecha de Elaboración \_\_\_\_/\_\_\_\_/\_\_\_\_  
M M D D Y Y

A4. Iniciales del Encuestador (a)\_\_\_\_\_

A5. Fecha de Nacimiento del niño (a) \_\_\_\_/\_\_\_\_/\_\_\_\_  
M M D D Y Y

A6. Nombre de la persona que cuida al niño(a)

A6a. \_\_\_\_\_ A6b. \_\_\_\_\_  
[NOMBRE] [APELLIDO]

A7. ¿Qué parentesco tiene con el niño(a) la persona que lo cuida?

Madre (biológica o adoptiva) .. 1

Padre (biológico o adoptivo) . 2

Madrastra ..... 3

Padrastra..... 4

Padre adoptivo..... 5 [No permitido]

Abuela .....6

Abuelo..... 7

Hermano (a).....8

Otro familiar ..... 9 Especifique: \_\_\_\_\_

Otra persona no familiar ....10 Especifique: \_\_\_\_\_

No sabe .....-2

### SECCION B .SALUD DEL NIÑO

Las primeras preguntas son en relación a la salud de su hijo(a).Empezaremos cuando el niño nació

B1. ¿Cuanto pesó el niño (a) al nacer?

[Si la persona contesta solo en kilos o libras pregunte “cuantos gramos o onzas ?] Si la persona solo recuerda los kilos o libras, escríbalos en B1a, escriba -2 para gramos o onzas en B1b.

Si no recuerda el peso en kilos/libras ni gramos/onzas escriba en ambos espacios -2 y conteste la pregunta B1c. Si la persona contesta media onza, redondee al entero superior ejemplo: 8 lbs 5.5 oz = 8 lbs 6 oz.

B1a.\_\_\_\_ Kg / lbs    B1b.\_\_\_\_ gramos /onzas

B1c. [Solo si B1a= -2.]

¿El niño(a) pesó más o menos de 2.3 kg ( 5 lb) ?

Más..... 1

Menos.. .... 2

No sabe ... -2

B2 ¿Cuando el niño nació, estuvo hospitalizado en el área de prematuros, cunero o terapia intensiva neonatal?

Sí ..... 1

No ..... 0

No sabe .... -2

B3. ¿Cuando el niño (a) nació, requirió un respirador artificial?

Sí ..... 1

No ..... 0

No sabe ... . -2

**SECCION C. MORBILIDAD** [Encuesta *al inicio del estudio*]

Ahora quisiera hablar con Ud sobre cómo afecta el asma la actividad diaria del niño(a).Las siguientes preguntas son sobre el estado de salud del niño en los últimos 14 días.

[Utilice un calendario y señale los días]

C1. ¿En las últimas 2 semanas, cuantos días presentó el niño estos síntomas?

Tos\_\_\_\_\_ Dificultad para respirar \_\_\_\_\_ Sibilancias \_\_\_\_\_

C2. ¿En las últimas 2 semanas, cuantos días el niño tuvo que dejar de jugar o disminuir su actividad debido al asma, por sibilancias (silbido en el pecho) , tos, o dificultad respiratoria?  
\_\_\_\_Días

C3. ¿En las últimas 14 noches, cuantas noches despertó el niño debido a la tos, silbidos en el pecho, o dificultad para respirar por el asma? \_\_\_\_Noches

C4. ¿En las últimas 2 semanas, cuantos días el niño tuvo que parar o disminuir sus actividades por mas de medio día? \_\_\_\_Días

C5. ¿En las últimas 14 noches, cuantas noches Ud despertó o perdió horas de sueño por los síntomas de asma en el niño(a)? \_\_\_\_Noches

C6. ¿Durante los últimos 14 días, cuantas veces tuvo que cambiar su rutina o planes durante el día o la noche debido al asma del niño (a)? \_\_\_\_Días

C7. ¿Durante los últimos 14 días, cuantas veces faltó el niño(a) a la escuela?

[Incluya solo los días de clase.]

\_\_\_\_ Días [Si la respuesta es 0, pase a la pregunta C8]

C7a. ¿Cuantos de esos días que no fue a la escuela fueron debidos al asma? \_\_\_\_ Días

C8.¿ Durante los últimos 2 meses, ha tenido que pasar una noche hospitalizado el niño (a) por alguna razón?

Sí ..... 1

No .....0 [pase a la pregunta C9.]

C8a. ¿Cuantas veces?

[Número de diferentes ingresos al hospital, no cuente número de noches que permaneció hospitalizado] \_\_\_\_ veces

[Empiece con la fecha mas reciente de hospitalización y complete la información siguiente.

Utilice un calendario . ]

C8b. Cuando fue la fecha de la última hospitalización? Día\_\_\_\_\_ Mes\_\_\_\_\_

C8c. ¿Cuantos días permaneció en el hospital? \_\_\_\_\_Días

C8d ¿ Cual fue el motivo de hospitalización del niño(a)?

[Seleccione las opciones siguientes, pero no lea la lista]

1=ASMA, 2= OTRAS, -2= NO SABE

C8e ¿ Requirió el niño estar en terapia intensiva? 1=Si , 0=No

Anote las Hospitalizaciones en los últimos 2 meses

	Fecha	Días	Motivo	Terapia Intensiva
Mas reciente:	1. ____/____/____	1. _____	1. _____	1. _____
Admisión #2	2. ____/____/____	2. _____	2. _____	2. _____
Admisión #3	3. ____/____/____	3. _____	3. _____	3. _____
Admisión #4	4. ____/____/____	4. _____	4. _____	4. _____

C9. Sin contar las hospitalizaciones, durante los últimos 2 meses, el niño(a) ha sido llevado a recibir consulta o atención Médica?

Si ..... 1

No ..... 0 [Pase a la siguiente sección]

C9a. ¿Cuántas veces? \_\_\_\_ veces

C9b. ¿Cuándo fue la última visita? Día\_\_\_\_\_ Mes\_\_\_\_\_

C9c. ¿Acudió a consulta por el asma? 1=Asma, 2=Otra causa

C9d. ¿Fue una consulta programada en un consultorio o una consulta en Urgencias?  
[1=Consulta programada en consultorio, 2=Urgencias, 3=Consulta no programada en consultorio ]

	C9b fecha (mm/dd/aa)	. C 9c.	C9d
Mas reciente:	1. ____/____/____	1. ____	1. ____
VISITA #2:	2. ____/____/____	2. ____	2. ____
VISITA #3:	3. ____/____/____	3. ____	3. ____
VISITA #4:	4. ____/____/____	4. ____	4. ____
VISITA #5:	5. ____/____/____	5. ____	5. ____
VISITA #6:	6. ____/____/____	6. ____	6. ____

#### **SECCION D. SERVICIO MEDICO**

Ahora le haré algunas preguntas sobre el servicio médico que tiene el niño(a) y los medicamentos que ha tomado

D1. Durante los últimos 12 meses cuando ha acudido a que su hijo reciba atención por el asma, es usualmente en los servicios de Urgencias o ha sido en el consultorio del médico?

[Seleccione la respuesta, No le lea la lista]

Urgencias. .... 1  
Consultorio ..... 2  
Ambos , pero mas en Urgencias ... .. 3  
Ambos, pero mas en el consultorio. .... 4  
No visitó al Doctor ..... 5

D2. Durante los últimos 2 meses, ha tomado su hijo(a) algún medicamento para el asma?

Sì ..... 1

No ..... 0 [pase a la preg D3]

D2a. Su hijo(a) toma actualmente medicamentos para prevenir el asma diariamente, aun cuando se encuentra bien, para prevenir los síntomas?

Sì ..... 1 [pase a la preg D3a]

No ..... 0

D3. En los últimos 2 meses, ¿le han recetado a su hijo(a) medicamentos que toma diariamente para prevenir el asma, aunque se encuentre bien?

Sì ..... 1

No ..... 0 [pase a la preg. D4]

No sabe ..... -2 [pase a la preg. D4 ]

D3a. ¿Cuál medicamento?

