Association of $PM_{2.5}$ and Ultrafine particle concentrations with diesel exhaust from truck traffic in Morgantown, WV

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ABSTRACT

Diesel exhaust contains a number of toxic air contaminants and has been classified as a probable human carcinogen by the US Environmental Protection Agency (EPA, 1994). Diesel engines are a major source of fine-particulate matter ranging in size from coarse (PM_{10} <10 μm and $PM_{2.5}$ <2.5 μm) to ultrafine (UFP <0.1μm). The microscopic nature of diesel exhaust particulates makes them readily respirable, contributing to a range of adverse health effects on the respiratory and immune systems of people exposed to it. These effects could be more severe in persons with asthma and other allergic diseases.

Diesel exhaust particles account for a high percentage of the particles emitted in many towns and cities. Human exposure to traffic-generated diesel exhaust near roadways has also become a worldwide concern. Hence, it is essential to characterize on-road vehicle exhaust and their impacts on near-road air quality to determine the best methods to mitigate near-road particulate concentrations. Environmental parameters such as wind speed, wind direction, and precipitation also seem to affect the concentrations of $PM_{2.5}$ and UFP. For this reason, the diesel exhaust study was conducted near Beechurst Avenue and University Avenue in Morgantown, WV. The objective was to determine the relationship between the number of large diesel engine trucks on concentrations of UFP as well as the effects of environmental parameters on concentrations of UFP. Aerosols monitoring was performed from March 30th to May 27th, 2015 for morning and afternoon periods. Concentrations of $PM_{2.5}$ and UFP were monitored along with a concurrent recording of traffic volume. In addition, environmental parameters, including wind speed and precipitation were recorded. Multivariate regression analysis was done to find the correlation between concentrations ($PM_{2.5}$ and UFP), traffic count and environmental parameters. Highly significant relationships ($p<0.0001$) were observed between UFP concentrations and the number of large diesel engine trucks that passed by each sampling location, indicating that diesel truck traffic is the major source of UFP in the air. Statistical analyses also showed that concentrations for UFP particle size ranges were significantly affected by wind speed and rain.

Number of trucks was not significantly related to $PM_{2.5}$ concentrations. The latter was significantly affected by the number of light vehicles passing by and by ($p<0.0001$).

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PURPOSE OF STUDY

Diesel particles have been of great concern due to their adverse health effects on human health and their elevated concentrations in the vicinity of roads, in particular in urban areas. Diesel exhaust (DE) is classified as a probable human carcinogen by both the International Agency for Research (IARC, 1989) and National Institute for Occupational Safety and Health (NIOSH, 1988). Therefore, great efforts are taken to reduce their emissions and their concentrations are strictly regulated.

The purpose of this study was to investigate the relationship between the volume of diesel truck traffic and concentrations of particulate matter, including both $PM_{2.5}$ (median diameter < 2.5 µm) and ultra-fine particles (UFPs, median diameter <0.1µm) and to investigate the influence of wind speed and rain as well as the effects of wind speed and rain on $PM_{2.5}$ and UFP.

In order to develop cost-efficient strategies to mitigate near-road air pollution for protecting public health and promoting sustainable growth, it is imperative to characterize on-road vehicle exhaust and its impacts on near-road air quality. The goal of this study is to characterize transportation-related diesel air pollution. These data may be useful in estimating exposures to fine and ultrafine particles in the vicinity of roadways for epidemiological studies and to evaluate the adverse health effects of such particles.

The particles emitted in diesel exhaust are very small (less than 1µm by size), which makes them readily respirable (Kittelson, 1998, EPA 2002). Monitoring of respirable dust exposures enables identification of potential overexposures and prioritized implementation of interventions to prevent or reduce these overexposures.

INTRODUCTION

Traffic emission is a major source of urban air pollution. Diesel powered trucks are a significant contributor of particulate air pollution on-road and near-roadways (Laden *et al*. 2000, Fraser *et al*. 2003, NRC 2002). Importantly, studies find that truck traffic volume is most strongly related to health risks rather than car volume and the particle levels on freeways are directly associated with volume of truck traffic. (Janssen, N. *et al* 2003, Ciccone, G *et al*. 1998, Fruin, S 2003). Diesel engine emissions consist of a wide range of organic and inorganic compounds distributed between the gaseous and particulate phases. Public health concern has arisen about these emissions because the particles released in diesel emissions are very small (i.e., approximately 90% of the particles are less than 1µm by mass) making them readily repairable (EPA 2002, Kittelson1998). These particles have hundreds of chemicals adsorbed onto their surfaces, including many known or suspected mutagens and carcinogens.

The atmospheric measurements of fine ($PM_{2.5}$) and ultrafine particulates (UFPs) were studied, on two busy roads in Morgantown. WV. The main hypothesis employed in this study was that there is a strong relationship between diesel truck traffic and UFP concentrations. It was assumed that $PM_{2.5}$ would not be strongly related to diesel truck traffic.

Background

Diesel engines provide power to a vast variety of equipment that has uses in a large number of industries. The main advantages of the diesel engine over the gasoline engine are its higher fuel efficiency and lower maintenance costs (Dunlap 1998). Diesel exhaust is produced during the combustion of diesel fuel and it is emitted from a broad range of diesel engines; including on-road diesel engines of trucks, buses and cars and the off-road diesel engines of locomotives, marine vessels and heavy duty equipment.

Diesel engine exhaust (DE) contains many toxic air contaminants and has been classified as a probable human carcinogen (IARC 1989, NIOSH 1988). The United States Environmental Protection Agency (EPA) has set regulations limiting the production of certain chemical species that is emitted from diesel engines (EPA 1971 and1994).

NIOSH recommends that diesel exhaust be regarded as "a potential occupational carcinogen," as defined in the Cancer Policy of the Occupational Safety and Health Administration (OSHA) ("Identification, Classification, and Regulation of Potential Occupational Carcinogens," 29 CFR 1990). Approximately 92% of the particles emitted from diesel engines are less than 1.0 µm in diameter (CARB 1997). Most diesel exhaust particles have aerodynamic diameters falling within a range of 0.1 to 0.25 µm (Groblicki 1979, Dolan *et al.*, 1980, NRC 1982, Williams 1982). The total particulate emission concentration from light-duty diesel engines is much smaller than that from heavy-duty diesel engines. In general, newer heavy-duty trucks emit diesel particulates at a rate 20 times that of gasoline-fuelled vehicles (IPCS 1996).

Diesel emissions (DE) are complex mixtures of gases and particulates. The particulates are mainly composed of particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO), and a number of air toxics (e.g., aldehydes, volatile organic compounds, polycyclic aromatic hydrocarbons [PAHs]). Human exposure to this exhaust comes from both highway uses (on-road) as well as non-road uses of the diesel engine.

Diesel vehicles are one of the largest sources of PM (EPA 1990). PM is a primary emission from diesel engines, and diesel engines can emit 10 to 100 times more PM mass than gasoline engines (Vallero 2008; Wayne et al. 2004; Kittelson 1998). PM is emerging as serious health effect. In 1998, diesel PM was declared as a toxic air contaminant by the California Air Resources Board.

Particulate matter (PM) is a mixture of solid particles and liquid droplets found in air. PM_{10} refers to particles with a diameter less than 10 µm. $PM_{2.5}$ refers to particles with a diameter of less than 2.5 µm. $PM_{0.1}$ refers to particles with a diameter less than 0.1 µm, and is called ultra-fine particles (UFPs). The term "ultrafine" can be described as nanometer size particles produced incidentally by processes involving industrial, combustion, welding, automobile, diesel, soil, and volcanic activities. UFPs reach high number concentrations, but their mass is very small. As a result UFPs are characterized by particle number (particles/cm^3, or pt/cc) as opposed to particle mass (mg/m^3 or $\mu g/m^3$) for $PM_{1.0}$ and larger.

PM emissions from diesel engines are regulated by the EPA. On Dec. 14, 2012 the U.S. Environmental Protection Agency (EPA) strengthened the nation’s Ambient Air Quality Standards (NAAQ’s) for fine particle pollution to improve public health protection by revising the primary annual $PM_{2.5}$ standard to 12 micrograms per cubic meter (μg/m3) and retaining the 24-hour fine particle standard of 35 $\mu g/m^3$. UFP exposure standards have not yet been established by the EPA. While the EPA bases its air quality standards on annual and 24-hour exposures, it is thought that peak exposures (one hour or less in duration) are most relevant to human health and may exacerbate of existing symptoms (Michaels and Kleinman 2000).

There are no legal exposure limits for DE in general occupational settings in the USA. An exposure limit for DE was proposed by the ACGIH, but was withdrawn from the ACGIH Notice of Intended Changes (NIC) in 2003.

Chemical nature and size of the particle decides the behavior and deposition of any particle after entry into the human respiratory system. Health hazards of many aerosols depend on particle size and the amount deposited in the respiratory tract. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends size-selective aerosol sampling procedures in setting threshold limit values for occupational exposures. U.S. Environmental Protection Agency (EPA) has also employed a size-selective sampling in setting the national ambient air quality standards (NAAQS) for particulate matter (PM).

Many countries and several international agencies have adopted criteria for particle size-selective sampling, which refers to the collection of particles of varying sizes that potentially reach and adversely affect specific regions of the respiratory tract (Brown et.al, 2013). Aerosol size fractions relate to the region of the respiratory tract where they deposit and are categorized as inhalable, thoracic and respirable size fractions.

Diesel emission particulates are of respirable size and contribute to the total burden of respirable dust present in an occupational environment. Respirable fraction is the inhaled airborne material that penetrates to the lower gas exchange region of the lung (50% cut point at 4 μm). This criteria is based on the exposure of a respiratory tract region (*i.e.,* particle penetration into that region, and not particle deposition in a respiratory tract region. These criteria are specifically developed for workplace atmospheres.

The conventions for the same are mentioned in ISO 7708 [ISO, 1995], EN 481 [CEN, 1993], ASTM D 6062 [ASTM International, 2007]; ACGIH, 1985.

Respirable dust particles are under 10 microns in diameter that are small enough to penetrate the nose and upper respiratory system and deep into the lungs. These particles are more likely to retain in the body and are beyond body's natural capacity to clear through cilia and mucous mechanisms.

Existing limits for occupational exposures limit exposures to the particulate fraction of diesel emissions. Occupational Safety and Health Associations have no permissible exposure limits (PEL) set for diesel exhaust. The American Conference of Governmental Industrial Hygienists (ACGIH) recently placed diesel exhaust on the ACGIH's Notice of Intended Changes for 1995/1996 (Threshold Limit Value (TLV) of 0.15 mg/m3 TWA with a designation as a suspected human carcinogen (A2)).

Literature review of Health effects of fine and ultrafine particles

The adverse health effects of particulate matter have been subjected to intense study in recent years. Many epidemiological studies have associated health effects with particle mass concentration, such as $PM_{2.5}$ (Pope, 2000), number concentration, i.e. UFP (Loomis, 2000), surface area concentration (Driscoll, 1996), and overall exposure rate (Siegmann & Siegmann, 1998). Exposure to airborne particulate matter has been associated with an increase in mortality and hospital admission due to respiratory and cardiovascular diseases. Higher risk of lung and ovarian cancer has also been linked with diesel exhaust and vehicular traffic exposure. Schwartz *et al.* (2002) reported 100,000 deaths annually in the United States in a concentration-response relationship between $PM_{2.5}$ and daily deaths. Peers *et al.* (2000, 2001) showed that short-term exposures to ambient $PM_{2.5}$ have been linked to cardiac autonomic dysfunction in older adults with histories of cardiac and other diseases. An increasing incidence of life threatening arrhythmia and triggering of myocardial infarction was also observed due to elevated levels of air pollution for short durations of more than 2 hours.

Most of the urban pollution studies consider the $PM_{2.5}$ particles as indicators because they have an anthropogenic origin, with an estimated 70–80% deriving from the combustion of diesel fuel in vehicles, which makes them a more reliable indicator of city pollution directly related to human activity.

