You are what you breathe:
Analysis of traffic exhaust particulates in the Ironbound community.

Brianne Flynn, Caitlyn Kennedy, Kristine Rogers, Sara Kerby, Megan Day, Michael Calabrese, Justin Camejo, Katharine Galpin, Victoria Mulligan, Alexander Pelham-Webb, Vi Phan, Eric Doyle, and Ryan Hinrichs

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Drew University, 36 Madison Ave., Madison, NJ 07950; rhinrich@drew.edu

Several studies quantitatively examined the relationship between particulate matter and health effects in metropolitan areas and found that particulate matter is associated with higher levels of cardiovascular failure, pulmonary problems, increased asthma rates, low birth weight, and premature death (Brook, 2004). Due to high traffic density from diesel port trucks, numerous industries, and a lower socioeconomic population, the negative impacts of air pollution have been proven far greater in susceptible urban port areas. This study focuses on monitoring air quality in the Ironbound section of Newark, New Jersey. Newark is a city where school children experience a 25% asthma rate, which is double the state and national rates (Clean Water Action, 2008). Drew University's Toxic Chemical research group monitored six sites near the Hawkins Elementary School in Newark's Ironbound. Air samples were collected from each site on four separate days to measure levels of three air pollutants emitted from diesel vehicles: particulate matter ($PM_{2.5}$), ultrafine particulates, and black carbon. During measurement collection, the times when trucks and buses passed were recorded and the number of cars that passed was tallied. The results indicate that emission levels of Black Carbon, $PM_{2.5}$ and ultrafine particulates spiked in correlation with the times trucks and buses passed. In addition, two different samples were collected to measure the levels of the three air pollutants in the suburban town of Madison, New Jersey. Levels of particulates were higher in Newark when compared with particulate levels in Madison. The average $PM_{2.5}$ in Newark, NJ (10.0 $\mu g\ m^{-3}$) was 40% higher than the average in Madison, NJ (7.0 $\mu g\ m^{-3}$), while ultrafine particulate levels in Newark (11,238 particles cm^{-3}) were 100% higher than Madison (5,508 particles cm^{-3}). Drew University's Toxic Chemical research students suggest the city of Newark have busses retrofitted with greener technology in order to lessen the particulates emitted into the air. Further recommendations and possible solutions to reduce the amount of ultrafine particles, black carbon, and $PM_{2.5}$ are discussed in this report.

I. Background.

Particulate pollution is defined as a mixture of acid sulfates, organic compounds, and metals in the air (Kinney et al., 2000). Although countless sources of particulate pollution exist, the diesel exhaust from trucks and buses is known to be a major source correlated with severe health problems for those living in metropolitan areas. The problem is especially prevalent for those living in areas with high traffic density or in communities surrounding ports because diesel trucks are known to idle for long periods of time. Therefore, although Newark, New Jersey has multiple sources of particulate pollution, this study focuses on diesel-emitting buses and trucks. Particulate pollution from diesel vehicles is particularly hazardous because unlike smokestack emissions, diesel emissions are released at ground level where people breathe (Goldsmith et al., 2006). Numerous studies have been conducted to monitor air quality in urban areas by examining the impact that vehicle emissions have on the concentration of airborne particulate matter (Ryan et al., 2005).

The burning of fossil fuels in diesel engines and at factories is a major source of black carbon and particulate matter (PM) emissions. Black carbon particles absorb solar radiation, diminish air quality, and cause negative health effects for residents who breathe in the air (Highwood and Kinnersley, 2006).

Particulate matter is divided into categories based on how large the particles are in size: PM_{10} includes particulates less than 10 micrometers in diameter, $PM_{2.5}$ includes particulates less than 2.5 micrometers in diameter, and ultrafine particulate matter is composed of particulates smaller than 0.1 micrometers (Matson, 2004). $PM_{2.5}$ and ultrafine particulates are of the greatest concern because they penetrate deepest into the lungs due and enter the blood to their small size (Highwood and Kinnersley, 2006). Once the particulates have entered the bloodstream they can have a multitude of harmful effects on the body (Highwood and Kinnersley, 2006).