[No lea la lista. Coloque el número 1 en el nombre del medicamento que le mencione, coloque 0 en todos los demás. Puede utilizar fotos de medicamentos]

D3b. [Para cada medicamento que le mencionó que ha utilizado, pregunte qué tan frecuente lo ha recibido durante los últimos 2 meses; para los demás coloque -1 “no aplica” (lea las opciones)]

Nunca o rara vez..... 0

Alguna veces .....1

Frecuentemente..... 2

Casi siempre..... 3

**D3a**

**D3b**

1. Jarabes o tabletas , no recuerda el nombre .....	_____	_____
2. medicamentos inhalados , no recuerda el nombre.....	_____	_____
3. medicamentos nebulizados, no recuerda el nombre .....	_____	_____
4. Salbutamol oral (ventolin) .....	_____	_____
5. Bromuro de Ipatropio (atrovet, combivent, berodual).....	_____	_____
6. Salbutamol inhalado (ventolin).....	_____	_____
7. Salbutamol nebulizado (ventolin) con nebulizador .....	_____	_____
8. Cromoglicato (Intal) inhalado .....	_____	_____
9. Cromoglicato (Intal) nebulizado .....	_____	_____
10. Cromoglicato spray nasal (Nazotral).....	_____	_____
11. Prednisona o Prednisolona oral (meticorten).....	_____	_____
12. Beclometasona inhalado ( Beconase) .....	_____	_____
13. Esteroides nasales (Uniclar , Rhinocort, ).....	_____	_____
14. Triamcinolone (Nasacort) inhalado.....	_____	_____
15. Flunisolide (Aerobid) inhalado .....	_____	_____
16. Fluticasona (Flixotide) inhalado.....	_____	_____
17. Teofilina (Elixofilina,) oral.....	_____	_____
18. Budesonida (Pulmicort) inhalado, nebulizado.....	_____	_____
19. Salmeterol/Fluticasona (Seretide).....	_____	_____
20. Otro (especificar ): D3a21a.....	_____	_____

D4a. Que medicamentos le administra a su hijo(a) cuando tiene síntomas de asma?

Coloque el número 1 en el medicamento que le mencione y 0 en todos los demás (no le lea la lista, puede utilizar fotos, especifique la presentación oral, inhalada etc.)



D4b. [Solo pregunte sobre los medicamentos que le refirieron haber administrado en la pregunta D4a, en los demás coloque un -1 para “No aplica” ] ¿ Durante los últimos 2 meses , el niño(a) utilizó este medicamento porque tenía síntomas o signos de asma?

Sì ..... 1  
 No ..... 0  
 No se ..... -2

D4c. [Solo pregunte sobre los medicamentos que le refirieron haber administrado en la pregunta D4b, en los demás coloque un -1 para “No aplica” ] ¿ Debe tomar este medicamento más de una vez al día?

Sì ..... 1  
 No ..... 0  
 No se ..... -2

	D4a	D4b	D4c
1. Jarabes o tabletas , no recuerda el nombre .....	_____	_____	_____
2. medicamentos inhalados , no recuerda el nombre.....	_____	_____	_____
3. medicamentos nebulizados, no recuerda el nombre .....	_____	_____	_____
4. Salbutamol oral (ventolin) .....	_____	_____	_____
5. Bromuro de Ipatropio (atrovet, combivent, berodual).....	_____	_____	_____
6. Salbutamol inhalado (ventolin).....	_____	_____	_____
7. Salbutamol nebulizado (ventolin) con nebulizador .....	_____	_____	_____
8. Cromoglicato (Intal) inhalado .....	_____	_____	_____
9. Cromoglicato (Intal) nebulizado .....	_____	_____	_____
10. Cromoglicato spray nasal (Nazotral).....	_____	_____	_____
11. Prednisona o Prednisolona oral (meticorten).....	_____	_____	_____
12. Beclometasona inhalado ( Beconase) .....	_____	_____	_____
13. Esteroides nasales (Uniclar , Rhinocort, ).....	_____	_____	_____
14. Triamcinolone (Nasacort) inhalado.....	_____	_____	_____
15. Flunisolide (Aerobid) inhalado .....	_____	_____	_____
16. Fluticasona (Flixotide) inhalado.....	_____	_____	_____
17. Teofilina (Elixofilina,) oral.....	_____	_____	_____
18. Budesonida (Pulmicort) inhalado, nebulizado.....	_____	_____	_____
19. Salmeterol/fluticasona (Seretide).....	_____	_____	_____
20. Otro (especificar ): D3a21a._____	_____	_____	_____

D4d. Cuántos medicamentos usualmente toma el niño(a) en un día para el asma?

\_\_\_\_\_ diferentes medicamentos

D5d. Ha tenido algún problema para que su hijo reciba el medicamento en la escuela?

Sì .....1  
 No .....0  
 [No toma medicamentos en la escuela] . . . -1

D6. Durante los últimos 12 meses ha tenido servicio médico por el Seguro Social, ISSTE u otra institución de gobierno?

Sì ..... 1  
No ..... 0  
No sè ..... -2

D7. Actualmente tiene un seguro médico privado que cubra hospitalización?

Sì ..... 1  
No ..... 0 [Pase a la preg E1]  
No sabe ..... -2 [Pase a la preg E1]

D7a. Cuál es el nombre de su aseguranza? \_\_\_\_\_

### **SECCION E . DATOS DEMOGRAFICOS**

Ahora pasaremos a preguntas generales en relación a su casa, la familia etc.

E1. ¿Que grado escolar esta cursando su hijo(a)? \_\_\_\_\_

E2. ¿Desde cuando el niño(a) vive en la dirección actual de su domicilio?

a. \_\_\_\_\_ años b. \_\_\_\_\_ meses

E3. ¿Alguien de la familia del niño(a) tiene asma? (Padres, hermanos, abuelos)

Sì ..... 1  
No ..... 0  
No sè ..... -2

E4. ¿Alguien de la familia del niño(a) tiene rinitis alérgica o dermatitis atópica ? ( Padres, hermanos, abuelos)

Sì ..... 1  
No ..... 0  
No sè ..... -2

E4a. ¿ El niño(a) tiene rinitis alérgica o dermatitis atópica?

Sì ..... 1  
No ..... 0  
No sè ..... -2

E5. ¿Cual es el mayor grado escolar que Ud completó?

Parentesco \_\_\_\_\_ Grado de Educación \_\_\_\_\_

1=Madre (bio o adoptiva)

2=Padre (bio or adoptivo)

3=Madrastra

4.Padrastro

0 = Nunca fue a la escuela

1-6 = Anote el grado de primaria de 1-6

7-9= Anote el grado de secundaria

10-12 = Anote el grado de preparatoria

4=Abuela  
 5= Abuelo  
 6= Hermano(a)  
 7= Otro familiar  
 8=Otro no familiar  
 -2 = No se

13 = 1 o 2 años de Universidad/carr técnica  
 14 = 3 or 4 años de Universidad o C técnica  
 15 = 5+ años de Universidad ò carrera técnica  
 16 = Otro  
 -2= No se

E6. ¿Cuántas personas viven en la casa, incluyendo al niño? \_\_\_\_\_  
 [La persona entrevistada debe incluirse si vive en la casa.]

E6a. ¿Cuántas personas de las que viven en la casa son adultos? (mayores de 18 años) \_\_\_\_\_

E7. ¿Quien es el jefe o la jefe de familia? (Nombre) \_\_\_\_\_

E7a. ¿Que parentesco tiene él o ella con el niño(a)? \_\_\_\_\_

E7b. ¿Cual es el máximo grado de estudio del jefe o la jefe de familia? \_\_\_\_\_

E8 . ¿De que nacionalidad, raza o grupo étnico pertenece el niño(a)? \_\_\_\_\_  
 (use los códigos siguientes)

Hispana  
 Puertorriqueño .....1  
 Dominicano .....2  
 Mexicano .....3  
 Suramericano .....4  
 Central Americano .....5  
 Cubano.....6  
 Otro Hispano .....7

Negra  
 Afro Americano .....8  
 Indios del oeste .....9  
 Negro caribeño .....10  
 Otros de raza negra .....11

Blancos .....12

Asiático .....13

E9 ¿A qué nacionalidad, raza o grupo étnico pertenece Ud ( utilice los mismos códigos anteriores) \_\_\_\_\_

E10. ¿Cuál es su estado civil? \_\_\_\_\_  
 Casada(o) .....1  
 Divorciada.....2

Soltera. .... 3  
 Viuda. .... 4  
 Separada. .... 5  
 Otro. .... 6    Especifique: \_\_\_\_\_

### **SECCION F – TABAQUISMO**

Ahora le haré algunas preguntas sobre el tabaquismo.