Additionally, these effects are thought to be more serious for children, because they inhale a greater air volume in relation to their weight than adults, their defense mechanisms are still in development stage, their immune systems are not fully developed, and they are likely to spend more time in polluted home environments, which makes them more vulnerable to urban pollution (Salvi, 2007). Elevated rates of respiratory illnesses and symptoms have been linked to the children living in cities with high particulate pollution due to the impact of fine particle on their respiratory health. Increased concentrations of $PM_{2.5}$ negatively affect bronchiolitis, pneumonia, asthma, bronchitis and other causes among children. With reduced daily average annual concentration of $PM_{2.5}$, reduction in annual average of children's hospital admissions have been observed due to respiratory diseases. (María de P. Pablo-Romero, 2015).

$PM_{2.5}$ appears to impact some aspects of mental health as well. A statistically significant association of emergency room admissions was found during 2002 for unspecified schizophrenia and airborne particulate matter in Baltimore, MD (D. J. Lary, 2015).

Health effects of UFPs may be strongly linked to particle size since this characteristic determines which region of the lung the particles deposit. It was found that UFPs remain suspended in the air for several days, have long lifetimes in the atmosphere, and can be transported over thousands of kilometers. Furthermore, UFPs with greater surface area can carry large amounts of adsorbed pollutants, oxidant gases, organic compounds, and transition metals (Hinds, 1999; Oberdisrster 2001). Based on high particle numbers, high lung deposition efficiency and surface chemistry, UFP may provide a greater potential than $PM_{2.5}$ for inducing lung inflammation. UFPs may directly injure the lung, inducing lung inflammation or translocation of inhaled particles from lung air spaces into the systemic circulation, eventually reaching other organs (Kreyling *et al*. 2002; Nemmar *et al*. 2002b; Oberdirster *et al*. 2002).

In comprehensive review of epidemiologic studies, Delfino *et al*. (2005) clearly associated UFPs with pathophysiologic changes that induce cardiovascular diseases. The strongest association with the ultrafine fraction, with fractions of other sizes were observed during an episode of severe air pollution that reported decrements in evening peak flow in a group of asthmatic patients (Peters *et al*., 2011).

Chronically elevated UFP levels, such as those to which residents living near heavily trafficked roadways are likely exposed, can lead to long-term or repeated increases in systemic inflammation that promote arteriosclerosis (EPA 2004, Pope CA *et al*. 1995, Chuang K *et al*. 2005, Brunekreef B *et al*. 2002). Large numbers of studies have reported associations between UFP exposure and morbidity in elderly and compromised individuals. Other investigations indicated UFPs particles induced inheritable mutations (Somers *et al.*, 2004).

Occupational exposure to diesel exhaust

DE are widely used in occupational settings. The National Institute for Occupational Safety and Health (NIOSH, 1988) estimated that approximately 1.35 million workers get exposed to DE emissions occupationally. Occupations with potential exposure to DE include miners, construction workers, heavy equipment operators, bridge and tunnel workers, railroad workers, oil and gas workers, loading dock workers, truck drivers, material handling operators, farmworkers, long-shoring workers, and auto, truck and bus maintenance garage workers.

However, many adverse health effects have been associated with DE. Occupational exposure to diesel exhaust from off-road vehicles was reported for construction and forklift operators in several settings (Pronk *et al*. 2009). Three studies reviewed by the International Agency for Research on Cancer found that toll booth worker had elevated levels of exposure to diesel exhaust particulates.

Diesel engines have been commonly used in U.S. mines since their first introduction in the early 1950s. The highest levels of occupational DE exposure have been reported among workers engaged in underground mining, tunnel construction, and underground mine maintenance (Boffetta P. 2004). Two influential papers describing the results of a cohort and a nested case-control analysis of the Diesel Exhaust in Miners Study (DEMS) reported a statistically significant increase in lung cancer mortality among both underground and surface miners exposed to DE (Attfield MD*et al*., 2012); Silverman DT, et *al*., 2012). The epidemiologic studies of exposure to DE and the occurrence of lung cancer furnish evidence that is consistent with a causal association. However, the underlying mechanism by which DE causes lung cancer in humans is still not understood. A cross-sectional molecular epidemiology study in a diesel engine truck testing facility suggested that, DE exposure is associated with higher levels of cells that play a key role in the inflammatory process, which is increasingly being recognized as contributing to the aetiology of lung cancer (Qing Lan1, 2015). Increase in lung cancer was observed among railroad workers and truckers who were exposed to DE (Järvholm B and Silverman D. 2003, Kauppinen T *et al*. 2003, Kishi Y *et al*.1992).

Some occupational studies of acute exposure to DE during work shifts suggested increased acute sensory and respiratory symptoms (cough, phlegm, chest tightness, wheezing) indicating possible health risks from exposure to DE than pulmonary function decrements. Chronic bronchitis and airway resistance changes have suggested obstructive airway disease in bridge and tunnel workers (IPCS 1996). Most studies have found increased morbidity and mortality associated with the potential for diesel particulate exposure, but they have not actually measured diesel exposure levels. However, many of these studies, could not differentiate between gasoline exhaust and diesel exhaust (IARC 1989).

METHODS

This section explains in detail the monitoring methods used to collect $PM_{2.5}$ and UFP concentrations, recording of traffic volume and measurement of environmental parameters.

Monitoring Locations and Times

The study was performed from March 30–May 27, 2015 at two different sites: Beechurst Avenue and University Avenue in Morgantown, West Virginia.

Monitoring was done for a four-hour period for each sampling day. Data were acquired for both a morning and afternoon time. The data acquisition period, mostly varied between 6.15 am to 6.00 pm for morning (6:15am – 10:15 am) and afternoon (2:00 pm – 6:00 pm) sampling.

Roadside measurements for both the locations were conducted at fixed, specific sites. The main monitoring site for Beechurst Avenue was located 10 m from the centerline of Beechurst Avenue on the ground floor of "St. John Parish Centre" (39° 37' 58.1016" N 79° 57' 23.3208" W). The St. John Parish Centre is located adjacent to the downtown campus of West Virginia University, Morgantown.

The monitoring site for University Avenue was roadside apartments as shown in the map in Figure 2. Due to the non-availability of electrical power connections, monitoring for University Avenue was done along the same route but at two different sites. The first site used, was an apartment which is located near Dille street. The apartment was located (39° 38' 47.7060" N 79° 57' 28.7964" W) and was approximately 6 m away from the centreline of the University Avenue. The second site used for monitoring on University Avenue was an apartment located near a Zenclay pottery studio. The apartment was located (39° 38' 54.5208" N 79° 57' 44.2692" W) and was 10m away from the centreline of the University Avenue.

Measurements for all the sites were performed on the ground floor about 5 m in height above the street level. All instruments were placed around the porch area at their respective locations around 5 m above the porch level. Hence, the total height of the entire set up was about 10m from the road elevation. The setup involved placing concentration monitoring instruments facing the road to allow correct concentration measurements. The camera was also placed in a manner that facilitated projecting sampling lines from the window that overlooked the streets. The instruments were powered by a battery/inverter power supply. Figure 2 (a, b), 3 (a, b) and 4 (a, b) show the locations of the sampling sites.

$PM_{2.5}$, UFP concentrations were measured over the study period along with the video recording of traffic data.

Diesel powered trucks use these roadways during the daytime. Accordingly, on-road measurements were conducted during the daytime to capture the impact of vehicle emission on air quality.

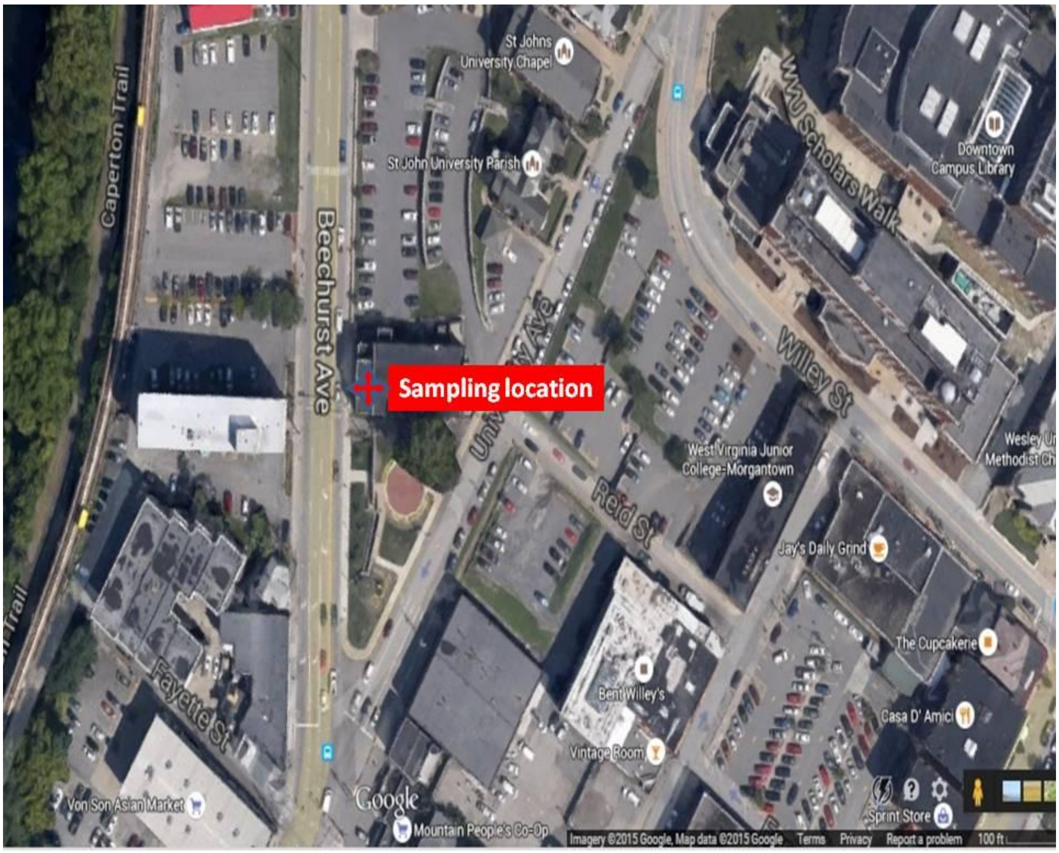

Figure 2a: Elevation view of the Beechurst Avenue {Courtesy of Google Maps}

Figure 2b: Street view of Beechurst Avenue

Figure 3a: University Ave Aerial View {Courtesy of Google Maps}

Figure 3b: University Ave Street View

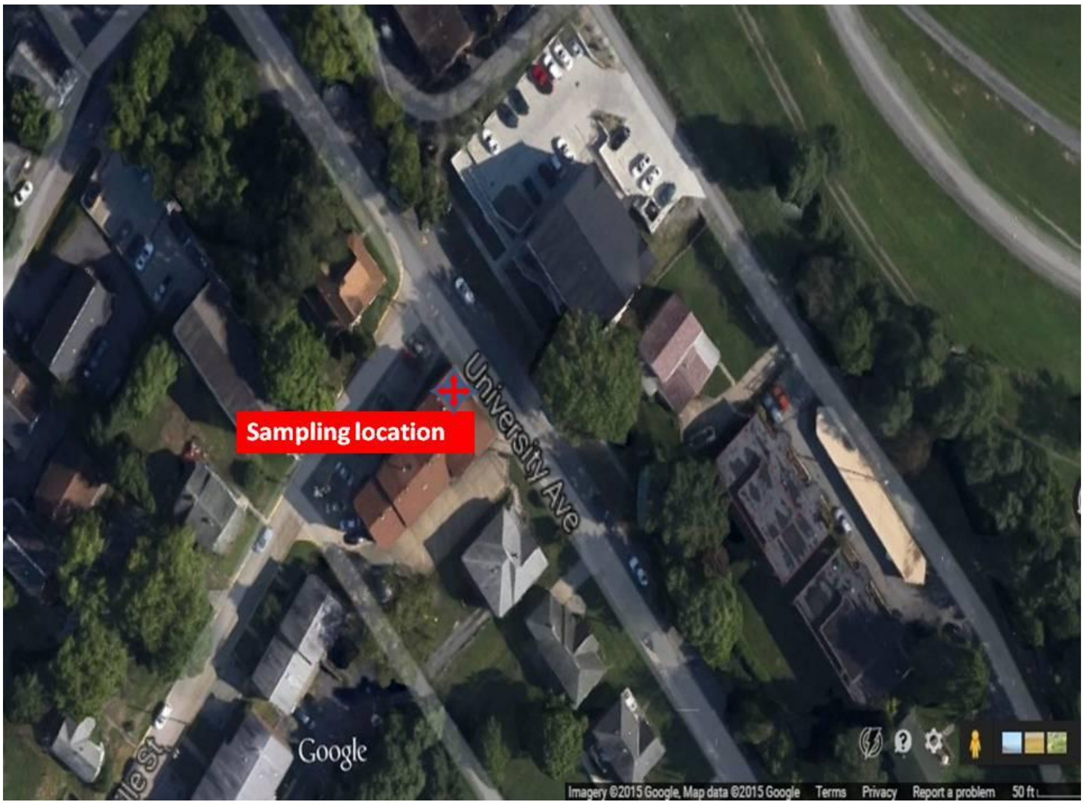

Figure 4a: University Ave Aerial View {Courtesy of Google Maps}

Figure 4b: University Ave Street View

Traffic Counting

Throughout each measurement period, the traffic volume on the streets, defined as the number of vehicles passing per minute, was continuously monitored by a video recorder (Microsoft LifeCam Studio Web camera). Tapes from this camera served to document the road and traffic conditions and helped confirm and identify emission sources. After each sampling session, the videotapes were replayed and traffic volume was counted manually.