The negative health impacts associated with particulate matter have been proven in several scientific studies (Brook et al., 2004). Air pollution in the form of particulate matter negatively impacts both the heart and lungs, however in times of high air pollution, more citizens perish from cardiovascular diseases than problems with lung function (Highwood and Kinnersley, 2006). According to Figure 1, asthma-related hospitalizations in New Jersey are correlated with air-polluting sites. This map reinforces the proven fact that asthma attacks are linked to air pollution. Epidemiological studies have consistently found that there is an increased risk for cardiovascular events when there is both short and long-term exposure to present-day concentrations of ambient particulate matter (Brook et al., 2004). Additionally, particulates in the air are associated with wheezing and coughing. Negative effects of air pollution on infants include coughing and wheezing and low birth weight. Infants living in areas near (<100 m) stop-and-go diesel traffic have been shown to have a higher prevalence of wheezing when compared to non-exposed infants (Ryan et al., 2005). Low birth weight is a predictor of infant mortality and the future health of the child is connected with cardiovascular diseases and cognitive development. (Morello-Frosch et al., 2010). Particulate matter has also been directly linked to mortality. Fine particulate levels are negatively correlated with life expectancy (Pope III et al., 2009). Thus, decreases in the concentration of fine particulate matter were associated with estimated increases in the mean life expectancy (Pope III et al., 2009). Finally, the results of the Health Effects Institute National Morbidity and Mortality Particulate Matter Study suggests there is no safe level of particulate matter (Goldsmith, 2006).

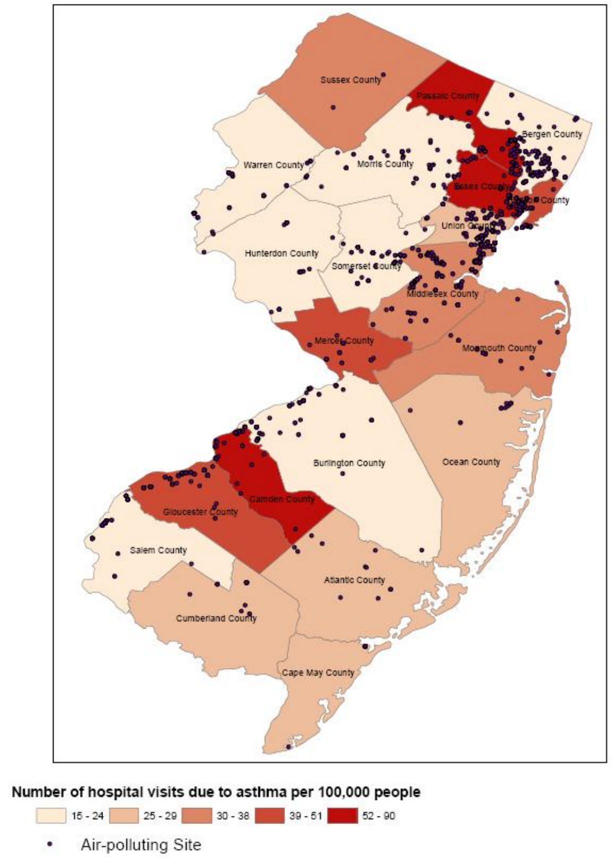

Figure 1. Annual hospital visits per 100,000 people for all New Jersey counties. (Map generated by Brianne Flynn.)

This study is an attempt to analyze Newark air quality in order to explain the city's high asthma rates among children. We chose to sample the air on various points along Hawkins Street because many children must walk on this road in order to get to the Hawkins Elementary School. We chose to monitor black carbon, ultrafine particulate matter, and $PM_{2.5}$ levels because they are contributors to asthma and asthma attacks and they are emitted from diesel-fueled vehicles. The experiment is designed to prove that diesel vehicles (specifically buses and trucks) emit significant amounts of the three criteria pollutants, therefore reducing the air quality in the Ironbound and posing a threat to people's health.