F1 . ¿Cuántas personas de las que viven en la casa del niño(a) fuman? \_\_\_\_\_

F2. ¿ Alguna otra persona que cuida del niño(a) fuma?  
 Sì ..... 1  
 No ..... 0

F3. ¿ Ud fuma cigarros, aunque sea ocasionalmente?  
 Sì ..... 1  
 No ..... 0 [pase a preg F4]

F3a. ¿Cuántos años hace que Ud fuma? \_\_\_\_\_ años

F3b. ¿Cuántos cigarros al día se fuma? \_\_\_\_ # cigarros /día

F3b1. ¿Cuántos de esos se fuma dentro de la casa? \_\_\_\_ # de cigarros diarios dentro de la casa.

F4. ¿El niño(a) fuma?  
 Sì ..... 1  
 No ..... 0  
 No sè..... -2

F5. Muchas personas tienen problemas para alejar a sus hijos del cigarro, Ud tiene problemas para que su hijo(a) se aleje de personas que fuman?  
 Sì ..... 1  
 No ..... 0  
 No sè ..... -2

F6. ¿Que tan frecuente está su hijo(a) cerca de personas que fuman? Ud diría que.....  
 [lea la lista]  
 Diariamente ..... 1  
 Varias veces a la semana ..... 2  
 Varias veces al mes. .... 3  
 Raramente ..... 4

### **SECCION G. OTROS FACTORES DE RIESGO**

G1 Que combustible utiliza para cocinar?  
 Gas.....1

Estufa Eléctrica.....2  
Madera, Leña.....3

G1a. ¿Su estufa tiene constantemente el piloto encendido?

Sì .....1

No.....0

No sé.....-2

## **Appendix F**

**Weekly Morbidity Questionnaire (English)**

**Weekly Morbidity Questionnaire (Spanish)**

## **WEEKLY MORBIDITY QUESTIONNAIRE**

[To be asked each week to the children]

Child Study ID #: \_\_\_\_\_

Date: \_\_\_\_\_

Field Staff: \_\_\_\_\_

Now I want to talk with you about how asthma affects you each day. The next few questions are about your health in the last week, that is, the past 7 days, from [7 days ago] to today.  
[USE CALENDAR and MARK DAYS.]

**B1. In the last week, how many days did you have wheezing or tightness in the chest or cough?**

\_\_\_\_ Days      Which days? \_\_\_\_\_

**B2. In the last week, how many days did you have to slow down or stop playing or activities because of asthma, wheezing or tightness in the chest, or cough?**

\_\_\_\_ Days      Which days? \_\_\_\_\_

**B3. In the last 7 nights, how many nights did you wake up because of asthma, wheezing or tightness in the chest, or cough?**

\_\_\_\_ Nights      Which nights? \_\_\_\_\_

**B4. In the last week, on how many days were you not able to participate in physical activities for more than half a day?**

\_\_\_\_ Days      Which days? \_\_\_\_\_

**B5. In the past 7 nights, how many nights did you wake up or lose sleep because of your asthma?**

\_\_\_\_ Nights      Which nights? \_\_\_\_\_

**B6. During the past 7 days, how many days did you miss school for any reason?**

[Include only days school was in session.]

\_\_\_\_ Days [IF 0, SKIP TO B8]      Which days? \_\_\_\_\_

**B6a. How many of those days did you miss school due to asthma?**

\_\_\_\_ Days      Which days? \_\_\_\_\_

**B7. During the past week, did you have to stay overnight in the hospital for any reason?**

[DO NOT INCLUDE OVERNIGHT WAITS IN THE ER.]

Yes ..... 1

No ..... 0 [SKIP TO B9]

**B8a. How many days were you] in the hospital then?**

\_\_\_\_\_ Days      Which days? \_\_\_\_\_

**B8b. What was the main reason that you were hospitalized that time?**

[USE THE FOLLOWING CODES, BUT DO NOT READ LIST.

1=ASTHMA, 2=OTHER, -2=DON'T KNOW]

**B8c. Were you in the ICU?**

[1=Yes, 0=No]

**B9. Not counting hospitalizations, during the past week did you see a doctor for any reason? Include visits to an emergency room, a doctor's office, or a clinic.**

Yes ..... 1

No ..... 0 [SKIP TO END]

**9 ICAS Measures of Morbidity Version 5.0 (August 3, 1998)**

**B9a. How many times?**

\_\_\_\_\_ visits

[Start with most recent visit and complete the grid below for up to 6 visits. Use calendar.]

**B9b. When was the (last) visit?**

[Ask date of each visit and insert on grid below. For an unknown date in a previous month, enter "15" if day is not known but month and year are known: e.g. 01/15/98. For an unknown date within the current month, if the interview is conducted between the 1st and 15th of the month, enter '1' as the day: e.g. 02/01/98. However, if the interview is being conducted on or after the 15th of the month, enter '15' as the day.]

**B9c. Was that visit for asthma or another reason?**

[1=Asthma, 2=Other]

**B9d. Was that an appointment that was scheduled at a clinic at least 24 hours ahead or was it an emergency visit at an ER or clinic?**

[1=Clinic, scheduled, 2=ER, 3=Clinic, unscheduled]



**B10. During the past 7 days, have you taken medicine because you were having asthma signs/symptoms?**

**What medicines did you take while having these asthma signs or symptoms?**

**What form is the medicine?** [DO NOT READ LIST. Can use pictures of medicines. If

not volunteered, read options for form of medicine: liquid or oral, inhaled or nebulizer/electric machine. In the chart below, enter 1 for all medicines that are named. Enter 0 for all other medicines.]

1. Liquid or tablets, can't remember name ..... \_\_\_\_\_
2. Inhaled medicine(s), can't remember name ..... \_\_\_\_\_
3. Nebulized medicine(s), can't remember name ..... \_\_\_\_\_
4. Albuterol (Ventolin, Proventil) by mouth..... \_\_\_\_\_
5. Ipratropium (Atrovent)..... \_\_\_\_\_
6. Albuterol (Ventolin, Proventil) by inhaler..... \_\_\_\_\_
7. Albuterol (Ventolin, Proventil) by nebulizer (electric machine)..... \_\_\_\_\_
8. Cromolyn (Intal, Nasalcrom) by inhaler..... \_\_\_\_\_
9. Cromolyn (Intal) by nebulizer (electric machine)..... \_\_\_\_\_
10. Nasalcrom by nasal spray..... \_\_\_\_\_
11. Prednisone or prednisolone (deltasone, medrol) by mouth..... \_\_\_\_\_
12. Beclomethasone (Qvar) by inhaler..... \_\_\_\_\_
13. Steroid by nasal spray (Nasonex, Rhinocort, Flonase)..... \_\_\_\_\_
14. Triamcinolone (Azmecort) by inhaler..... \_\_\_\_\_
15. Flunisolide (Aerobid) by inhaler..... \_\_\_\_\_
16. Fluticasone (Flovent) by inhaler..... \_\_\_\_\_
17. Theophylline (Slo-phyllin, Slo-bid, Theo-dur) by mouth..... \_\_\_\_\_
18. Budesonide (Pulmacort) by diskhaler..... \_\_\_\_\_
19. Other (Specify): B3a20a. \_\_\_\_\_

**B11. What days/nights did you take these medicines during the last week?**

Sat      Sun      Mon      Tue      Wed      Thu      Fri      (Circle)

Approximately what time of the day/night was this medication taken? \_\_\_\_\_

MEDICION DE MORBILIDAD [ preguntar cada semana al niño(a) ]

Num Identificación\_\_\_\_\_ Fecha\_\_\_\_\_ I.Personal\_\_\_\_\_

H1. ¿En los últimos 7 días (utilize un calendario), cuantos días has tenido tos, silbidos en el pecho?