The vehicles were categorized into two main groups: light-duty vehicles, heavy-duty vehicles, which almost implied gasoline and diesel engine vehicles, respectively. Passenger cars, delivery vans, minivans, pick-up trucks, mini-trucks, bus and motorcycles, were all considered as light-duty vehicles, termed as “Car Count”, whereas multi-axle trucks/buses were considered as heavy-duty vehicles termed as “Truck Count”, which almost implied diesel engine vehicles.

Tally marks were entered for each vehicle type and the counts were aggregated for every 15 mins of each hour of sampling. Ntziachristos *et al*. (2007) used manual and videotaped counts and sampled at random during 1 min out of every five. After the manual counting was completed, these observational data were entered into spreadsheets as 15- minute counts for each vehicle type. Hence, there were total 368 data points of traffic count for all the locations.

Aerosols Measurements

The main instruments used for aerosols sampling, where TSI DustTrak II Aerosol Monitor 8532 (TSI, Inc. St. Paul, MN, USA) and TSI's P-Trak Ultrafine Particle Counter 8525 (TSI, Inc. St. Paul, MN, USA). Total $PM_{2.5}$ was measured with a TSI DustTrak aerosol monitor with a $PM_{2.5}$ size-selective nozzle.

The TSI DustTrak Model 8532 functions primarily as an aerosol monitor. In this role, it providesdreal time determinations of aerosol mass concentrations between the ranges of 0.001-100 mg/m-3 for particles ranging in size from 0.1 to 10 µm. $PM_{2.5}$ was monitored using Dusttrak (TSI, Inc. Model 8532) portable continuous aerosol concentration monitors fitted with a size-selective nozzle having a 50% cut-point at 2.5 µm.The DustTrak uses 90-deg light scattering to measure the mass concentrations of particles in an air stream that passes through an impactor assembly. The DustTrak was factory reference calibrated by the manufacturer using Arizona road dust (particle size range from 0.1 to 10 mm). For most applications, Arizona Road Dust calibration would be appropriate to consider because it is a representative of a wide variety of aerosols.

The data obtained by the DustTrak can be logged at user specified intervals and gives an average reading of mass concentration over any specified timeframe. The logged data can then be analyzed using the TrakPro Data Analysis Software. For this work, readings were logged every one minute and averaged over fifteen minutes.

Ultrafine particle counts as 10-second resolution was made using P-track Ultra fine Particle Counters (TSI Model 8525), for particles in the size range 0.02–1 µm. The P-TRAK is based on the condensation particle counting technique using isopropyl alcohol (TSI, 2002). The P-TRAK was used because it is a handheld, field instrument having a relatively robust performance whilst in motion, rapid warm-up, battery-powered, and the ability to detect high concentrations (maximum detectable limit: 500,000 particles cm^{-3}). Moreover, it has a high data-logging resolution and a fast response time. Data logging at intervals as short as 1s facilitates observation of rapid fluxes in UFP concentrations.

The experimental data collected is actual counts of fine and ultra-fine particles in the $PM_{2.5}$ and less than 0.1 micron diameter range. Instruments that are used to record fine and ultra-fine particles measure by counting the numbers of particles of specific sizes.

Measurement of Environmental Values

Environmental conditions, such as rain and wind speed also have a bearing on determining the final concentration. For instance, according to Queensland (QLD) EPA 1994, the wind speed alone can mix and disperse particles, moving them significant distances from their production site, while rain can wash them out of the air. Thus, investigating the complex interactions that occur between the independent variables is crucial to the development of any mathematical model.

The environmental parameters were divided into different categories, such as weather as rain and no rain. Wind speed was divided into three categories as low(0-5km/hr), medium(5-10km/hr) and strong speed(10km/hr and above).

Statistical Methods

Particle concentration data at each site were collected as fifteen-minute period averages, and matched to the corresponding vehicle counts. Environmental data (e.g. wind speed and rain) were recorded manually during sampling at both the locations.

A multivariate regression analysis was used to measure associations of $PM_{2.5}$ and UFP to truck and car counts, time of day, day of the week and environmental variables at both locations.

General linear model ANOVA were performed using Data Desk (7.0.2) for 15-min average concentrations of $PM_{2.5}$ and UFP and 15min-counts for traffic and 15-min averages of environmental values.

The main hypothesis employed was that diesel truck traffic is strongly related to levels of UFP. It was expected the diesel truck traffic and $PM_{2.5}$ concentrations would be only weakly related, at most. Relationships between these variables were examined statistically using multivariate linear regression, which has the formulation given as follows:

$$Log(c) = \beta 0 + \beta 1Tfti + \beta 2Tfci + \beta 3\ Wti + \beta 4Wsi + \beta 5Dayi + e_i$$

Where:

i = 1, 2,3…, n

C = dependent variable (either $PM_{2.5}$ or UFP concentrations)

β0 = the intercept

β = 1…5, the model parameters

Tft = Truck count

Tfc = Car count

Wt = Weather (rain/no-rain)

Us = Wind speed (low, medium, strong)

Day = Day of the week

Ei = residual for the i^{th} unit

The regression was run using the General Linear Models function of the Data Desk (Version 7.0.2, Data Desrciption Inc., Ithaca, NY, USA). The data on $PM_{2.5}$ and UFP concentrations for all day were combined with traffic counts and environmental parameters during the sampling period with 368 data points in each regression. The significance of each independent model coefficient of the regressions was determined using the F-test, and contributions of the variability of each covariates to the overall variability in $PM_{2.5}$ and UFP.

Data were organized into dependent and independent variables. The independent variables were further organized into location, traffic count, and weather categories (see Table I (a, b)).

Table Ia: Dependent Variables Definition

Variables	Definition	Unit
Particulates		
$PM_{2.5}$	Continuous variable describing concentration in 15-min average interval	mg/m^3
UFP	Continuous variable describing concentration in 15-min average interval	pt/cc

Table Ib: Independent Variables Definitions

Variables	Definition	Unit
Location	Categorical variable describing monitoring location =1 if Beechurst Avenue; location= 2 if University avenue	1,2
Traffic		
Car count	Continuous variable describing number of vehicles present during 15-min intervals	veh/hour
Truck count	Continuous variable describing number of heavy vehicles (Multi-axle) present during 15-min intervals	veh/hour
ENVIRONMENTAL PARAMETERS		
Rain	Categorical variable describing weather, =1 If rain; =0 if no rain	0,1
Wind Speed	Categorical variable describing wind speed, =1 If low; =2 if medium; =3 if strong	1-3
Days	Categorical variable describing days, =1 if Monday; =2 if Tuesday; =3 if Wednesday; =4 if Thursday; =5 if Friday; =6 if Saturday; =7 if Sunday	1-7

RESULTS

Table II details summary statistics for particulates, traffic count, and weather variables. The mean UFP concentration was 9,4300 pt/cc for all data collected. The mean value of $PM_{2.5}$ was 11.54 µg/m3.

Independent variables investigated include monitoring location (Becchurst and University Avenue), wind speed, car count, and truck count and time of day, day of the week.

Table II: Summary Statistics, All Data

	Mean	Median	Min	Max	St. Dev.
Beechurst Avenue					
PM 2.5	9.93	7.60	1.33	48.87	6.65
UFP	9613.80	7309.43	1463.33	43937.13	7645.53
Car #	293.82	295.5	132	2296	146.87
Truck #	6.01	4	0	32	6.144
University Avenue					
PM 2.5	13.15	10.47	3.00	50.47	9.19
UFP	9250.21	6296.70	1827.67	41649.27	7043.12
Car #	170.95	158	88	317	47.60
Truck #	1.37	1	0	4	1.14

Effects of Location

Beechurst Avenue, (Beechurst Avenue) is one of the most heavily traveled roads in Morgantown. University Avenue is narrower and is located in a residential area and as expected, had much less traffic. On Beechurst Avenue, two lanes in the southeast and one northwest direction, were monitored. At University Avenue, one southeast and one northwest lane direction were monitored.

In the present study, the concentration of pollutants was found to vary from 1.33 to 48.87 $\mu g/m^3$ ppm for $PM_{2.5}$ for Beechurst Avenue and 3.0 to 50.47 $\mu g/m^3$ for University Avenue. For Beechurst Avenue, UFP pollutants varied from 1463.33 to 43937.13 pt/cc, for University Avenue it varied from 1827.67 to 41649.27 pt/cc. Concentrations of UFP and $PM_{2.5}$ were seen to be very high at sites located adjacent to roadways in this study for both the locations. Based on these observations, it appeared that emissions were likely the dominant source of UFP and $PM_{2.5}$ during our study.

Effects of Trucks and Cars

Traffic volume averaged 944 vehicles per hour, including all lanes of travel, three lanes of Beechurst Avenue and two lanes for University Avenue. On average, 6.01 diesel vehicles and 293.8 gasoline vehicles passed for Beechurst Avenue during the 15-min, interval, while 1.37

diesel vehicles and 170.95 gasoline vehicles passed for University Avenue for the same interval.

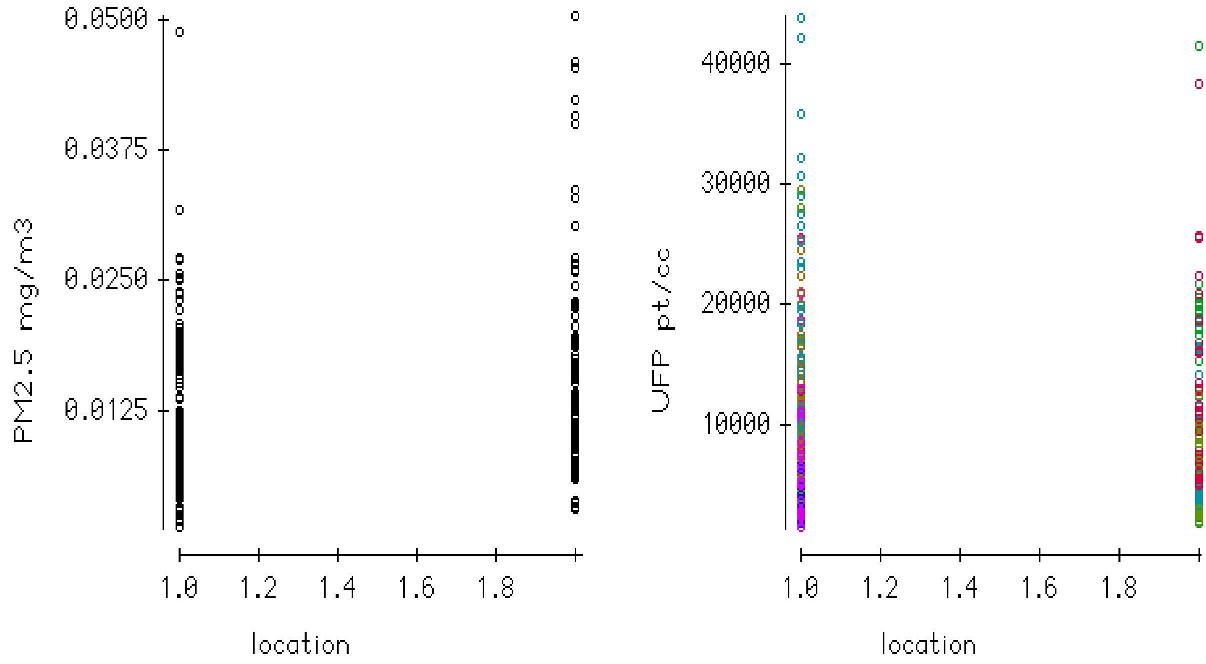

Figure 1 : $PM_{2.5}$ and UFP concentrations for Beechurst and University Avenue

The median UFP concentrations sampled for both the locations and weather was the same. Beechurst Avenue (location 1) showed high concentrations of UFP due to heavy truck traffic. However, $PM_{2.5}$ concentrations were higher for Univerisity avenue (location 2) mainly because of gasoline- powered vehicles.