II. Methods.

Groups of four researchers participated in weekly measurements for four non-consecutive weeks between March 24 and April 14 (Table 1). The groups

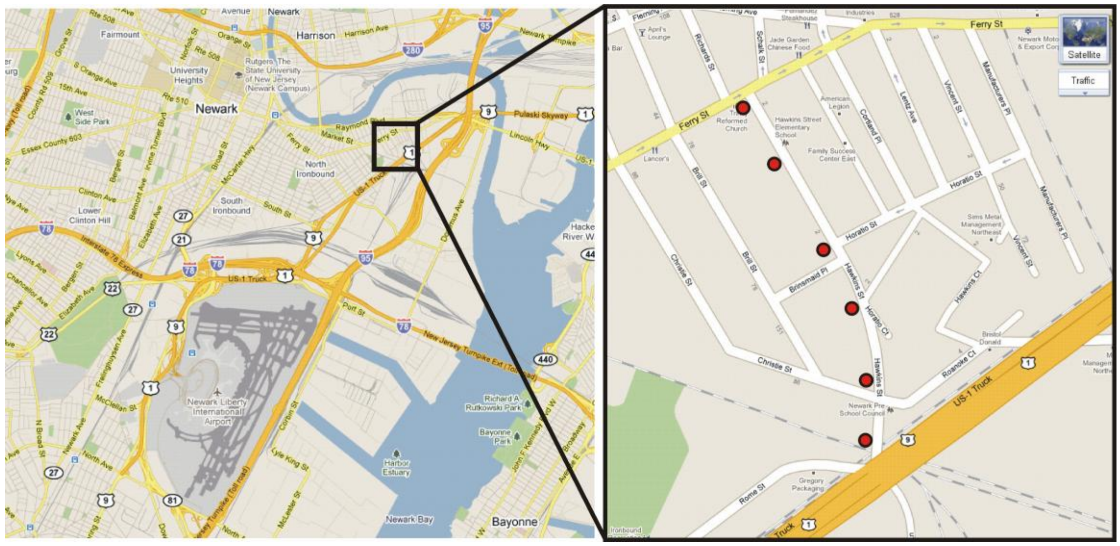

Figure 2. Traffic exhaust particulates were monitored at six sites along Hawkins Street in the Ironbound neighborhood of Newark, NJ. This location was selected to measure the exposure of children attending Hawkins Street Elementary School, which is adjacent to Ferry St. and within 600 meters of US Truck Route 1.

Table 1. Weather conditions of sampling days.

Date	Location	Time	Temperature	Humidity	Wind (mph)
24 March 2011	Newark	14:00-16:00	45 ^{o}F	61 %	13-14 NW
7 April 2011	Newark	14:00-16:00	50 ^{o}F	73 %	0-5 SE
14 April 2011	Newark	14:00-16:00	70 ^{o}F	54 %	5-13 NW
21 April 2011	Madison	13:00-14:00	54 ^{o}F	50 %	15 N
21 April 2011	Newark	14:00-16:00	58-60 ^{o}F	37 %	18-23 NW
21 April 2011	Madison	16:00-17:00	58 ^{o}F	50 %	20 NW

walked along Hawkins Street in the Ironbound section of Newark, stopping for approximately five to ten minutes at each of six predetermined sites (see Figure 2) along the way to record air pollutant levels. Sites 1 and 6 experienced the most traffic; thus, additional data was collected at these sites. Two of the researchers were responsible for collecting air samples with the monitors, another researcher kept the time, tallied car counts, and recorded the times when trucks and buses passed, and the fourth member accompanied each group as a supervisor. The supervisor was present for all of the weekly measurements and ensured procedural accuracy and consistency throughout the trials.