\_\_\_\_\_ días Cuáles \_\_\_\_\_

H2. ¿En la última semana, cuantos días tuviste que dejar de jugar o hacer tus actividades por el asma, por tener tos, sentirte agitado o con silbidos en el pecho?

\_\_\_\_\_ días Cuáles \_\_\_\_\_

H3. ¿En la última semana cuantas noches despertaste por los síntomas de asma (tos, silbidos, dificultad para respirar)?

\_\_\_\_\_ días Cuáles \_\_\_\_\_

H4. ¿En la última semana cuantos días tuviste que sentarte o dejar de jugar o detener lo que hacías por más de mediodía por los síntomas de asma: tos, silbidos etc.?

\_\_\_\_\_ días Cuáles \_\_\_\_\_

H5. ¿Durante los últimos 7 días cuantas veces faltaste a la escuela?

\_\_\_\_\_ días Cuáles \_\_\_\_\_

H6. ¿Cuántos de los días que faltaste a la escuela fue por el asma: tos, silbidos, dificultad para respirar?

\_\_\_\_\_ días Cuáles \_\_\_\_\_

H7. En los últimos 7 días, te han llevado al hospital?

No \_\_\_\_\_

Sí \_\_\_\_\_ cuántos días \_\_\_\_\_ cuáles \_\_\_\_\_

H8. Porqué te llevaron al hospital, estabas enfermo de:

Asma \_\_\_\_\_

Otra enfermedad \_\_\_\_\_

No sabe \_\_\_\_\_

H9. En los últimos 7 días has ido a ver algún Doctor?

No \_\_\_\_\_

Sí \_\_\_\_\_ cuantas veces \_\_\_\_\_ cuando fue la última visita \_\_\_\_\_

Esta última vez que te llevaron a ver un Doctor fue porque tenías asma?

Sí \_\_\_\_\_ No \_\_\_\_\_

H10. Te llevaron a urgencias?

Sí \_\_\_\_\_ No \_\_\_\_\_

H11- Que medicamentos has tomado los últimos 7 días?

1. Jarabes o tabletas , no recuerda el nombre ..... \_\_\_\_\_
2. medicamentos inhalados , no recuerda el nombre..... \_\_\_\_\_
3. medicamentos nebulizados, no recuerda el nombre ..... \_\_\_\_\_
4. Salbutamol oral (ventolin) ..... \_\_\_\_\_
5. Bromuro de Ipatropio (atrovet, combivent, berodual)..... \_\_\_\_\_
6. Salbutamol inhalado (ventolin)..... \_\_\_\_\_
7. Salbutamol nebulizado (ventolin) con nebulizador ..... \_\_\_\_\_
8. Cromoglicato (Intal) inhalado ..... \_\_\_\_\_
9. Cromoglicato (Intal) nebulizado ..... \_\_\_\_\_
10. Cromoglicato spray nasal (Nazotral)..... \_\_\_\_\_
11. Prednisona o Prednisolona oral (meticorten)..... \_\_\_\_\_
12. Beclometasona inhalado ( Beconase) ..... \_\_\_\_\_
13. Esteroides nasales (Uniclar , Rhinocort, )..... \_\_\_\_\_
14. Triamcinolone (Nasacort) inhalado..... \_\_\_\_\_
15. Flunisolide (Aerobid) inhalado ..... \_\_\_\_\_
16. Fluticasona (Flixotide) inhalado..... \_\_\_\_\_
17. Teofilina (Elixofilina,) oral..... \_\_\_\_\_
18. Budesonida (Pulmicort) inhalado, nebulizado..... \_\_\_\_\_
19. Salmeterol/fluticasona (Seretide)..... \_\_\_\_\_
20. Montelukast..... \_\_\_\_\_
21. Otro (especificar ): . \_\_\_\_\_

H12. Que días tomaste estos medicamentos?

Sab	Dom	Lun	Mart	Mièrc	Juev	Vier
-----	-----	-----	------	-------	------	------

## **Appendix G**

**Daily Symptoms Diary – (English)**

**Daily Symptoms Diary – (Spanish)**



## Children's Asthma And Traffic Pollution Study



### SYMPTOMS AND MEDICATIONS DIARY

To be completed by field staff only:

Study ID: \_\_\_\_\_

Field Staff: \_\_\_\_\_

**FRIDAY**

Date: \_\_\_\_\_

SYMPTOMS	In the Morning 6am-12pm	In the Afternoon 12pm-5pm	In the Evening 5pm-12am	Overnight 12am-6am
	Fever			
Cough				
Wheeze (whistling in the chest)				
Difficulty breathing				
Cold				
Other symptoms				
Medical visit				
School absenteeism				
MEDICATIONS				
Bronchodilators				
Salbutamol (Ventolin)				
Albuterol				
Serevent				
Inhaled Steroids				
Fluticasone (Pulmicort)				
Advair				
Oral or Injected Steroids				
Prednisone				
Cortisone				
Other				
Antihistamines				
Antibiotics (record name)				
Other (record name)				
PHYSICAL ACTIVITY				
How many hours was your child outdoors?				

# **SATURDAY**

Date: \_\_\_\_\_

SYMPTOMS	In the Morning 6am-12pm		In the Afternoon 12pm-6pm		In the Evening 6pm-12am		Overnight 12am-6am
Fever							
Cough							
Wheeze (wheezing in the chest)							
Difficulty breathing							
Cold							
Other symptoms							
Medical visit							
School absenteeism							
<b>MEDICATIONS</b>							
Bronchodilators	Salbutamol (Ventolin) Atrovent Serevent Flovent Budesonide (Pulmicort) Advair						
Inhaled Steroids							
Oral or Injected Steroids	Prednisone						
Antihistamines	Claritin						
Antibiotics (record name)	Other						
Other (record name)							
<b>PHYSICAL ACTIVITY</b>							
How many hours was your child outdoors?							

# **SUNDAY**

Date: \_\_\_\_\_

SYMPTOMS	In the Morning 6am-12pm		In the Afternoon 12pm-6pm		In the Evening 6pm-12am		Overnight 12am-6am
Fever							
Cough							
Wheeze (wheezing in the chest)							
Difficulty breathing							
Cold							
Other symptoms							
Medical visit							
School absenteeism							
<b>MEDICATIONS</b>							
Bronchodilators	Salbutamol (Ventolin) Atrovent Serevent Flovent Budesonide (Pulmicort) Advair						
Inhaled Steroids							
Oral or Injected Steroids	Prednisone						
Antihistamines	Claritin						
Antibiotics (record name)	Other						
Other (record name)							
<b>PHYSICAL ACTIVITY</b>							
How many hours was your child outdoors?							

**MONDAY**

Date: \_\_\_\_\_

SYMPTOMS	In the Morning 6am-12pm		In the Afternoon 12pm-6pm		In the Evening 6pm-12am		Overnight 12am-6am
Fever							
Cough							
Wheeze (whistling in the chest)							
Difficulty breathing							
Cold							
Other symptoms							
Medical visit							
School absenteeism							
<b>MEDICATIONS</b>							
Bronchodilators	<div> <div>Salmeterol (Ventolin)</div> <div> <div>Albuterol</div> <div>Servent</div> <div>Flovent</div> <div>Budesonide (Pulmicort)</div> <div>Advair</div> <div>Prednisone</div> <div>Claritin</div> <div>Other</div> </div> </div>						
Inhaled Steroids							
Oral or Injected Steroids							
Antihistamines							
Antibiotics (record name)							
Other (record name)							
<b>PHYSICAL ACTIVITY</b>							
How many hours was your child outdoors?							