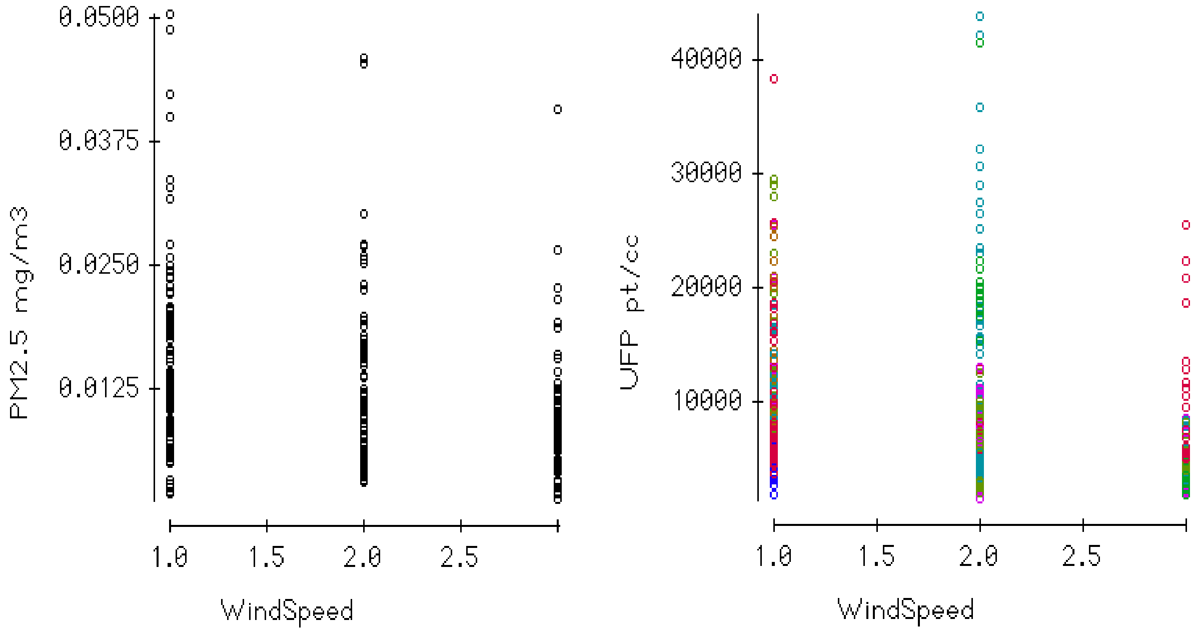

Figure 2: $PM_{2.5}$ and UFP concentrations for different Wind Speeds

UFP concentrations were decreased for rain over $PM_{2.5}$ concentrations which showed increased concentrations. With the increasing wind speed $PM_{2.5}$ and UFP concentrations increased. Rain was a significant predictor for UFP ($p<0.005$) and moderately for $PM_{2.5}$ ($p<0.0004$).

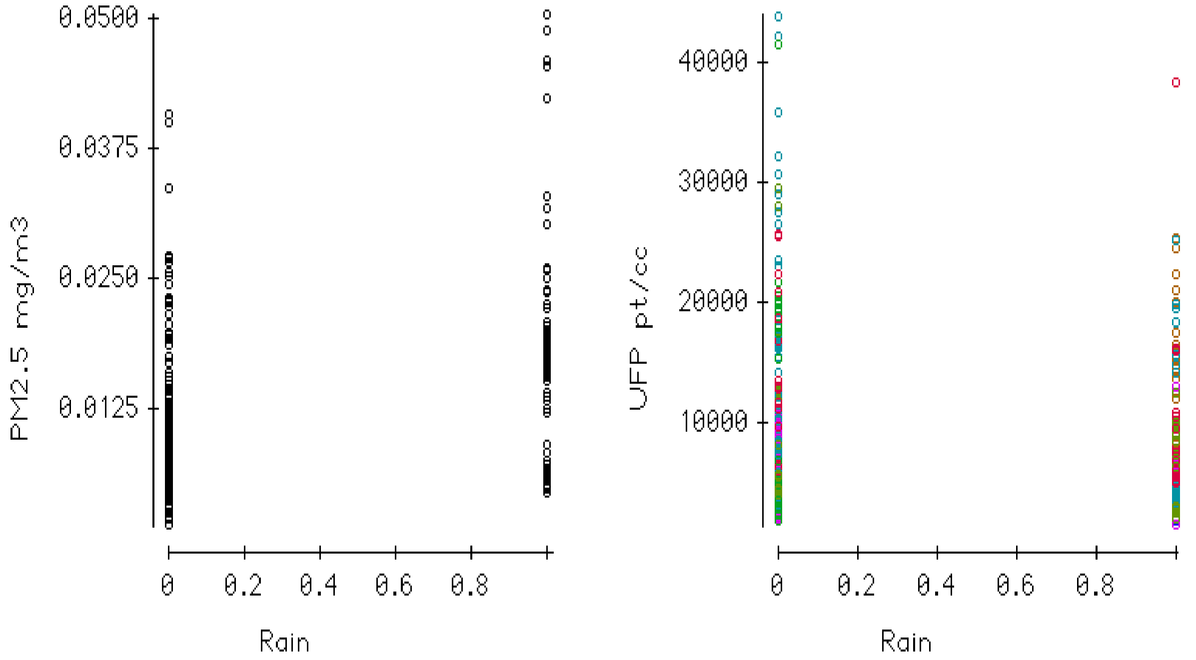

Figure 3: $PM_{2.5}$ and UFP concentrations for Rain Vs No-Rain

Effects of Rain

The correlation between particulate concentration and rain yield varied results for the two size ranges of particulates. The correlation between $PM_{2.5}$ concentrations and rain amount shows positive results, as opposed to UFP concentration, which shows negative results. The negative relation might be particulate concentration, reduced through the washout process. Sham (1979) pointed out that a poor relation between particulate matter and rain amount may probably be due to the generally more stable atmospheric condition and hence less pollution dispersion when rain occurs. Kerker and Hampel (1974) stated that washout may be a significant factor in cleansing the atmosphere of 0.1 nm aerosol. The lighter rainfall is much more efficient in cleansing the atmosphere of 0.1 nm aerosol because of the greater collection efficiency of the smaller raindrops. Precipitation is important through the absorption processes within the cloud, known as rainout, and that termed washout, which is a scavenging of air pollutants by falling raindrops (Cf. Elsom and Chandler 1978).

Discussion

Non-independence of "independent" variables

An important assumption of linear regression is that the independent variables are actually independent of each other. Some collinearity is tolerable. As shown in Table III, the Pearson Product Moment Correlations for the variables in this study show substantial collinearity between TruckCount and Car Count, which one would expect. It also shows a negative correlation between Wind Speed and TruckCount and strong correlations between vehicle counts and Location, which is expected since one road carried far more traffic than the other. It is also not surprising that Time24 was strongly correlated to TruckCount since trucks are generally restricted from some locations during the middle of the day by either regulations or slow traffic.

Even though the correlations are not surprising, they should not be ignored. They suggest that only one of each pair of variables that are correlated with each other should be used in statistical models.

Table III Pearson Product-Moment Correlation

	UFP	Truck Ct	CarCt	Rain	WindSp	Day	Location	Time	PM2.5
UFP pt/cc	1.000								
TruckCount	0.444	1.000							
CarCount	0.059	0.284	1.000						
Rain	-0.054	0.057	-0.151	1.000					
WindSpeed	-0.301	-0.230	-0.053	-0.191	1.000				
Day	-0.202	-0.271	0.062	0.094	-0.112	1.000			
location	-0.024	-0.431	-0.752	0.079	0.117	-0.349	1.000		
Time24	-0.164	-0.434	0.164	-0.005	0.225	-0.045	0.122	1.000	
PM2.5mg/m^3	0.145	0.150	-0.335	0.465	-0.260	-0.038	0.199	-0.408	1.000

Histograms

Histograms for both $PM_{2.5}$ and UFP showed non-normal distributions. When each were Log-transformed they showed highly normal distributions. Figure 4 and 5, shows that the log-transformed data following a normal or near normal distribution for $PM_{2.5}$ and UFP.