Measurements of atmospheric composition were obtained using three monitors, which record particulate counts in real time. The TSI Dust Track 2 measured $PM_{2.5}$, the TSI Model AE51 measured black carbon, and the TSI Condensation Particle Counter Model 3007 measured ultrafine particulates (TSI.com). The TSI Model AE51 detects and quantifies aerosol black carbon by Aethalometry. The device measures the attenuation of a light beam transmitted through aerosol particles that are collected from the atmosphere through a filter. The TSI Dust Track 2 measured $PM_{2.5}$ by using continuous real-time, single-channel, 90 degrees light-scattering laser photometer that determine the mass concentration of aerosols and size fraction. The TSI Condensation Particle Counter Model 3007 measures ultrafine particles by drawing an aerosol sample continuously through a heated saturator. Because the ultrafine particles are too small to effectively refract light on their own, the TSI Condensation Particle Counter must also vaporize alcohol with the air sample, which then condenses upon the particles, making them large enough that the laser can process the particle counts.

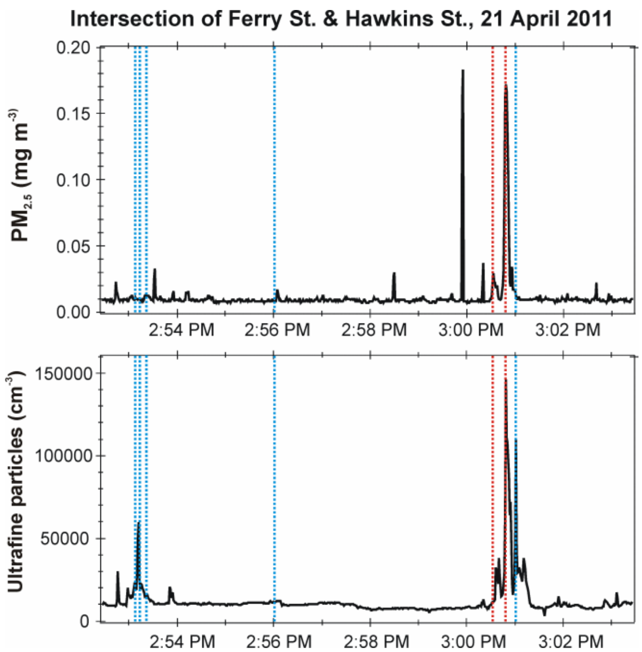

Figure 3. $PM_{2.5}$ (black line, top panel) and ultrafine particulates (black line, bottom panel) measured at the intersection of Ferry St. and Hawkins St. Blue and red ticks denote times when diesel trucks and city buses, respectively, passed by the sampling site.

All monitors were set to take samples at 1 second intervals, and were simultaneously calibrated to make the sampling times for each machine congruent. Recording began at approximately 2:00PM until approximately 4:00PM for all of the sampling days. The ultrafine particulate monitor was carried by hand, while black carbon and the $PM_{2.5}$ monitors were placed in a backpack. The air sampling tubes attached to each machine were put outside the side of the backpack that faced the street to ensure similar collection conditions, and the person wearing the backpack made sure that the hand-held machine was steady while recording.

III. Results.

Figure 3 shows a typical set of data for $PM_{2.5}$ (top panel, black line) and ultrafine particulates (bottom panel, black line) measured over a ten minute interval at the intersection of Ferry Street and Hawkins Street in Newark, NJ. This specific data was recorded on April 21, 2011 from 2:53 PM to 3:03 PM. The times when diesel trucks and city buses passed the sampling site are indicated by blue and red ticks, respectively. Spikes in Black Carbon, $PM_{2.5}$ and ultrafine particulates are generally correlated with diesel vehicle traffic (shown in Figure 3); however the intensity of emissions varied greatly for individual vehicles. For instance, around 2:54 PM, three trucks passing the monitoring site correlated with a small $PM_{2.5}$ signal but a more significant UFP accumulation immediately following the second truck. The most significant spike in particulates measured during this time period correlated with two city buses. It should be noted that this site is near a bus stop, and both buses stopped briefly to drop-off passengers. A correlation between particulates and diesel vehicles was not always observed likely because vehicles with newer technology are less likely to emit high levels of particulates (e.g., truck at 2:56 PM). Furthermore, a significant spike near 3:00 PM was not associated with any diesel vehicles on Ferry or Hawkins Street. This $PM_{2.5}$ signal showed no UFP increase suggesting it was associated with a more distant source which was transported by prevailing winds.