**TUESDAY**

Date: \_\_\_\_\_

SYMPTOMS	In the Morning 6am-12pm		In the Afternoon 12pm-6pm		In the Evening 6pm-12am		Overnight 12am-6am
Fever							
Cough							
Wheeze (whistling in the chest)							
Difficulty breathing							
Cold							
Other symptoms							
Medical visit							
School absenteeism							
<b>MEDICATIONS</b>							
Bronchodilators	<div> <div>Salmeterol (Ventolin)</div> <div> <div>Albuterol</div> <div>Servent</div> <div>Flovent</div> <div>Budesonide (Pulmicort)</div> <div>Advair</div> <div>Prednisone</div> <div>Claritin</div> <div>Other</div> </div> </div>						
Inhaled Steroids							
Oral or Injected Steroids							
Antihistamines							
Antibiotics (record name)							
Other (record name)							
<b>PHYSICAL ACTIVITY</b>							
How many hours was your child outdoors?							

# WEDNESDAY

Date: \_\_\_\_\_

	In the Morning 6am-12pm	In the Afternoon 12pm-5pm	In the Evening 6pm-12am	Overnight 12am-6am
<b>SYMPTOMS</b>				
Fever				
Cough				
Wheeze (whizzing in the chest)				
Difficulty breathing				
Cold				
Other symptoms				
Medical visit				
School absenteeism				
<b>MEDICATIONS</b>				
Bronchodilators	Salbutamol (Ventolin)			
	Atrovent			
	Serevent			
	Flovent			
Inhaled Steroids	Budesonide (Pulmicort)			
	Advair			
Oral or Injected Steroids	Prednisone			
Antihistamines	Claritin			
	Other			
Antibiotics (record name)				
Other (record name)				
<b>PHYSICAL ACTIVITY</b>				
How many hours was your child outdoors?				

# THURSDAY

Date: \_\_\_\_\_

	In the Morning 6am-12pm	In the Afternoon 12pm-5pm	In the Evening 6pm-12am	Overnight 12am-6am
<b>SYMPTOMS</b>				
Fever				
Cough				
Wheeze (whizzing in the chest)				
Difficulty breathing				
Cold				
Other symptoms				
Medical visit				
School absenteeism				
<b>MEDICATIONS</b>				
Bronchodilators	Salbutamol (Ventolin)			
	Atrovent			
	Serevent			
	Flovent			
Inhaled Steroids	Budesonide (Pulmicort)			
	Advair			
Oral or Injected Steroids	Prednisone			
Antihistamines	Claritin			
	Other			
Antibiotics (record name)				
Other (record name)				
<b>PHYSICAL ACTIVITY</b>				
How many hours was your child outdoors?				





# Estudio Binacional de Contaminación vial y Asma Infantil



## DIARIO DE SINTOMA Y MEDICAMENTOS

Completar sólo por personal del estudio:

Study ID: \_\_\_\_\_

Personal del estudio: \_\_\_\_\_

**VIERNES : FRIDAY**

Fecha: \_\_\_\_\_

SINTOMA	Por la Mañana	Por la Tarde	Por la Noche	De la Noche a la Mañana
	6am-12 pm	12 pm-6 pm	6 pm-12 am	12 am-6 am
Fiebre				
Tos				
Sibilancias (silbidos en el pecho)				
Dificultad respiratoria				
Catarro				
Otro síntoma				
Visite al médico				
Falte a la escuela				
MEDICAMENTOS				
Broncodilatadores				
	Salbutamol (Ventolin)			
	Albuterol			
	Serevent			
	Flonase			
Esterores inhalados	Budesonida (Pulmicort)			
	Fluticasona			
Esterores oral o inyectada	Clarithin			
Antihistamínicos	Otro			
Antibióticos (escriba nombre)				
Otros (escriba nombre)				
ACTIVIDAD FISICA				
Marcar las horas en que estuvo al aire libre				

# SÁBADO

SATURDAY

Fecha: \_\_\_\_\_

	Por la Mañana 6am-12pm	Por la Tarde 12pm-6pm	Por la Noche 6pm-12am	De la Noche a la Mañana 12am-6am
<b>SINTOMA</b>				
Fiebre				
Tos				
Sibilancias (silbidos en el pecho)				
Dificultad respiratoria				
Catarro				
Otro síntoma				
Visite al médico				
Falte a la escuela				
<b>MEDICAMENTOS</b>				
Broncodilatadores	Salbutamol (Ventolin)			
	Alrovent			
	Serevent			
	Flovent			
Esteroides inhalados	Budesonida (Pulmicort)			
Esteroides oral o inyectada	Prednisona			
Antihistamínicos	Claritin			
	Otro			
Antibióticos (anote nombre)				
Otros (anote nombre)				
<b>ACTIVIDAD FÍSICA</b>				
Marcar las horas en que estuvo al aire libre				

# DOMINGO

SUNDAY

Fecha: \_\_\_\_\_

	Por la Mañana 6am-12pm	Por la Tarde 12pm-6pm	Por la Noche 6pm-12am	De la Noche a la Mañana 12am-6am
<b>SINTOMA</b>				
Fiebre				
Tos				
Sibilancias (silbidos en el pecho)				
Dificultad respiratoria				
Catarro				
Otro síntoma				
Visite al médico				
Falte a la escuela				
<b>MEDICAMENTOS</b>				
Broncodilatadores	Salbutamol (Ventolin)			
	Alrovent			
	Serevent			
	Flovent			
Esteroides inhalados	Budesonida (Pulmicort)			
Esteroides oral o inyectada	Prednisona			
Antihistamínicos	Claritin			
	Otro			
Antibióticos (anote nombre)				
Otros (anote nombre)				
<b>ACTIVIDAD FÍSICA</b>				
Marcar las horas en que estuvo al aire libre				

**LUNES** MONDAY

Fecha: \_\_\_\_\_

	Por la Mañana 6am-12pm	Por la Tarde 12pm-6pm	Por la Noche 6pm-12am	De la Noche a la Mañana 12am-6am
<b>SINTOMA</b>				
Fiebre				
Tos				
Sibilancias (silbidos en el pecho)				
Dificultad respiratoria				
Catarro				
Otro síntoma				
Visita al médico				
Falta a la escuela				
<b>MEDICAMENTOS</b>				
Broncodilatadores	Salbutamol (Ventolin)			
	Albuterol			
	Serevent			
	Flovent			
Esteroides inhalados	Budesonida (Pulmicort)			
	Prednisona			
Esteroides oral o inyectada	Claritin			
Antihistamínicos	Otro			
Antibióticos (anote nombre)				
Otros (anote nombre)				
<b>ACTIVIDAD FÍSICA</b>				
Marcar las horas en que estuvo al aire libre				

**MARTES** TUESDAY

Fecha: \_\_\_\_\_

	Por la Mañana 6am-12pm	Por la Tarde 12pm-6pm	Por la Noche 6pm-12am	De la Noche a la Mañana 12am-6am
<b>SINTOMA</b>				
Fiebre				
Tos				
Sibilancias (silbidos en el pecho)				
Dificultad respiratoria				
Catarro				
Otro síntoma				
Visita al médico				
Falta a la escuela				
<b>MEDICAMENTOS</b>				
Broncodilatadores	Salbutamol (Ventolin)			
	Albuterol			
	Serevent			
	Flovent			
Esteroides inhalados	Budesonida (Pulmicort)			
Esteroides oral o inyectada	Prednisona			
Antihistamínicos	Claritin			
	Otro			
Antibióticos (anote nombre)				
Otros (anote nombre)				
<b>ACTIVIDAD FÍSICA</b>				
Marcar las horas en que estuvo al aire libre				

# MIÉRCOLES WEDNESDAY

Fecha: \_\_\_\_\_

SINTOMA	Por la Mañana	Por la Tarde	Por la Noche	De la Noche a la Mañana
	6am-12pm	12pm-6pm	6pm-12am	12am-6am
Fiebre				
Tos				
Sibilancias (silbidos en el pecho)				
Dificultad respiratoria				
Cisero				
Otro síntoma				
Visite al médico				
Falta a la escuela				
MEDICAMENTOS				
Broncodilatadores	Salbutamol (Ventolin)			
	Albuterol			
	Serevent			
	Flovent			
Esteroides inhalados	Budesonida (Pulmicort)			
	Prednisona			
Esteroides oral o inyectada	Claritin			
Antihistamínicos	Otro			
Antibióticos (anote nombre)				
Otros (anote nombre)				
ACTIVIDAD FÍSICA				
Marcar las horas en que estuvo al aire libre				