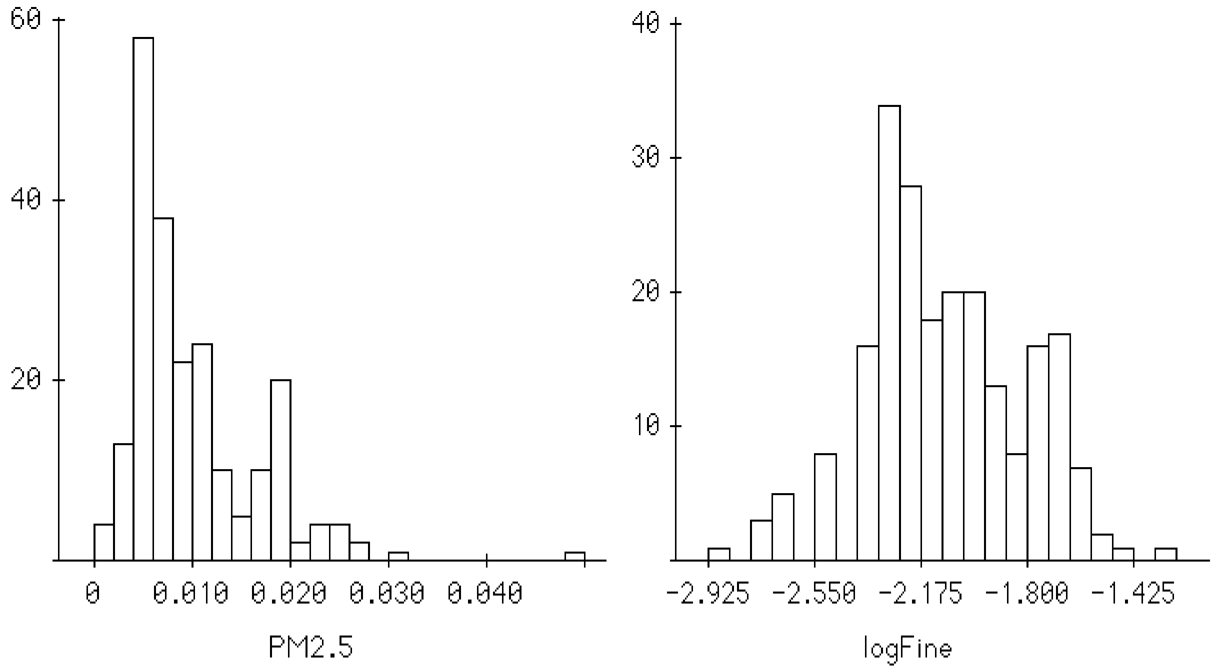

Figure 4: Histograms for Non-log transformed Vs Log-transformed $PM_{2.5}$

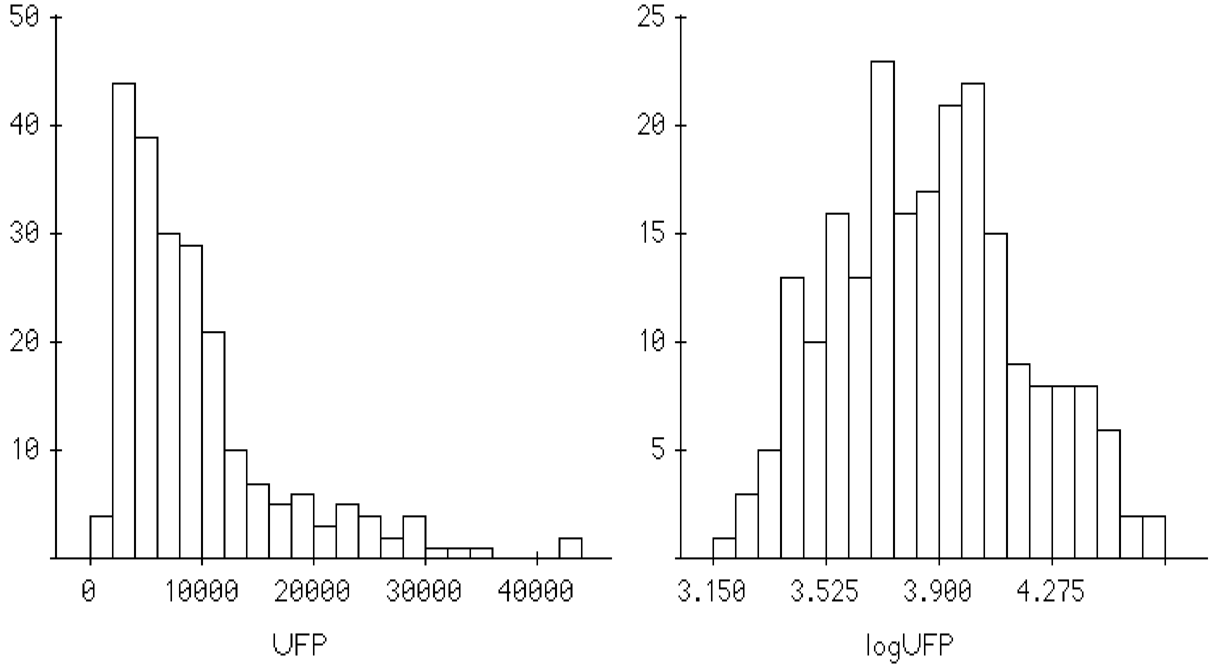

Figure 5: Non-log transformed Vs Log-transformed UFP

The normality of histograms when UFP and $PM_{2.5}$ were log-transformed suggests that statistical analyses should be done after log-transformation.

Table IV: General Linear Model for Log (UFP)

Source	df	Sum Sq	Mean Sq	F-ratio	P-value
Intercept	1	5499.5	5499.5	98841	0.010%
Truck Count	1	1.09208	1.09208	19.628	0.010%
Car Count	1	0.193503	0.193503	3.4778	6.3%
Rain	1	0.453153	0.453153	8.1444	0.46%
Wind speed	2	4.45465	2.22732	40.031	0.010%
Day of week	6	0.522314	0.0870523	1.5646	15.7%
Location	1	0.267329	0.267329	4.8046	2.9%
TruckCount*Loc	1	0.163731	0.163731	2.9427	8.7%
Error	354	19.6966	0.0556401		
Total	367	34.2961			
	R^2 =	0.426			

General Linear Models for PM2.5 and UFP

As shown in Table IV for the general linear model of log (UFP), Wind Speed is by far the most important variable, suggesting that the UFP particles were released on the street and were otherwise not strongly represented in ambient air. Since UFP are also strongly affected by TruckCount but not Car Count, this suggests that the UFP are produced by diesel engines. Rain also had moderately significant effects ($p < 0.5\%$), suggesting that rain is efficient at removing UFP from the air. The location was significant ($p < 2.9\%$) but accounted for less than 1% of the sum of squares. The lack of importance of Location suggests that the effects of Location are represented by TruckCount.

Table V: General Linear Model for Log (PM2.5)

Source	df	Sums of Squares	Mean Square	F-ratio	P-value
Intercept	1	1535.02	1535.02	36536	0.010%
Truck Count	1	0.0350841	0.0350841	0.83505	36%
Car Count	1	1.19301	1.19301	28.395	0.010%
Rain	1	0.535262	0.535262	12.74	0.040%
Windspeed	2	0.251179	0.125589	2.9892	5.16%
Day of week	6	3.61243	0.602072	14.33	0.010%
Location	1	0.00141371	0.00141371	0.033648	85%
TruckCount*Loc	1	0.0117673	0.0117673	0.28008	60%
Error	354	14.8731	0.0420143		
Total	367	30.0839			
	R^2 =	0.506			

The results for the general linear model of log ($PM_{2.5}$) are quite different. Wind Speed is dramatically less important and is non-significant ($p > 5\%$) but Rain is highly significant ($p < 0.04\%$). Since TruckCount is not significant, but Car Count is highly significant, this suggests that $PM_{2.5}$ is far more strongly affected by the larger particles in its range and diesel emissions are therefore unimportant. Rain is highly significant ($p < 0.04\%$), suggesting that rain removes some fraction of $PM_{2.5}$.

UFP concentrations are highly significant with the truck count with partial F-tests producing ($p<0.0001$). The remaining covariates in the model showed varied levels of significance for $PM_{2.5}$ and UFP concentrationsUFP. These covariates can be analyzed to discern the relative importance of traffic behaviors, fuel type, and meteorology.

Environmental factors are important contributors to dispersion patterns in urban environments (Newsome *et al.*, 2005) and were all significant in the multiple regression models developed here. Among the environmental variables tested, wind speed was a significant predictor for UFP ($p<0.0001$) over $PM_{2.5}$ which was not a significant predictor. Kukkonen *et al*. (2003) demonstrated that contaminant concentrations tend to increase with decreasing wind speed when by using measured data and the Operational Street Pollution Model (OSPM). The negative correlation of $PM_{2.5}$ and wind speed may be observed due to the wind direction. Wind direction plays a crucial role in predicting concentrations, because wind from different directions advects different types of air masses.

The high significance level of the overall F-tests of the models suggest that the set of independent variables was fairly sufficient for describing the measured $PM_{2.5}$ and UFP concentration. However, it is likely that some important variables were overlooked or not measured as a result of equipment limitations or manual recording used for monitoring.

LIMITATIONS

The primary limitation of this study involves the accuracy of environmental parameters such as wind speed and the lack of information on wind direction. The data were recorded manually for the entire sampling period, which may have posed some implications in representing the entirety of the environment considered for monitoring. In a complicated near-road environment, wind is affected by myriad factors ranging from tail winds of tractor-trailers to turbulence created by trees and signposts. Though this may initially appear to severely limit the usefulness of the wind data, it is important to mention that the wind speed was categorized accurately as per the intensity of the wind, which constitutes a fair representation of particulate dependence on wind speed at both the locations.

Passenger cars, delivery vans, minivans, pick-up trucks, mini-trucks, bus and motorcycles, were all considered as light-duty vehicles, termed as “Car Count”. It should be noted that, these vehicles were assumed to use gasoline, but many of these vehicles may have been diesel-powered. If so, the number of sources of diesel emissions would have been undercounted, which would have under-estimated the strength of the relationship between diesel engines and $PM_{2.5}$ and UFP concentrations.

This study focuses on a few aspects of particulate concentrations in an environment that includes wind speed, traffic volume, and routine presence of large diesel vehicles. Although wind speed, and traffic volume appear to have an impact on exposure levels, future studies will need to consider environmental data with variables such as wind direction, temperature, humidity, vehicle flow to effectively control for as many factors as possible when determining the significance of varying particulate levels. Many factors could affect the concentration levels, including the percentage of heavy duty and light-duty trucks on the roadway, and distance to curb. Air quality data synchronized with these missing factors can most accurately determine relationships between particulate levels, traffic volume and vehicle type, and the monitoring site.

Location and environmental factors may all contribute to the observed variability, and the results gathered here from the limited pool of samples require further validation in order to develop a more complete understanding of the associations.

CONCLUSIONS

The trends and variability of $PM_{2.5}$ and UFP concentrations at two sites in Morgantown, WV were investigated. Statistical modeling by means of Generalized Linear Models was used to estimate the effect of several environmental variables to $PM_{2.5}$ and UFP concentrations and estimate concentrations adjusted for the effect of environmental conditions. Wind speed, and rain were observed as the most important environmental variables affecting both the concentrations. Average concentrations of $PM_{2.5}$, UFP concentrations also varied strongly by traffic volumes, suggesting a relationship between these concentrations and traffic density.

- A negative correlation between wind speed and track count along with strong correlations between vehicle counts and location were observed using Perason product moment correlation since one road carried far more traffic than the other.
- Time24 (Average concentrations for 24-hour period of monitoring) was strongly correlated to truck count since trucks are generally restricted from some locations during the middle of the day by either regulations or slow traffic.
- UFP concentrations were highly significant ($p<0.010\%$) with the wind speed and truck count indicating high emission of UFP due to diesel engines.
- Rain also had significant effects ($p < 0.5\%$), suggesting that rain was efficient at removing UFP from the air. The location was significant ($p < 2.9\%$) but accounted for less than 1% of the sum of squares. The lack of importance of Location suggests that the effects of Location are represented by TruckCount.

- The results for the general linear model of log ($PM_{2.5}$) were quite different. Wind Speed was dramatically less important and was non-significant ($p > 5\%$) but Rain was highly significant ($p < 0.05\%$). Since TruckCount was not significant, but Car Count was highly significant, this suggests that $PM_{2.5}$ was far more strongly affected by the larger particles in its range and diesel emissions are therefore unimportant. Rain was highly significant ($p < 0.04\%$), suggesting that rain removes some fraction of $PM_{2.5}$.

These data may be useful in estimating exposure to ultrafine particles in the vicinity of major highways for epidemiological studies and in evaluating the adverse health effects of such particles. These data also suggest that the relationship between UFP and truck count is not strong enough to allow confident prediction of truck count from UFP or vice-versa.

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APPENDIX A

Monitoring Data

PM2.5 mg/m3	PM2.5 µg/m3	UFP pt/cc	Truck count	Car count	Rain	Wind Speed	Date	Day	location	Sampling day
0.00800	8.00	9561.067	8	325	0	1	4/1/2015	3	1	2
0.00653	6.53	10575.93	8	328	0	1	4/1/2015	3	1	2
0.00680	6.80	8515.133	6	305	0	1	4/1/2015	3	1	2
0.00820	8.20	12228.67	5	365	0	1	4/1/2015	3	1	2
0.00720	7.20	13033.4	6	306	0	1	4/1/2015	3	1	2
0.00633	6.33	10453.8	3	315	0	1	4/1/2015	3	1	2
0.00760	7.60	11629.47	2	332	0	1	4/1/2015	3	1	2
0.00607	6.07	12611.6	4	340	0	1	4/1/2015	3	1	2
0.00587	5.87	19654.13	3	375	0	1	4/1/2015	3	1	2
0.00687	6.87	18606.33	7	352	0	1	4/1/2015	3	1	2
0.00553	5.53	11597.13	2	391	0	1	4/1/2015	3	1	2
0.00620	6.20	10838.8	1	390	0	1	4/1/2015	3	1	2
0.00567	5.67	10588.87	3	420	0	1	4/1/2015	3	1	2
0.00513	5.13	9699.6	0	216	0	1	4/1/2015	3	1	2
0.00593	5.93	7569.4	1	350	0	1	4/1/2015	3	1	2
0.00600	6.00	8674.933	1	402	0	1	4/1/2015	3	1	2
0.01207	12.07	25527.07	18	150	0	1	5/2/2015	6	1	14
0.01100	11.00	20924.67	7	200	0	1	5/2/2015	6	1	14
0.01160	11.60	22371.6	8	228	0	1	5/2/2015	6	1	14
0.01240	12.40	18799.47	12	187	0	1	5/2/2015	6	1	14
0.01080	10.80	13589.93	11	185	0	1	5/2/2015	6	1	14
0.01120	11.20	12907.27	8	190	0	1	5/2/2015	6	1	14
0.01040	10.40	11799.4	11	224	0	1	5/2/2015	6	1	14
0.00873	8.73	11185.93	13	228	0	1	5/2/2015	6	1	14
0.00867	8.67	9385.067	13	240	0	1	5/2/2015	6	1	14
0.00840	8.40	10603.8	8	280	0	1	5/2/2015	6	1	14
0.00720	7.20	6722.467	10	290	0	1	5/2/2015	6	1	14
0.00847	8.47	7376.933	12	292	0	1	5/2/2015	6	1	14
0.00627	6.27	5958	10	273	0	1	5/2/2015	6	1	14