A comparison of particulates in the Ironbound was made with data from Madison, NJ, a suburban town located approximately 20 miles west of Newark, on April 21, 2011. Samples of this data are shown in Figure 4, and average values of $PM_{2.5}$ and UFP are reported in Table 2. Madison, NJ data was collected before and after the Ironbound data to ensure that results were not impacted by temporal fluctuations of regional particulate levels. The $PM_{2.5}$ data is relatively consistent with the ultrafine particulate matter data for each of the sites. For the most part, whenever there is a significant spike in the ultrafine dataset, there is often a corresponding spike in the $PM_{2.5}$ dataset; however there is some variation. The Ironbound region of Newark shows comparatively higher emissions rates of $PM_{2.5}$, UFP, and BC compared to the emissions for Madison. Generally, the Black Carbon levels showed no real trend. However at 3:00 pm in Newark when a bus stopped to pick up passengers there was a large spike in the Black Carbon data, indicating a significant increase in Black Carbon levels. The average $PM_{2.5}$ in Newark, NJ (10.0 μg m^{-3}) was 40% higher than the average in Madison, NJ (7.0μg m^{-3}). Approximately half of this increase was associated with a higher $PM_{2.5}$ baseline, while the remaining difference was correlated with "spikes" associated with local traffic emissions. The average UFP levels for Ironbound were more than double the levels measured in Madison, NJ. This difference is opposite the trend of car counts,