# JUEVES THURSDAY

Fecha: \_\_\_\_\_

SINTOMA	Por la Mañana	Por la Tarde	Por la Noche	De la Noche a la Mañana
	6am-12pm	12pm-6pm	6pm-12am	12am-6am
Fiebre				
Tos				
Sibilancias (silbidos en el pecho)				
Dificultad respiratoria				
Cisero				
Otro síntoma				
Visite al médico				
Falta a la escuela				
MEDICAMENTOS				
Broncodilatadores	Salbutamol (Ventolin)			
	Albuterol			
	Serevent			
	Flovent			
Esteroides inhalados	Budesonida (Pulmicort)			
	Prednisona			
Esteroides oral o inyectada	Claritin			
Antihistamínicos	Otro			
Antibióticos (anote nombre)				
Otros (anote nombre)				
ACTIVIDAD FÍSICA				
Marcar las horas en que estuvo al aire libre				

## **Appendix H**

**Subject Recruitment Protocol**

**Health Sampling Protocol**

**Exhaled Nitric Oxide Protocol**

**Exposure Sampling Protocol**

**Two-Stage Cascade Impactor Assembly Protocol**

## **SUBJECT RECRUITMENT PROTOCOL**

We will recruit 15 children between the ages of 6 and 12 from four schools in El Paso – Juarez to participate in the study. The recruitment process will proceed as follows:

- 1) Contact school principals in high and low exposure zones in each city
  - a. Inquire their interest and willingness for the study to be conducted in their school
    - i. Initial contact via letter
  - b. Contact school districts, and fill out appropriate paper work, if needed
    - i. E.g., *EPISD research proposal form.doc*
    - ii. E.g., *EPISD access to confidential data form.doc*
  - c. If interested, obtain numbers of asthmatic children, ages 6 to 12
  - d. Determine whether these numbers will enable the recruitment of 15 children
- 2) At each interested school, give brief recruitment presentations to school nurses and in student classrooms. Distribute flyer with research staff contact information to the children to take home to their parents.
- 3) Phone calls with parents/guardians of interested children
  - a. Parents of interested children will be asked to initiate contact with us by phone
  - b. In Juarez, we can contact the parents of children that participated in our previous study to facilitate recruitment
  - c. Conduct phone screening with interested parents.
  - d. Determine eligibility of children
- 4) Meetings with eligible children and parents/guardians
  - a. Set up in-person meetings with parents/guardians and eligible children
  - b. Provide a summary of the study and describe the measurements that will be taken and the questionnaires that are to be filled out by the children and their parents, should they wish to participate in the study
  - c. Provide a copy and orally review the consent form with the parent/guardian and the assent form with the children
  - d. Provide a copy and orally review the HIPAA authorization form and revoke letter with the parent/guardian.
  - e. Ask parents/guardians and children if they have any questions
  - f. If parent/guardian is interested in having their child participate in the study, obtain written consent on page 4 of study's copy of consent form:
    - i. Print child's name
    - ii. Obtain date and signature from parent/guardian and date
    - iii. Date and sign the form yourself under "Person obtaining consent's signature"
  - g. Obtain child's assent on pages 5-6 of study's copy of consent form
    - i. Obtain signature from child (if 11-12 years old)
    - ii. Obtain verbal assent from child (if 6-10 years old)
    - iii. Date and sign the form yourself under "Person soliciting assent"
  - h. Assign the child a subject ID number (EP-XX for El Paso, CJ-XX for Juarez) to be used, in place of their name, on all future study questionnaires and log sheets
  - i. Administer baseline questionnaire
- 5) Follow-up with parents/guardians of children that are not deemed eligible to participate
- 6) Log all recruitment and screening activity in *Screening log.xls*

## **HEALTH SAMPLING PROTOCOL**

We will conduct health measurements on each child on Friday mornings at each school. The health sampling will proceed as follows:

- 1) Determine time and location of weekly health sampling at each school
- 2) Determine how children will be pulled from classrooms for their sampling time (?)
- 3) Each week, set up health sampling station
- 4) Fill out weekly morbidity questionnaire with child (*Weekly morbidity questionnaire*)
- 5) Review daily symptoms and time-activity diary with child
- 6) Conduct exhaled nitric oxide measurements
- 7) Redistribute daily symptoms and time-activity diary for coming week
- 8) Log all health sampling activity at each school

## **EXHALED NITRIC OXIDE MEASUREMENT PROTOCOL**

1. Record the school, date and NIOX MINO serial number on the exhaled NO data log sheet
2. Throughout the sampling, verify that:
  - There are no electronic devices near the NIOX MINO
  - You do not connect the NIOX MINO power without a sensor
3. Collect three ambient (outdoor) NO readings throughout the sampling
  - One prior to collecting the exhaled NO measurements on the children
  - One during the exhaled NO collection
  - One after all exhaled NO samples have been collected
4. Run each child through the exhaled NO measurement protocol
  - Record your initials on the log sheet
  - Record the subject ID on the log sheet
  - Record the time of measurement on the log sheet
  - Record the temperature of the room (°C) on the log sheet
  - Measurement criteria
    - i. Verify that the child has not eaten any green vegetables within the previous 2 hours
    - ii. Verify that the child has not eaten within the previous hour
    - iii. Verify that the child has not been exercising during the previous hour
    - iv. If these cannot be verified, ask child to wait until sufficient time has passed
  - Record whether the child is suffering from any respiratory illness
  - Record whether the child is taking any medications; if so,
    - i. Record type of medication: inhaler, oral or injection on Comments section of log sheet
    - ii. Record name of medication on Comments section of log sheet
  - Collect first exhaled NO measurement
    - i. Review the collection method with the child
    - ii. Verify that the NIOX MINO screen indicates “ready to go”
    - iii. Conduct the eNO measurement**
    - iv. Record the exhaled NO value on the log sheet
    - v. Record the number of attempts before a successful value was obtained on the log sheet
    - vi. Record whether the quality control (QC) criteria were met on the log sheet
  - Collect second exhaled NO measurement
    - i. Repeat steps i – vi above
  - Record any comments specific to the measurements on child



## **EXPOSURE SAMPLING PROTOCOL**

We will conduct a variety of air pollution measurements throughout the study at each school:

- 48-hr (Monday-Wednesday; Wednesday-Friday) indoor and outdoor PM<sub>10-2.5</sub>, PM<sub>2.5</sub> and EC
- Weekly (96-hr, Monday-Friday) indoor and outdoor NO<sub>2</sub>;
- Continuous outdoor PM<sub>2.5</sub> (at El Paso high exposure zone school)

All field work is to be completed in the mornings, ideally between 7:00 - 9:00 am. Lab work will be completed upon returning from the field or will be assigned to those not involved with the day's field work.

Before any field work, all pumps should be set to run for 24-48 hours in order for flows to stabilize. Ensure there is an inline filter to prevent foreign bodies from entering the pump. Continue to run the pumps until used for field sampling.

**\*\*NOTE: ALL SAMPLER CLEANING, ASSEMBLY AND DISASSEMBLY  
REQUIRES THE USE OF POWDER-FREE GLOVES\*\***

### **A. On the day before each sampling day – sampler assembly**

1. Build sufficient number of samplers for next day's field work
  - a. 8 samplers (4 schools x 2 microenvironments) + blank and collo samplers
  - b. See the "*Blanks and collo schedule.xls*" to determine final number to build
  - c. Follow assembly instructions according to *Coarse Mode PM Sampler Protocol*
  - d. Note: during assembly, minimize exposure time of filters to the air to reduce deposition. Keep samplers covered or in a container while assembling others.
  - e. Note: Samples to be used as blanks are to be handled the same way as all other samples.
2. Leak test all samplers at 5 LPM using a non-flow control pump with a valve
  - a. Adjust the flow and measure using the Buck calibrator
  - b. Attach the sampler and measure the flow again using the appropriate calibration cap. There should be less the 5% difference in flows.
3. Once all samples are built and leak-tested, load them into resealable bags marked "clean" for each school and microenvironment. Blanks need to be put into a bag marked "blank" and then added to the sample bags with other samples. Check the blank schedule to find out which school and microenvironment should receive the blanks.