0.00627	6.27	5461.533	4	305	0	1	5/2/2015	6	1	14
0.00613	6.13	4978.8	5	313	0	1	5/2/2015	6	1	14
0.00607	6.07	5107.8	2	300	0	1	5/2/2015	6	1	14
0.01387	13.87	29028.33	8	390	0	1	4/15/2015	3	1	8
0.01220	12.20	28122.07	9	317	0	1	4/15/2015	3	1	8
0.00907	9.07	17128.13	13	323	0	1	4/15/2015	3	1	8
0.00713	7.13	23078.07	3	308	0	1	4/15/2015	3	1	8
0.00807	8.07	11567.67	6	299	0	1	4/15/2015	3	1	8
0.00540	5.40	9580.067	6	285	0	1	4/15/2015	3	1	8
0.00493	4.93	9318.333	12	276	0	1	4/15/2015	3	1	8
0.00540	5.40	12788.47	4	291	0	1	4/15/2015	3	1	8
0.00493	4.93	11289	6	264	0	1	4/15/2015	3	1	8
0.00327	3.27	6828.2	9	275	0	1	4/15/2015	3	1	8
0.00287	2.87	6439	5	271	0	1	4/15/2015	3	1	8
0.00233	2.33	6799	7	308	0	1	4/15/2015	3	1	8
0.00187	1.87	6191.533	10	318	0	1	4/15/2015	3	1	8
0.01133	11.33	29577.47	7	340	0	1	4/15/2015	3	1	8
0.00193	1.93	5196	4	298	0	1	4/15/2015	3	1	8
0.00200	2.00	5213.133	3	290	0	1	4/15/2015	3	1	8
0.02707	27.07	42282.4	12	302	0	2	4/6/2015	1	1	4
0.01753	17.53	32319.73	7	266	0	2	4/6/2015	1	1	4
0.01753	17.53	43937.13	15	275	0	2	4/6/2015	1	1	4
0.02567	25.67	27553.6	10	309	0	2	4/6/2015	1	1	4
0.02720	27.20	26593.8	12	313	0	2	4/6/2015	1	1	4
0.02533	25.33	29024.27	20	257	0	2	4/6/2015	1	1	4
0.02313	23.13	23149.93	15	296	0	2	4/6/2015	1	1	4
0.02313	23.13	30749.07	12	311	0	2	4/6/2015	1	1	4
0.01187	11.87	16747.87	12	271	0	2	4/6/2015	1	1	4
0.01067	10.67	15622.67	16	329	0	2	4/6/2015	1	1	4
0.00680	6.80	7900.467	13	280	0	2	4/6/2015	1	1	4
0.00540	5.40	11589.93	13	309	0	2	4/6/2015	1	1	4

0.00513	5.13	10251.33	11	307	0	2	4/6/2015	1	1	4
0.00533	5.33	9023.867	11	266	0	2	4/6/2015	1	1	4
0.00573	5.73	10093.8	18	307	0	2	4/6/2015	1	1	4
0.00660	6.60	6396.667	15	353	0	2	4/6/2015	1	1	4
0.01493	14.93	23531	15	300	0	2	4/13/2015	1	1	7
0.01700	17.00	35920.47	18	265	0	2	4/13/2015	1	1	7
0.01400	14.00	17212.73	12	276	0	2	4/13/2015	1	1	7
0.01027	10.27	7786.733	14	310	0	2	4/13/2015	1	1	7
0.01053	10.53	5288.2	10	316	0	2	4/13/2015	1	1	7
0.01020	10.20	5813.333	11	255	0	2	4/13/2015	1	1	7
0.01247	12.47	8958.867	14	299	0	2	4/13/2015	1	1	7
0.01987	19.87	8768.2	13	309	0	2	4/13/2015	1	1	7
0.01113	11.13	6119.067	15	273	0	2	4/13/2015	1	1	7
0.00900	9.00	5215.733	11	326	0	2	4/13/2015	1	1	7
0.00813	8.13	4407.933	10	277	0	2	4/13/2015	1	1	7
0.00787	7.87	5036.2	12	304	0	2	4/13/2015	1	1	7
0.00747	7.47	4541.267	9	308	0	2	4/13/2015	1	1	7
0.00660	6.60	3919.667	10	256	0	2	4/13/2015	1	1	7
0.00707	7.07	4452.533	11	310	0	2	4/13/2015	1	1	7
0.00633	6.33	3910.8	10	350	0	2	4/13/2015	1	1	7
0.00760	7.60	12856.6	3	349	0	2	4/17/2015	5	1	9
0.00760	7.60	8147.2	10	265	0	2	4/17/2015	5	1	9
0.00860	8.60	7922.933	3	357	0	2	4/17/2015	5	1	9
0.00900	9.00	9214.333	4	344	0	2	4/17/2015	5	1	9
0.01133	11.33	6316.933	6	378	0	2	4/17/2015	5	1	9
0.01093	10.93	6701	2	331	0	2	4/17/2015	5	1	9
0.01047	10.47	5654.267	8	352	0	2	4/17/2015	5	1	9
0.01260	12.60	7501.4	5	350	0	2	4/17/2015	5	1	9
0.00940	9.40	7132.333	4	377	0	2	4/17/2015	5	1	9
0.00967	9.67	6237.733	1	354	0	2	4/17/2015	5	1	9
0.01087	10.87	5106.6	4	397	0	2	4/17/2015	5	1	9

0.00953	9.53	6061.6	4	384	0	2	4/17/2015	5	1	9
0.01060	10.60	4423.733	0	440	0	2	4/17/2015	5	1	9
0.01033	10.33	4102.2	1	395	0	2	4/17/2015	5	1	9
0.01093	10.93	3825	0	434	0	2	4/17/2015	5	1	9
0.01033	10.33	3338.333	1	450	0	2	4/17/2015	5	1	9
0.00593	5.93	5496	0	319	0	2	5/2/2015	6	1	14
0.00580	5.80	10334.8	2	268	0	2	5/2/2015	6	1	14
0.00613	6.13	6354.6	1	335	0	2	5/2/2015	6	1	14
0.00587	5.87	6134.867	2	330	0	2	5/2/2015	6	1	14
0.00547	5.47	7630	2	303	0	2	5/2/2015	6	1	14
0.00560	5.60	9977.8	1	299	0	2	5/2/2015	6	1	14
0.00507	5.07	9582.6	0	287	0	2	5/2/2015	6	1	14
0.00527	5.27	9187.733	0	305	0	2	5/2/2015	6	1	14
0.00520	5.20	10143.53	2	290	0	2	5/2/2015	6	1	14
0.00513	5.13	11089.27	1	286	0	2	5/2/2015	6	1	14
0.00513	5.13	11320.8	0	278	0	2	5/2/2015	6	1	14
0.00500	5.00	11052.47	0	337	0	2	5/2/2015	6	1	14
0.00520	5.20	10694.33	1	265	0	2	5/2/2015	6	1	14
0.00520	5.20	9319.867	0	294	0	2	5/2/2015	6	1	14
0.00547	5.47	8587.533	2	281	0	2	5/2/2015	6	1	14
0.00600	6.00	9027.8	0	303	0	2	5/2/2015	6	1	14
0.00460	4.60	9597.4	1	276	0	2	4/25/2015	6	1	10
0.00413	4.13	3892.6	0	295	0	2	4/25/2015	6	1	10
0.00453	4.53	4120.067	0	296	0	2	4/25/2015	6	1	10
0.00420	4.20	2212.133	0	280	0	2	4/25/2015	6	1	10
0.00493	4.93	3177.733	2	289	0	3	4/4/2015	6	1	3
0.00440	4.40	4296.733	0	286	0	3	4/4/2015	6	1	3
0.00420	4.20	3103.533	0	277	0	3	4/4/2015	6	1	3
0.00433	4.33	1913.8	0	291	0	3	4/4/2015	6	1	3
0.00400	4.00	2528.533	1	278	0	3	4/4/2015	6	1	3
0.00320	3.20	3799.733	0	266	0	3	4/4/2015	6	1	3

0.00307	3.07	4925.333	0	264	0	3	4/4/2015	6	1	3
0.00320	3.20	5077.2	0	252	0	3	4/4/2015	6	1	3
0.00307	3.07	4732.467	0	300	0	3	4/4/2015	6	1	3
0.00320	3.20	3507.933	0	327	0	3	4/4/2015	6	1	3
0.00300	3.00	4849.533	0	291	0	3	4/4/2015	6	1	3
0.00233	2.33	5316.067	0	270	0	3	4/4/2015	6	1	3
0.00207	2.07	7274.8	0	324	0	3	4/4/2015	6	1	3
0.00207	2.07	6672.867	0	232	0	3	4/4/2015	6	1	3
0.00180	1.80	7344.067	0	227	0	3	4/4/2015	6	1	3
0.00133	1.33	8369.533	0	190	0	3	4/4/2015	6	1	3
0.00453	4.53	8183.2	6	324	0	3	4/8/2015	1	1	5
0.00487	4.87	4545.733	3	375	0	3	4/8/2015	3	1	5
0.00440	4.40	5471.6	8	285	0	3	4/8/2015	3	1	5
0.00413	4.13	2766.333	10	328	0	3	4/8/2015	3	1	5
0.00653	6.53	4449.333	2	296	0	3	4/8/2015	3	1	5
0.00647	6.47	3347.8	5	331	0	3	4/8/2015	3	1	5
0.00727	7.27	3947.6	9	332	0	3	4/8/2015	3	1	5
0.00760	7.60	4494.267	5	368	0	3	4/8/2015	3	1	5
0.01600	16.00	7088.4	5	325	0	3	4/8/2015	3	1	5
0.00940	9.40	3470.867	2	352	0	3	4/8/2015	3	1	5
0.00813	8.13	2203.867	2	324	0	3	4/8/2015	3	1	5
0.00867	8.67	2787.333	3	281	0	3	4/8/2015	3	1	5
0.01047	10.47	2997.8	3	332	0	3	4/8/2015	3	1	5
0.01200	12.00	3409.933	6	403	0	3	4/8/2015	3	1	5
0.01120	11.20	3507.533	5	429	0	3	4/8/2015	3	1	5
0.01167	11.67	2640.933	1	337	0	3	4/8/2015	3	1	5
0.00627	6.27	2935.4	1	157	0	3	4/11/2015	6	1	6
0.00667	6.67	2927.6	1	162	0	3	4/11/2015	6	1	6
0.00753	7.53	2124.467	1	214	0	3	4/11/2015	6	1	6
0.00827	8.27	2107.2	3	176	0	3	4/11/2015	6	1	6
0.00853	8.53	2592.933	1	200	0	3	4/11/2015	6	1	6