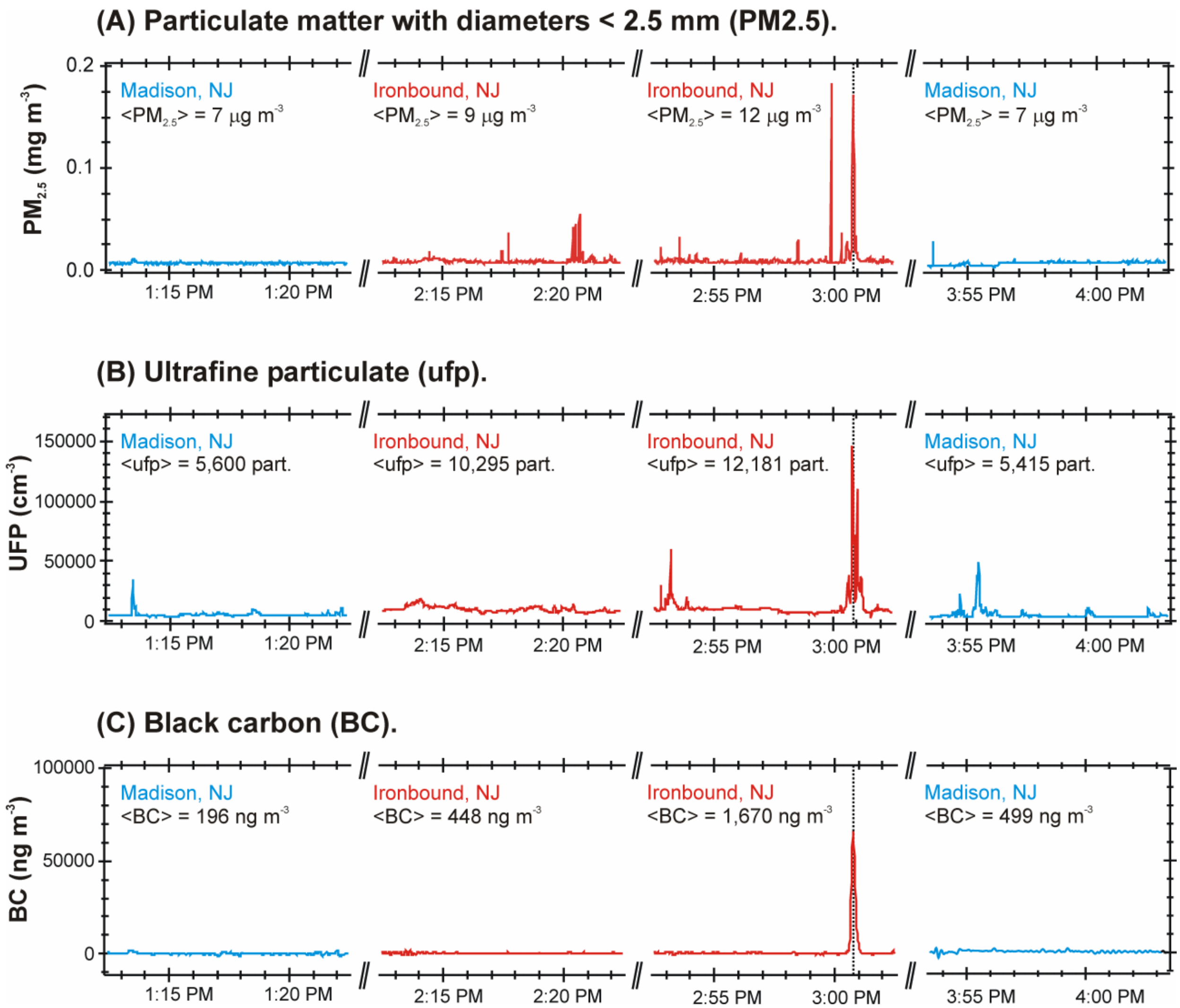

Figure 4. $PM_{2.5}$ (panel A), ultrafine particulates (panel B), and black carbon (panel C) measured in Madison, NJ (blue) before and after measurements in the Ironbound (red). Averages for each 10 minute period included in Table 2. Average Ironbound $PM_{2.5}$ was 40% higher than in Madison, while the average UFP in Ironbound was 100% higher than Madison (i.e., twice as high).

Table 2. Average particulate for 10 minute averages on April 21, 2011.

Location	Time	$PM_{2.5}$	UFP	BC	Cars	Trucks
Madison, Rt. 124	13:12	6.9	5,600	196	175	2
Ironbound, 1&9 Underpass	14:14	9.4	10,295	448	37	5
Ironbound, Ferry & Hawkins	14:52	11.5	12,181	1,670	119	8
Madison, Rt. 124	15:52	7.0	5,415	499	168	3

indicating automobile emission do not result in significant $PM_{2.5}$ or UFP levels. The difference in diesel traffic intensity, however, could account for this difference in emissions. The combined data confirms that the average emissions concentrations were much higher in the Ironbound compared to the area of Madison where diesel vehicles and general traffic intensity are relatively lower.

IV. Policy discussion.

Newark, like many other port cities in America, has a serious air pollution problem that is caused by numerous mobile pollutant sources. Throughout the study, the large number of diesel trucks travelling to and from the Port of Newark contributed to the elevated air pollution levels in the area. While many different options to reduce air pollution levels have been considered, some policy options would be more effective than others in the Ironbound.

One option is to reroute the diesel trucks away from residential areas, as seen in San Diego, California (Karner et al., 2004). While this policy might be effective in reducing air pollution in specific locations for the short run, it also has the potential to increase regional pollution levels because trucks would have to take less direct routes. More problematic for the Ironbound neighborhood is the overlap of residential and industrial sites making alternative truck routes that completely avoid residential areas nearly impossible.

The most effective option to reduce air pollution from diesel vehicles is to upgrade the pollution control technology of diesel vehicles. The effects of this have been seen the Ports of Los Angeles and Long Beach Clean Trucks Program. The Ports of Los Angeles and Long Beach established grants to partially fund the replacement of outdated technology in the diesel trucks ("Ports", 2008). As of January 2010 the Clean Trucks Program has reduced pollution from port trucks by 80% ("Ports", 2008). For qualifying trucks, the owner of the truck received up to $50,000 in state funds to upgrade their system to cleaner technology. However, truck drivers only qualify for receiving these state funds if they already paid a substantial amount of the upgrade prior to qualification.