### **B. In the lab prior to field work**

1. Check contents of toolbox for:

Wire cutters	Large plastic wire ties
Large Phillips head screwdriver	Needlenose pliers
Paper tape	Pens/Pencils
Plastic forceps	Kimwipes in plastic bag
Duct tape	Plastic wire ties
Buck calibrator	Extra Buck fluid
Calibration cap	Buck AC adaptor

2. Check contents of crate for:
  - Clean samplers – enough for sampling and blanks
  - Extra tubing
  - Resealable plastic bags
  - School folders with current week's sampling logs (7 active, 1 passive log)
3. For the continuous monitors, pick up laptop, power cord and appropriate cables
4. On Mondays, take one passive NO<sub>2</sub> badge for each school. Check blank schedule. If blanks are scheduled, take an extra badge. Place bottles in crate. If badges were refrigerated, leave out the samples for the first school (including blanks, if scheduled) to warm to ambient temperature during transport.

### **C. Sampling set-up**

1. Attach the new sampler to the pump
  - a. Record watch time on the active sampling log sheet and enter it as "Time ON".
  - b. Avoid putting fingers over the sampler inlet, since it can destroy the filters inside.
  - c. Remove one label from the sampler for each pollutant (PM<sub>10-2.5</sub>, PM<sub>2.5</sub>) from the back of the sampler and place it into the relevant box on the log sheet.
2. Check air flows using the BUCK calibrator
  - a. Record initial flow
  - b. Adjust pump valve to bring the flow to target (5 lpm) and record adjusted flow
  - c. If flow is significantly lower than the previous day's flow (e.g. 200 cc lower), try tightening the screws. If flows are much higher than the previous day's value, open the sampler to check for a dislodged filter.
3. On Mondays, carefully add the NO<sub>2</sub> badge to the elutriator. Badges are not to be touched by hand; use the plastic bag or forceps. Remove one label from the outside of the bottle and place onto the passive sampling log sheet.
4. Blank samples should be treated exactly as the actual samples.
  - a. Remove blank PM sampler from its plastic bag, put into the elutriator, remove, put back into plastic bag and place near the sampling set up. Place labels from the blank sampler in the appropriate box on the active sampling log sheet.
  - b. Blank passive badges should be put into the elutriator, removed, put into plastic bag, put into vial and placed near the sampling set up. Blank badge labels should be placed on the passive sampling log sheet on the line marked "B".
5. At School A, download TEOM data
6. Check over the log sheet and make sure that all details are completed.

### **D. Sampling take-down (48 hours later)**

1. End active sampling from previous two-days
  - a. Take “off-flows” and record watch times from the log sheet and enter it as “Time OFF”.
  - b. Put used sampler into plastic bag that the new sampler came in, and put in the zipper bag marked “dirty”.
  - c. Collect any PM blank samples from the previous day and put in the zipper bag marked “dirty”
2. On Fridays, end passive sampling from previous week
  - a. Collect NO<sub>2</sub> badge from elutriator and put into resealable plastic bags, then into bottle. If badge does not fall freely out of the elutriator, use forceps or a screwdriver to push it out from the inside of the elutriator.
  - b. Note on and off times on log sheet.
  - c. Collect any NO<sub>2</sub> blank badges from the week, and place in bottle.
3. Repeat steps 2-8 above to set up for another sampling period

**E. Each day after field work – sampler disassembly**

1. Disassemble samplers from current day’s field work
  - a. As samplers are returned from the field, keep in plastic bags until disassembly.
  - b. Check “clean” bag to make sure all blanks were deployed in the field. If not, make a note in the sampler lab log sheet and deploy the next day.
  - c. Disassemble one sampler at a time, leaving other samplers in their plastic bags according to the sampler SOP.
  - d. Make notes in the sampler lab log sheet for any unusual findings, such as dislodged filter, yellow-colored filter (indicates tobacco smoke), dropped filter, hole in filter, etc. The more detail, the better, as this log is very important for interpreting unusual results later on.
  - e. Place filters back into their labeled Petri dishes and transfer to fridge for storage
2. On Fridays, transfer used NO<sub>2</sub> badges in their bottles from coolers to fridge
3. Follow the standard cleaning instructions in the sampler SOP before proceeding with next day’s sampler building and assembly.

## TWO-STAGE CASCADE IMPACTOR ASSEMBLY PROTOCOL



### Assembly of the Two-Stage Cascade Sampler for the PAHO Border Study

#### Preparation –

Use non-powdered gloves when handling all equipment.

Do not touch the Teflon filters with your hands; use only forceps. Filters are located in the cooler and are in labeled Petri dishes.

To clean forceps using Milli-Q water or ethanol, hold them over the sink or a waste beaker and allow them to air dry.

Cover clean trays with Kimwipes.

#### Assembly of the Cascade sampler –

Assemble as many units as required for the monitoring. Typically 8 units will fit on a tray. See Figure 1 for all components.

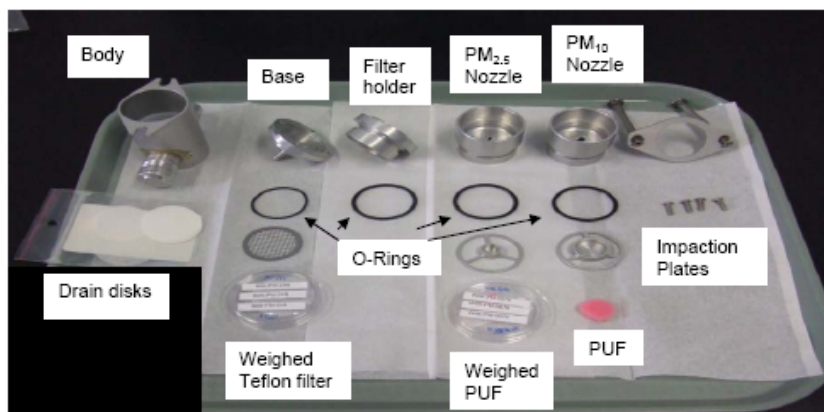


Figure 1 – Two-stage Cascade sampler components

Place small black o-ring into the base, place the metal screen on top. Ensure that the screen sits flat in the base. Sit the base face-up in the body (with connector barb facing down) so that it is flat. See A of Figure 2.

Place larger black o-rings into grooves on the nozzles and filter holder.

Place larger pink PUF into the larger impaction plate then place impaction plate face

down in the PM<sub>10</sub> nozzle (you should not be able to see the PUF). See B in Figure 2.



Figure 2.

Use clean forceps to place a drain disc onto the metal screen followed by a filter. Keep the Petri dish lined up with the correct unit so that it is obvious which labels correspond to which filter.

Use clean forceps to place the smaller pink PUF from the labeled Petri dish into the PM<sub>2.5</sub> impaction plate. Place the impaction plate face down into the PM<sub>2.5</sub> nozzle.

Stack the PM<sub>2.5</sub> nozzle on top of the PM<sub>10</sub> nozzle.

Attach the filter holder to the PM<sub>2.5</sub> nozzle so that all 3 components are tightly sealed.

Place the assembled nozzle sections on top of the filter; ensure that the drain disc ring sits between the nozzles and the filter.

Carefully turnover the whole unit, hold onto the base to ensure that the base and nozzles stay together.

Once all units are loaded with filters remove the tray from the hood.

Line up the screw holes and screw together the units using the torque screwdriver.

Using the torque screwdriver tighten all the screws evenly. Place pressure on the top of the unit to ensure even tightening.

Remove both of the labels from each of the Petri dishes and attach to the side of the unit.

To ensure that all the components stay together attach the bracket and screw the body and sampling sections together. See Figure 3. Do not overtighten as the bracket will bend.

**Washing – Two-stage Cascade Particle Sampler components**

All metal components need to be washed after each use. Wash in Milli-Q water with liquid soap. Rinse twice with Milli-Q water and once with distilled water. Set out to dry on clean trays and cover in Kimwipes.