0.00747	7.47	5164.933	3	199	0	3	4/11/2015	6	1	6
0.00727	7.27	3484.333	5	287	0	3	4/11/2015	6	1	6
0.00500	5.00	2168.667	3	223	0	3	4/11/2015	6	1	6
0.00513	5.13	3085.533	2	226	0	3	4/11/2015	6	1	6
0.00473	4.73	1771.533	1	293	0	3	4/11/2015	6	1	6
0.00473	4.73	2567.133	0	266	0	3	4/11/2015	6	1	6
0.00467	4.67	2763	2	227	0	3	4/11/2015	6	1	6
0.00460	4.60	4699	3	292	0	3	4/11/2015	6	1	6
0.00520	5.20	3446.133	1	287	0	3	4/11/2015	6	1	6
0.00500	5.00	3036.8	0	320	0	3	4/11/2015	6	1	6
0.00507	5.07	2507.8	1	299	0	3	4/11/2015	6	1	6
0.04887	48.87	4833.467	0	132	1	1	5/17/2015	7	1	20
0.03173	31.73	3576.667	0	145	1	1	5/17/2015	7	1	20
0.02367	23.67	3003.533	1	176	1	1	5/17/2015	7	1	20
0.02080	20.80	1813.8	0	179	1	1	5/17/2015	7	1	20
0.01987	19.87	2518.533	0	189	1	1	5/17/2015	7	1	20
0.01973	19.73	3699.733	0	198	1	1	5/17/2015	7	1	20
0.02047	20.47	4825.333	0	233	1	1	5/17/2015	7	1	20
0.01973	19.73	4077.2	0	190	1	1	5/17/2015	7	1	20
0.01907	19.07	4722.467	0	235	1	1	5/17/2015	7	1	20
0.01900	19.00	3407.933	0	238	1	1	5/17/2015	7	1	20
0.01807	18.07	4749.533	0	288	1	1	5/17/2015	7	1	20
0.01800	18.00	5216.067	0	343	1	1	5/17/2015	7	1	20
0.01653	16.53	6274.8	0	390	1	1	5/17/2015	7	1	20
0.01600	16.00	6572.867	0	344	1	1	5/17/2015	7	1	20
0.01660	16.60	7244.067	0	348	1	1	5/17/2015	7	1	20
0.01527	15.27	8169.533	0	325	1	1	5/17/2015	7	1	20
0.01860	18.60	8235.667	3	224	1	1	5/21/2015	4	1	22
0.01907	19.07	14643.07	16	276	1	1	5/21/2015	4	1	22
0.01900	19.00	9758.933	13	308	1	1	5/21/2015	4	1	22
0.01973	19.73	22368.47	17	362	1	1	5/21/2015	4	1	22

0.01940	19.40	21129.87	13	356	1	1	5/21/2015	4	1	22
0.01900	19.00	15460.93	13	298	1	1	5/21/2015	4	1	22
0.01853	18.53	12114.67	14	286	1	1	5/21/2015	4	1	22
0.01813	18.13	13719.8	13	289	1	1	5/21/2015	4	1	22
0.01767	17.67	9625.733	12	261	1	1	5/21/2015	4	1	22
0.01820	18.20	8725.8	11	275	1	1	5/21/2015	4	1	22
0.02500	25.00	25355.33	19	233	1	1	5/21/2015	4	1	22
0.01953	19.53	24623.87	20	230	1	1	5/21/2015	4	1	22
0.01913	19.13	20062.93	16	235	1	1	5/21/2015	4	1	22
0.01980	19.80	8296	16	238	1	1	5/21/2015	4	1	22
0.02213	22.13	16514	11	236	1	1	5/21/2015	4	1	22
0.02400	24.00	17586.47	18	265	1	1	5/21/2015	4	1	22
0.01367	13.67	14274.33	20	309	1	2	3/30/2015	1	1	1
0.01533	15.33	14884.6	32	280	1	2	3/30/2015	1	1	1
0.01567	15.67	19903.4	23	324	1	2	3/30/2015	1	1	1
0.01367	13.67	18350.93	11	318	1	2	3/30/2015	1	1	1
0.01700	17.00	25225.33	20	277	1	2	3/30/2015	1	1	1
0.01240	12.40	19624.53	15	279	1	2	3/30/2015	1	1	1
0.00900	9.00	15767.53	12	311	1	2	3/30/2015	1	1	1
0.00827	8.27	14296.27	12	271	1	2	3/30/2015	1	1	1
0.01193	11.93	10025	16	329	1	2	3/30/2015	1	1	1
0.01687	16.87	9014.333	13	280	1	2	3/30/2015	1	1	1
0.00433	4.33	1463.333	0	269	1	2	4/25/2015	6	1	10
0.00433	4.33	2434.8	0	278	1	2	4/25/2015	6	1	10
0.00467	4.67	3622.533	0	298	1	2	4/25/2015	6	1	10
0.00500	5.00	2546.267	0	290	1	2	4/25/2015	6	1	10
0.00487	4.87	2791.667	0	280	1	2	4/25/2015	6	1	10
0.00500	5.00	8383	1	289	1	2	4/25/2015	6	1	10
0.00500	5.00	4848.533	0	275	1	2	4/25/2015	6	1	10
0.00513	5.13	5326.067	0	330	1	2	4/25/2015	6	1	10
0.00573	5.73	7273.8	0	311	1	2	4/25/2015	6	1	10

0.00607	6.07	6472.867	0	225	1	2	4/25/2015	6	1	10
0.00613	6.13	2544	0	323	1	2	4/25/2015	6	1	10
0.00700	7.00	13123.53	2	349	1	2	4/25/2015	6	1	10
0.00640	6.40	16607.87	0	88	0	1	4/27/2015	1	2	11
0.00633	6.33	16203.8	0	101	0	1	4/27/2015	1	2	11
0.00600	6.00	18513.33	2	118	0	1	4/27/2015	1	2	11
0.00600	6.00	16353.93	0	163	0	1	4/27/2015	1	2	11
0.00600	6.00	14267.13	0	214	0	1	4/27/2015	1	2	11
0.00600	6.00	11096.33	2	184	0	1	4/27/2015	1	2	11
0.00600	6.00	11663.87	1	161	0	1	4/27/2015	1	2	11
0.00593	5.93	12379	2	199	0	1	4/27/2015	1	2	11
0.00607	6.07	10429.27	1	180	0	1	4/27/2015	1	2	11
0.00600	6.00	8480.333	0	204	0	1	4/27/2015	1	2	11
0.00600	6.00	7445.6	0	153	0	1	4/27/2015	1	2	11
0.00620	6.20	7294.867	0	156	0	1	4/27/2015	1	2	11
0.00680	6.80	7270	2	180	0	1	4/27/2015	1	2	11
0.00647	6.47	5562.667	1	137	0	1	4/27/2015	1	2	11
0.00607	6.07	4654.533	1	145	0	1	4/27/2015	1	2	11
0.00580	5.80	4397.4	2	133	0	1	4/27/2015	1	2	11
0.04000	40.00	9594.733	3	95	0	1	5/8/2015	5	2	17
0.03373	33.73	8087.133	2	118	0	1	5/8/2015	5	2	17
0.02727	27.27	6484.267	1	140	0	1	5/8/2015	5	2	17
0.02453	24.53	5076.467	2	159	0	1	5/8/2015	5	2	17
0.02233	22.33	15491.13	3	145	0	1	5/8/2015	5	2	17
0.02293	22.93	25811.07	4	157	0	1	5/8/2015	5	2	17
0.01980	19.80	18739.53	3	170	0	1	5/8/2015	5	2	17
0.02060	20.60	13050.27	2	158	0	1	5/8/2015	5	2	17
0.01967	19.67	16992.47	3	140	0	1	5/8/2015	5	2	17
0.01533	15.33	6421.133	2	160	0	1	5/8/2015	5	2	17
0.01440	14.40	6290.467	2	145	0	1	5/8/2015	5	2	17
0.01320	13.20	4839.133	0	150	0	1	5/8/2015	5	2	17

0.01273	12.73	4429.933	2	166	0	1	5/8/2015	5	2	17
0.01380	13.80	5169.733	3	150	0	1	5/8/2015	5	2	17
0.01360	13.60	4356.6	2	160	0	1	5/8/2015	5	2	17
0.01400	14.00	3519.2	1	174	0	1	5/8/2015	5	2	17
0.01373	13.73	20646.2	2	138	0	1	5/1/2015	5	2	13
0.01300	13.00	18201.87	3	157	0	1	5/1/2015	5	2	13
0.01060	10.60	5472.4	2	142	0	1	5/1/2015	5	2	13
0.01040	10.40	5016.667	0	151	0	1	5/1/2015	5	2	13
0.00933	9.33	5728.733	2	163	0	1	5/1/2015	5	2	13
0.01033	10.33	5005	3	145	0	1	5/1/2015	5	2	13
0.01127	11.27	6794.6	2	164	0	1	5/1/2015	5	2	13
0.00893	8.93	4647.8	3	176	0	1	5/1/2015	5	2	13
0.00367	3.67	41649.27	3	208	0	2	4/28/2015	2	2	12
0.00347	3.47	19957.07	1	232	0	2	4/28/2015	2	2	12
0.00300	3.00	15491.73	0	193	0	2	4/28/2015	2	2	12
0.00307	3.07	18700.87	0	194	0	2	4/28/2015	2	2	12
0.00300	3.00	19407.4	1	251	0	2	4/28/2015	2	2	12
0.00300	3.00	21679.07	2	253	0	2	4/28/2015	2	2	12
0.00300	3.00	18893	0	255	0	2	4/28/2015	2	2	12
0.00300	3.00	17537.2	1	284	0	2	4/28/2015	2	2	12
0.00307	3.07	20573.13	2	250	0	2	4/28/2015	2	2	12
0.00300	3.00	18091.4	0	248	0	2	4/28/2015	2	2	12
0.00300	3.00	18935	0	270	0	2	4/28/2015	2	2	12
0.00300	3.00	19635.67	1	317	0	2	4/28/2015	2	2	12
0.00307	3.07	21739.8	1	277	0	2	4/28/2015	2	2	12
0.00313	3.13	21731.53	1	283	0	2	4/28/2015	2	2	12
0.00307	3.07	22476.2	3	281	0	2	4/28/2015	2	2	12
0.00320	3.20	20061.2	2	263	0	2	4/28/2015	2	2	12
0.00800	8.00	5722.867	0	189	0	3	5/4/2015	1	2	16
0.00727	7.27	4793.267	0	147	0	3	5/4/2015	1	2	16
0.00713	7.13	4663.333	0	207	0	3	5/4/2015	1	2	16

0.00700	7.00	4357.667	1	203	0	3	5/4/2015	1	2	16
0.00720	7.20	4727.267	0	253	0	3	5/4/2015	1	2	16
0.00707	7.07	5729.467	0	223	0	3	5/4/2015	1	2	16
0.00827	8.27	5106.133	1	239	0	3	5/4/2015	1	2	16
0.00767	7.67	5369.8	0	211	0	3	5/4/2015	1	2	16
0.00833	8.33	7796.6	0	210	0	3	5/4/2015	1	2	16
0.00767	7.67	3901.333	1	208	0	3	5/4/2015	1	2	16
0.00740	7.40	3116.733	1	240	0	3	5/4/2015	1	2	16
0.00707	7.07	2812.2	0	237	0	3	5/4/2015	1	2	16
0.00747	7.47	2892.067	0	229	0	3	5/4/2015	1	2	16
0.00713	7.13	3177.867	1	247	0	3	5/4/2015	1	2	16
0.00720	7.20	3481.867	0	253	0	3	5/4/2015	1	2	16
0.00713	7.13	3438.267	0	221	0	3	5/4/2015	1	2	16
0.04080	40.80	3849.867	1	116	0	3	5/12/2015	2	2	18
0.02667	26.67	3219.467	1	103	0	3	5/12/2015	2	2	18
0.02287	22.87	3486.933	0	131	0	3	5/12/2015	2	2	18
0.02160	21.60	4398.8	1	156	0	3	5/12/2015	2	2	18
0.01940	19.40	4114.867	1	148	0	3	5/12/2015	2	2	18
0.01880	18.80	6716.867	2	128	0	3	5/12/2015	2	2	18
0.01560	15.60	4534.267	2	115	0	3	5/12/2015	2	2	18
0.01433	14.33	5146.867	3	134	0	3	5/12/2015	2	2	18
0.01320	13.20	4686.6	2	105	0	3	5/12/2015	2	2	18
0.01253	12.53	3554.4	1	100	0	3	5/12/2015	2	2	18
0.01260	12.60	2819.067	2	114	0	3	5/12/2015	2	2	18
0.01160	11.60	3408.867	1	139	0	3	5/12/2015	2	2	18
0.01060	10.60	2288.333	2	115	0	3	5/12/2015	2	2	18
0.01053	10.53	2300.733	0	133	0	3	5/12/2015	2	2	18
0.01007	10.07	2185.4	3	142	0	3	5/12/2015	2	2	18
0.00947	9.47	1827.667	1	117	0	3	5/12/2015	2	2	18
0.00980	9.80	4309.267	1	120	0	3	5/13/2015	3	2	19
0.00967	9.67	5335.333	0	125	0	3	5/13/2015	3	2	19