Due to the effectiveness of the Clean Trucks Program in Los Angeles and Long Beach, it would be ideal to implement a similar program in the Ironbound. However, there are the problems of whether or not this would be feasible for Newark and how long it would take to be implemented on a large enough scale for there to be results. There would be many challenges facing this program in Newark, the main one being the cost of the upgrade to the truckers. Most of Newark's truck drivers are independent contractors without the necessary funds to pay for their part of the upgrade even with financial assistance from a grant. Despite this obstacle, the Toxic Chemical research group believes this policy should be pursued as a long term option. We believe this technology upgrade is an integral part of a multi-tiered solution, and that although this may take time it will eventually be very effective. The long term plan should be a policy implemented to provide financial assistance to truck drivers who want to upgrade the technology of their vehicles. After being qualified for an upgrade by the state, independent contractors will only have to cover 25% of the cost. This will give them an incentive to upgrade their system so they have a better functioning and more efficient engine. Additionally, Truck Stop Electrification, which allows drivers to heat or cool their trucks without running their engines, can be integrated into the vehicle's system. This would make no-idling policies more feasible for the drivers ("Diesel", 2005). Finally, truck drivers must be educated about the harm that the diesel exhaust is causing for Ironbound residents. Although this change will require a large amount of funding from both the State and the truck drivers, the end result will be a beneficial investment towards a healthier environment.

Drew University's student researchers believe the best short term solution to quickly reduce pollution levels in the Ironbound is to upgrade the city's buses to newer technology. Unlike the Clean Trucks Program, this would be completely funded by the city of Newark and the State of New Jersey. For that reason, there is the potential for the buses to be upgraded rather quickly. As seen in Figure 3 and Figure 4, the most significant spike in the Newark dataset for all three pollutants occurred at 3:00 pm when a bus stopped by site 1 to pick up passengers. This demonstrates the significant impact that city buses have on air pollution levels. One way to address this issue is to convert bus engines that currently run on diesel to engines that run on natural gas. Another possibility is to install diesel particulate matter filters along with ultra-low sulfur diesel can reduce emissions by 60 to 90 percent ("Diesel", 2005). It is much easier for city buses rather than private contractors, to begin this change because the city has the necessary funding to begin this movement, even if only a fraction of the buses are upgraded each year.

V. Conclusion

This study has found that diesel-fueled buses and trucks have a significant negative impact on air quality in the Ironbound. Diesel-fueled buses and trucks were found to emit high levels of ultrafine particulates, black carbon, and $PM_{2.5}$. The high traffic density in the city and the amount of trucks traveling through has resulted in unhealthy living conditions for Newark residents and especially susceptible populations such as children. The Newark air quality data was also compared to air quality data collected in Madison, New Jersey. It was found that Newark had significantly higher levels of particulates, and thus inferior air quality. Drew University's Toxic Chemicals research students recommend that the city of Newark retrofit public transit buses with greener technology in order to immediately begin lessening the particulates emitted into the air.

VI. References.

Brook, Robert D.; Franklin, Barry; Cascio, Wayne; Hong, Yuling; Howard, George; Lipsett, Michael; Luepker, Russell; Mittleman, Murray; Samet, Jonathan; Smith, Sidney C. Jr.; Tager, Ira. et al. "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* 109. (2004): 2655-71.

"CNG Vehicles." *CNG Now*. American Gas Association, n.d. Web. 28 Apr 2011. <http://www.cngnow.com/EN-US/Vehicles/HeavyDuty/Pages/default.aspx>.

Currie, Janet; Matthew Neidell; Johannes F. Schmieder. "Air pollution and infant health: Lessons from New Jersey." *Journal of Health Economics* 28.3 (2009): 688-703.

"Diesel Emissions Mitigation Opportunities." *West Coast Collaborative*. June 2005. Web. 16 Apr 2011. <http://www.westcoastcollaborative.org/files/outreach/Diesel%20Emission%20Mitigation.pdf>.

Goldsmith, Amy; Gaddy, Deborah K.. "Diesel Hot Spots: A Snapshot of Newark, New Jersey". New Jersey Environmental Federation and Clean Water Fund. June 2006. Article.