Wash o-rings and metal screens separately. Do not use alcohol to dry the O rings.

## **Appendix I**

**Health Sampling Log Sheet**

**Exhaled Nitric Oxide Log Sheet**

**Active Sampling Log Sheet**

**Passive Sampling Log Sheet**

**HEALTH SAMPLING LOG SHEET**

Comments:

Emory/UTEP – Winter 2007-2008

School: \_\_\_\_\_

Date: \_\_\_\_\_ Start Time: \_\_\_\_\_

End Time: \_\_\_\_\_

	Subject ID	Morbidity?	Daily Diary?	eNO?	Comments
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					



# EXHALED NITRIC OXIDE DATA LOG SHEET

Emory/UTEP – Winter 2007-2008

Overall comments:

School: \_\_\_\_\_ Indoor NO Reading #1: \_\_\_\_\_ Time: \_\_\_\_\_ (before sampling)  
 Date: \_\_\_\_\_ Indoor NO Reading #2: \_\_\_\_\_ Time: \_\_\_\_\_ (during sampling)  
 NIOX MINO SN: \_\_\_\_\_ Indoor NO Reading #3: \_\_\_\_\_ Time: \_\_\_\_\_ (after sampling)

	Initials	Subject ID	Time	Indoor Temp.	Criteria met?	Resp. altered?	Medication?		eNO Reading #1			eNO Reading #2			Comments
							Type	Name	Value	# Tries	QC ?	Value	# Tries	QC?	
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															

**ACTIVE SAMPLING DATA LOG SHEET**

Emory/UTEP – Winter 2007-2008

Comments:

Weather conditions sample start:

School: \_\_\_\_\_

Weather conditions sample end:

OUTDOOR						
Pump No.	Day of week: M Tu We Th Fr (circle)		Day of week: M Tu We Th Fr (circle)			
	Start Date:	Time ON	Buck ID	Field Staff	End Date:	Time OFF

Pollutant	Label ID	Start Flow (lpm)		End Flow (lpm)	Blank Label ID
		Initial	Adjusted		
PM <sub>10-2.5</sub> (PUF)	Place 1 label from sampler here				
PM <sub>2.5</sub> (Teflon)	Place 1 label from sampler here				

NOTE: Target flow = 5 LPM

INDOOR						
Pump No.	Day of week: M Tu We Th Fr (circle)		Day of week: M Tu We Th Fr (circle)			
	Start Date:	Time ON	Buck ID	Field Staff	End Date:	Time OFF

Pollutant	Label ID	Start Flow (lpm)		End Flow (lpm)	Blank Label ID
		Initial	Adjusted		
PM <sub>10-2.5</sub> (PUF)	Place 1 label from sampler here				
PM <sub>2.5</sub> (Teflon)	Place 1 label from sampler here				

NOTE: Target flow = 5 LPM

**PASSIVE SAMPLING DATA LOGSHEET**

Emory/UTEP – Winter 2007-2008

Comments:

School: \_\_\_\_\_

**OUTDOOR**

Pollutant (Passive)	Sample Date & Time		Label ID	Comments	Operator Initials	
	On	Off			On	Off
NO <sub>2</sub>			S Place 1 label from bottle here			
			B Place 1 label from bottle here			

**INDOOR**

Pollutant (Passive)	Sample Date & Time		Label ID	Comments	Operator Initials	
	On	Off			On	Off
NO <sub>2</sub>			S Place 1 label from bottle here			
			B Place 1 label from bottle here			

## **Appendix J**

### **Calculation for Reflectance Measurements**

### Simplified Calculations for Reflectance Measurements

1. The traditional calculation determines the value of the “absorption coefficient”,  $a$ , in units of reciprocal meters:

$$a = (A/2V) * \ln(R_o/R) \quad (1)$$

where:  $R$  is the reflectance of the filter (when blank filter is nominally 100)

$R_o$  is the reflectance of the clean reference filter (initially set to 100, but actual value is measured before and after each set of samples)

$V$  is the volume sampled, in cubic meters

$A$  is the deposit area on the filter, in square meters

2. It is also traditional to express the absorption coefficient in units multiplied by a factor of  $10^5$ , for the sake of convenience. This transforms equation (1) to the following:

$$“a” = (A * 10^5 / 2V) * \ln(R_o/R) \quad (2)$$

3. Typical comparisons of measurements of absorption coefficient with collocated measurements of EC by TOR (from quartz filters, “EC/OC”) show that the relation between  $\mu\text{g EC}/\text{m}^3$  and “ $a$ ” vary by factors between about 0.83 and 2. For these calculations we will assume a factor of 1.
4. For a given sample, the atmospheric concentration of EC is the measured amount of EC, in  $\mu\text{g}$ , divided by the sample volume  $V$ , in  $\text{m}^3$ . This leads to the following:

$$\mu\text{g EC}/V = “a” = (A * 10^5 / 2V) * \ln(R_o/R) \quad (3)$$

5. The volume,  $V$ , cancels from both sides, leaving:

$$\mu\text{g EC} = (A * 10^5 / 2) * \ln(R_o/R) \quad (4)$$

6. For a 37mm Teflo filter (with ring), the deposit diameter is 29mm, and thus the deposit area is  $0.000660 \text{ m}^2$ . This allows computation by transformation and substitution into equation (4) to get:

$$\mu\text{g EC} = (0.000660 * 10^5 / 2) * \ln(R_o/R) = 33 * \ln(R_o/R) \quad (5)$$

7. Remember that this relation depends on using a 37mm filter and a factor of 1 for  $\mu\text{g EC}/\text{m}^3$  vs “ $a$ ”. If the factor is different for 1 for a given location or season, the estimated value of  $\mu\text{g EC}$  from equation 6 just needs to be adjusted accordingly (if the factor was 2 instead of 1, then the calculated value of  $\mu\text{g EC}$  would need to be divided by 2).

Actual calculations can use the mean value of  $R_o$ , measured before and after each set of sample values of  $R$ .

## **Vita**

Amit U. Raysoni holds a MS degree in Civil & Environmental Engineering from Carnegie Mellon University, Pittsburgh, PA. His focus was primarily on the PCB contamination in the three rivers of Pittsburgh. He received a Bachelor of Civil Engineering degree from the University of Mumbai (Bombay), India in 2001. Additionally, he holds a second undergraduate degree in Ecology & Environment from the Indian Institute of Ecology & Environment, New Delhi, India.

After pursuing his MS degree, Amit worked with Prof. Penelope Simoes Ferreira at the H John Heinz III School of Public Policy & Management, Carnegie Mellon University. He assisted Prof. Ferreira in developing graduate courses like ‘International Environment Law & Policy’, ‘Climate Change, Environment & Energy Policy’ & ‘National Security & International Terrorism’.

Amit came to the University of Texas at El Paso (UTEP) in August 2005 to pursue his Ph.D. in Environmental Sciences & Engineering. At UTEP’s Air Quality Laboratory in the Department of Civil Engineering, Amit worked on two Air Epidemiologic Longitudinal studies under the tutelage of Dr. Wen-Whai Li. These projects, funded by the Pan American Health Organization, the United States Environment Protection Agency, and the Mickey Leland National Urban Air Toxics Research Center, investigated the impact of traffic-related air pollutants on school-going asthmatic children in El Paso, Texas and Ciudad Juárez, Chihuahua. These projects were a collaborative effort between UTEP, the Rollins School of Public Health at Emory University, Atlanta, GA, and the University of Pittsburgh Medical Center, Pittsburgh, PA. During the course of these projects, Amit implemented and executed a rigorous air quality

monitoring and respiratory health data collection protocol and prepared the project's final reports including peer-reviewed publications and conference presentations.

At UTEP, Amit was the recipient of the Graduate School's 2011 Dodson Dissertation Fellowship and was also bestowed with the UTEP Miner Hero Award in the Research Category. The title of Amit's dissertation is: Assessment of Intra-urban Traffic-Related Air Pollution on Asthmatic Children's Exposure at schools in the Paso del Norte region.

This dissertation was typed by Amit U. Raysoni.