0.00900	9.00	4342.8	2	141	0	3	5/13/2015	3	2	19
0.00920	9.20	8111.4	1	114	0	3	5/13/2015	3	2	19
0.00907	9.07	5561.733	2	129	0	3	5/13/2015	3	2	19
0.00900	9.00	3864.667	1	153	0	3	5/13/2015	3	2	19
0.01180	11.80	25527.07	2	95	0	3	5/1/2015	5	2	13
0.00947	9.47	20924.67	2	115	0	3	5/1/2015	5	2	13
0.00953	9.53	22371.6	1	130	0	3	5/1/2015	5	2	13
0.00800	8.00	18799.47	2	158	0	3	5/1/2015	5	2	13
0.00740	7.40	13589.93	3	144	0	3	5/1/2015	5	2	13
0.00693	6.93	12907.27	3	150	0	3	5/1/2015	5	2	13
0.00707	7.07	11799.4	3	166	0	3	5/1/2015	5	2	13
0.00720	7.20	11185.93	4	146	0	3	5/1/2015	5	2	13
0.05047	50.47	10911.8	2	97	1	1	5/1/2015	5	2	13
0.04233	42.33	10093.8	2	120	1	1	5/1/2015	5	2	13
0.03307	33.07	38439	4	138	1	1	5/1/2015	5	2	13
0.02593	25.93	16274.87	2	160	1	1	5/1/2015	5	2	13
0.01920	19.20	7206.4	3	145	1	1	5/1/2015	5	2	13
0.01560	15.60	10046.4	3	155	1	1	5/1/2015	5	2	13
0.01413	14.13	16015.6	3	172	1	1	5/1/2015	5	2	13
0.01340	13.40	7756	1	155	1	1	5/1/2015	5	2	13
0.04540	45.40	4715.467	0	235	1	2	5/18/2015	1	2	21
0.02607	26.07	3678.867	0	232	1	2	5/18/2015	1	2	21
0.01947	19.47	5369.933	0	222	1	2	5/18/2015	1	2	21
0.01760	17.60	4140.867	0	230	1	2	5/18/2015	1	2	21
0.01720	17.20	4594.933	1	210	1	2	5/18/2015	1	2	21
0.01647	16.47	3226.4	0	220	1	2	5/18/2015	1	2	21
0.01620	16.20	4045.2	0	195	1	2	5/18/2015	1	2	21
0.01587	15.87	4220.867	0	233	1	2	5/18/2015	1	2	21
0.01580	15.80	4415.6	0	236	1	2	5/18/2015	1	2	21
0.01660	16.60	4896.733	0	212	1	2	5/18/2015	1	2	21
0.01640	16.40	4884.733	0	211	1	2	5/18/2015	1	2	21

0.01687	16.87	4974.2	0	205	1	2	5/18/2015	1	2	21
0.01693	16.93	4041.067	0	167	1	2	5/18/2015	1	2	21
0.01727	17.27	4504.8	0	173	1	2	5/18/2015	1	2	21
0.01700	17.00	4618.8	0	118	1	2	5/18/2015	1	2	21
0.01700	17.00	3967.2	0	155	1	2	5/18/2015	1	2	21
0.04600	46.00	9632.6	2	99	1	2	5/27/2015	3	2	22
0.03027	30.27	6302.933	3	115	1	2	5/27/2015	3	2	22
0.02260	22.60	2949.8	1	144	1	2	5/27/2015	3	2	22
0.01893	18.93	2832.533	1	153	1	2	5/27/2015	3	2	22
0.01707	17.07	2334.8	3	147	1	2	5/27/2015	3	2	22
0.01640	16.40	1856.286	2	153	1	2	5/27/2015	3	2	22
0.01647	16.47	5989.4	2	175	1	2	5/27/2015	3	2	22
0.01673	16.73	12516.67	2	155	1	2	5/27/2015	3	2	22
0.01667	16.67	8900	3	141	1	2	5/27/2015	3	2	22
0.01687	16.87	7173.733	3	158	1	2	5/27/2015	3	2	22
0.01800	18.00	8364.6	0	140	1	2	5/27/2015	3	2	22
0.01713	17.13	9131.867	2	144	1	2	5/27/2015	3	2	22
0.01647	16.47	9899.2	2	162	1	2	5/27/2015	3	2	22
0.01647	16.47	6933.4	2	152	1	2	5/27/2015	3	2	22
0.01707	17.07	9585.933	0	165	1	2	5/27/2015	3	2	22
0.01753	17.53	7191.667	3	168	1	2	5/27/2015	3	2	22
0.00740	7.40	9385.067	2	150	1	3	5/1/2015	5	2	13
0.00707	7.07	10603.8	3	155	1	3	5/1/2015	5	2	13
0.00693	6.93	6722.467	2	139	1	3	5/1/2015	5	2	13
0.00607	6.07	7376.933	0	157	1	3	5/1/2015	5	2	13
0.00660	6.60	5958	2	170	1	3	5/1/2015	5	2	13
0.00653	6.53	5461.533	3	167	1	3	5/1/2015	5	2	13
0.00627	6.27	4978.8	2	163	1	3	5/1/2015	5	2	13
0.00613	6.13	5107.8	1	178	1	3	5/1/2015	5	2	13

APPENDIX B

The DATA DESK

Multivariate Analysis Procedure

DESIGN

ANOVA

Analysis of Variance For logFine

cases selected according to sel = location 1

368 total cases of which 150 are missing

Source	df	Sums of Squares	Mean Square	F-ratio	P-value
Intercept	1	951.22	951.22	42328	⍰ 0.0001
Trk	1	0.113891	0.113891	5.068	0.0255
Lcn	0	0	•	•	•
Wtr	1	0.018709	0.018709	0.83253	0.3626
Day	12	5.66487	0.472072	21.007	⍰ 0.0001
Wnd	1	0.0917531	0.0917531	4.0829	0.0446
Car	1	0.0102381	0.010238	0.45559	0.5005
Error	201	4.51696	0.0224724		
Total	217	16.4375			

DESIGN

ANOVA

Analysis of Variance For logUFP

cases selected according to sel

368 total cases of which 150 are missing

Source	df	Sums of Sq	Mean Sq	F-ratio	P-value
Intercept	1	3263.23	3263.23	87686	⍰ 0.0001
Trk	1	0.630569	0.630569	16.944	⍰ 0.0001
Lcn	0	0	•	•	•
Wtr	1	203.343e-6	203.343e-6	0.005464	0.9411
Day	12	5.56556	0.463797	12.463	⍰ 0.0001

Wnd	1	0.0621472	0.0621472	1.67	0.1977
Car	1	611.648e-6	611.648e-6	0.016436	0.8981
Error	201	7.48016	0.0372147		
Total	217	21.1807			

Results for factor Trk

Coefficients

DESIGN

Response variables

Name	Code
logFine	lgF

ANOVA

Analysis of Variance For logFine

cases selected according to sel = 2

368 total cases of which 218 are missing

Source	df	Sums of Squares	Mean Square	F-ratio	P-value
Intercept	1	584.957	584.957	42311	⍰ 0.0001
Trk	1	0.0118943	0.0118943	0.86035	0.3553
Lcn	0	0	•	•	•
Wtr	1	0.135805	0.135805	9.8231	0.0021
Day	8	4.72071	0.590089	42.683	⍰ 0.0001
Wnd	1	0.896814	0.896814	64.869	⍰ 0.0001
Car	1	0.195248	0.195248	14.123	0.0003
Error	137	1.89403	0.013825		
Total	149	12.4895			

ANOVA

Analysis of Variance For logUFP

cases selected according to sel

368 total cases of which 218 are missing

Source	df	Sums of Squares		Mean Square		F-ratio	P-values
Intercept	1	2236.28	2236.28	62963	⍰ 0.0001		
Trk	1	0.271689	0.271689	7.6494	0.0065		
Lcn	0	0	•	•	•		
Wtr	1	0.0353088	0.0353088	0.99412	0.3205		
Day	8	5.93004	0.741255	20.87	⍰ 0.0001		
Wnd	1	0.0141865	0.0141865	0.39942	0.5284		
Car	1	0.192949	0.192949	5.4325	0.0212		
Error	137	4.8659	0.0355175				
Total	149	13.11					

Pearson Product-Moment Correlation

No Selector

	UFP p…	TruckC…	CarCou…Rain	WindS…Day	location	Time24PM2.5 …
UFP pt/cc	1.000					
TruckCount	0.444	1.000				
CarCount	0.059	0.2841.000				
Rain	-0.054	0.057-0.151	1.000			
WindSpeed	-0.301	-0.230	-0.053-0.191	1.000		
Day	-0.202	-0.271	0.0620.094	-0.1121.000		
location	-0.024	-0.431	-0.7520.079	0.117-0.349	1.000	
Time24	-0.164	-0.434	0.164-0.005	0.225-0.045	0.122	1.000
PM2.5 mg/…	0.145	0.150-0.335	0.465-0.260	-0.0380.199	-0.408	1.000

ANOVA for logUFP

Source	df	Sums of Squares	Mean Square	F-ratio	P-value
Intercept	1	5499.5	5499.5	98841	⍰ 0.0001
Truck Count	1	1.09208	1.09208	19.628	⍰ 0.0001
Car Count	1	0.193503	0.193503	3.4778	0.063
Rn	1	0.453153	0.453153	8.1444	0.0046
WSd	2	4.45465	2.22732	40.031	⍰ 0.0001
Day	6	0.522314	0.087052	1.5646	0.1565
Icn	1	0.267329	0.267329	4.8046	0.029
TCt*Icn	1	0.163731	0.163731	2.9427	0.0871
Error	354	19.6966	0.05564		
Total	367	34.2961			
	R^2 =	0.42569			

ANOVA for cases selected according to UFP pt/cc sel

Source	df	Sums of Squares	Mean Square	F-ratio	P-value
Intercept	1	3.30E+10	3.30E+10	900.89	⍰ 0.0001
TCt	1	8.68E+08	8.68E+08	23.708	⍰ 0.0001
CCt	1	4.54E+07	4.54E+07	1.24	0.2662
Rn	1	2.29E+08	2.29E+08	6.2528	0.0129
WSd	2	1.48E+09	7.38E+08	20.163	⍰ 0.0001
Day	6	4.40E+08	7.34E+07	2.0045	0.0644
Icn	1	4.46E+07	4.46E+07	1.2185	0.2704
TCt*Icn	1	1.98E+08	1.98E+08	5.4074	0.0206
Error	354	1.30E+10	3.66E+07		
Total	367	2.01E+10			
	R^2 =	0.355017			

ANOVA for cases selected log(Fine) sel

according to

Source	df	Sums of Squares	Mean Square	F-ratio	P-value
Intercept	1	1535.02	1535.02	36536	0.0001
TCt	1	0.035084	0.035084	0.83505	0.3614
CCt	1	1.19301	1.19301	28.395	0.0001
Rn	1	0.535262	0.535262	12.74	0.0004
WSd	2	0.251179	0.125589	2.9892	0.0516
Day	6	3.61243	0.602072	14.33	0.0001
lcn	1	0.001414	0.001414	0.033648	0.8546
TCt*lcn	1	0.011767	0.011767	0.28008	0.597
Error	354	14.8731	0.042014		
Total	367	30.0839			
	R^2 =	0.505613			

ANOVA for cases selected according to sel — PM2.5 mg/m3

Source	df	Sums of Squares	Mean Square	F-ratio	P-value
Intercept	1	0.046509	0.046509	1281	0.0001
TCt	1	2.08E-05	2.08E-05	0.57377	0.4493
CCt	1	0.001296	0.001296	35.683	0.0001
Rn	1	5.69E-04	5.69E-04	15.673	0.0001
WSd	2	2.82E-04	1.41E-04	3.8823	0.0215
Day	6	0.001951	3.25E-04	8.9563	0.0001
lcn	1	7.51E-05	7.51E-05	2.0682	0.1513
TCt*lcn	1	1.30E-07	1.30E-07	0.003587	0.9523
Error	354	0.012853	3.63E-05		
Total	367	0.023108			
	R^2 =	0.443808			