Highwood, Eleanor J., and Robert P. Kinnersley. "When smoke gets in our eyes: The multiple impacts of atmospheric black carbon on climate, air quality, and health." *Environmental International* 32. (2006): 560-566.

Karner, Alex; Eisinger, Douglas; Bai, Song; Niemeier, Deb. 2004. "Mitigating Diesel Truck Impacts in Environmental Justice Communities: Transportation Planning and Air Quality in Barrio Logan, San Diego, California. 1-8.

"Kids Help Monitor Newark's Dirty Diesel Near Their School." *Clean Water Action*. December 30, 2008. Web. 7 June 2011. <http://www.cleanwateraction.org/njef/sustainer/2009/01/kids-help-monitor-newarks-dirty-diesel-near-their-school>.

Matson, Uve. 2004. "Indoor and outdoor concentrations of ultrafine particles in some Scandinavian rural and urban areas." *Science of the Total Environment* 343, 169-176.

McCreanor, J.; Cullinan P.; Nieuwenhuijsen, M.J.; Stewart-Evans, J.; Malliarou, E.; Jarup, L.; Harrington, R.; Svartengren, M.; Han, I.K.; Ohman-Strickland, P.; Chung K.F.; Zhang, J. "Respiratory Effects of Exposure to Diesel Traffic in Persons with Asthma." *New England Journal of Medicine* 357.23 (2007): 2348-58.

Morello-Frosch, Rachel; Jesdale, Bill M.; Sadd, James L.; Pastor, Manuel. "Ambient air pollution exposure and full-term birth weight in California." *Environmental Health* 9.44 (2010): 1-13.

"Particulate Matter | Air & Radiation | US EPA." *US Environmental Protection Agency*. 2005. Web. 24 Mar. 2011. <http://www.epa.gov/pm/>.

Patel, Molini M.; Hoepner, L.; Garfinkel, R.; Chillrud, S.; Reyes, A.; Quinn, J.W.; Perera, F.; Miller, R.L. "Ambient Metals, Elemental Carbon, and Wheeze and Cough in New York City Children through 24 Months of Age." *American Journal of Respiratory and Critical Care Medicine* 180. (2009): 1107-13.

Patel, Sejal. "From Clean to Clunker: The Economics of Emission Control." *Clean and Safe Ports*. Sierra Club, 15/04/2010. Web. 28 Apr 2011. <http://www.cleanandsafeports.org/fileadmin/files_editor/FromCleantoClunker.pdf>.

Polidori, A.; Kown, J.; Turpin, B.J.; Weisel, C. "Source Proximity and Residential Outdoor Concentrations of PM2.5, OC, EC, and PAHs." *Journal of Exposure Science & Environmental Epidemiology* 20.5 (2010): 457.

Pope III, C. Arden, Majid Ezzati, and Douglas W. Dockery. "Fine-Particulate Air Pollution and Life Expectancy in the United States." *New England Journal of Medicine* 360.4 (2009): 376-86.

Ryan, Patrick H.; LeMasters, Grace; Biagini, Jocelyn; Bernstein, David; Grinshpun, Sergey A.; Shukla, Rakesh; Wilson, Kimberly; Villareal, Manuel; Burkle, Jeff; Lockey, James. "Is it traffic type, volume or distance? Wheezing in infants living near truck and bus traffic." *Journal of Allergy and Clinical Immunology* 116.2 (2005): 279-84.

"The Ports of Los Angeles and Long Beach Clean Trucks Program." 20 Oct. 2008: 1-10.

Wallace, Lance A., Edo D. Pellizzari, Ty D. Hartwell, Charles M. Sparacino, Linda S. Sheldon, and Harvey Zelon. "Personal Exposures, Indoor-outdoor Relationships, and Breath Levels of Toxic Air Pollutants Measured for 355 Persons in New Jersey." *Atmospheric Environment (1967)* 19.10 (1985): 1651-661.

Wang, T.; Xie, S. "Assessment of traffic-related air pollution in the urban streets before and during the 2008 Beijing Olympic Games traffic control period." *Elsevier*. 43.35 (2009): 5682-5690.