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Assessment of Ambient Exposures Firefighters Encounter while at the Fire Station: An Exploratory Study

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Abstract

Objective—Firefighters are at increased risk for many types of cancer. While most studies on this topic focus on exposures encountered while fighting fires, exposures at the fire station are also cause for concern. This pilot study aimed to describe air quality within a few fire stations in and around Boston, Massachusetts, and to investigate physical and organizational factors that may influence levels of contaminants in stations.

Methods—Air sampling of particulate matter less than 2.5μm in diameter ($PM_{2.5}$) and particle-bound polycyclic aromatic hydrocarbons (PAHs) was completed at four fire stations in Spring, 2016. Sampling occurred in the kitchen, truck bay, and just outside the station. Data were analyzed to assess differences between and within stations. Interviews (n=7) were conducted with officers at each station to explore health and safety-related organizational policies and practices. Interviews were transcribed and analyzed for thematic content.

Results—At each station, levels of contaminants were higher in the truck bays than either the outdoors or kitchen, and varied the most throughout the day. The station with the highest exposures in the truck bay had the lowest levels in the kitchen, which was possibly explained by new building materials and effective separation between building zones. The age and layout of the

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stations appeared to determine the extent to which policies favoring exhaust capture were implemented.

Conclusion—Levels of $PM_{2.5}$ and PAH inside fire stations may contribute to firefighter cancer risk. Through understanding contaminant variability, we can begin to design and test interventions that improve cancer prevention.

Introduction

Firefighters are frequently exposed to a wide range of dangerous situations, ranging from car accidents to house and industrial fires. Their occupation puts them at risk of increased injury [1, 2] and illness.[3-6] Cancer, in particular, is one area in which firefighters experience higher risk than the general public, as well as other occupational groups.[4, 5, 7-9] Several large studies in the United States and Scandinavia have found firefighters to be at elevated risk for a range of cancers, including the following: lung cancer, mesothelioma, melanoma, esophageal, brain, and kidney cancers;[7, 10] prostate and skin cancer in younger firefighters, [9] as well as multiple myeloma, adenocarcinoma of the lung, and mesothelioma in older ages. [9]

Most previous research on firefighter cancer risk has focused on exposures encountered while fighting fires and does not account for potential additional carcinogens they may be exposed to at the fire station. [11, 12] Firefighters spend large portions of their shift waiting for calls in a station, [13] during which they can be exposed to diesel exhaust from idling trucks (which is a known carcinogen) [14-16] and off-gassing from contaminated post-fire gear (which may be contaminated with a variety of known and/or possible carcinogens). [17] Few studies have examined the effect of station-level exposures on firefighter health, and those that did are several decades old, [16] assessed exposures using only qualitative methods, [18, 19], dust samples [20] or used only fire-truck run data and building design characteristics to assess exposure.[21] Several recent studies examined levels of polycyclic aromatic hydrocarbons [22-24], however, the sampling periods in these studies were either 4 or 8 hours. This is much less time that the 24-hour shifts of Massachusetts firefighters and therefore may not accurately represent their exposures.

The limitations of these previously completed studies and potential exposure misclassification may underestimate firefighters' true risk of cancer. Exposure misclassification may also explain some of the inconsistencies seen in the epidemiologic literature, such as why certain cancers are at elevated risk in some studies but not in others. Furthermore, compared with some exposures encountered during firefighting, exposures at the fire station may be more easily modified through changes in systems and protocols, thus potentially representing useful intervention targets.

This pilot study had two primary goals: 1) to provide preliminary data on the air quality within a few fire stations in and around Boston, Massachusetts; and, 2) to investigate some of the environmental and organizational factors that may influence the levels of contaminants in the air at the fire stations. This pilot represents the first step in investigating the contribution of exposures at the fire station to overall firefighter cancer risk. The central hypothesis of the study is that ventilation practices and off-gassing from post-fire equipment within the fire station are associated with high levels of air contaminants. We tested this hypothesis by comparing the levels of certain contaminants associated with diesel exhaust (an *a priori* indoor source of a factor potentially influencing levels of contaminants in the air) between the truck bay and outside. We also compared levels of contaminants in the kitchens of older buildings to that of a newer structure, to assess the impact of new building materials on exposure levels. Finally, we compared organizational policies and practices among fire stations and assessed how these policies and practices might impact the levels of contaminants in the air.

Methods

Sampling Locations

Through a collaboration with the Boston Fire Department (BFD) we collected data from four fire stations: Stations #1, #2, and #3 (each containing one ladder and one engine company) were located in Boston, Massachusetts, and Station #4 (containing one engine company) was located in Arlington, just outside of Boston (Table 1). Representatives from the BFD selected the fire stations included in this pilot study because they varied by layout and had different frequencies of fire truck runs. Data collection methods used in this study were reviewed and approved by the Harvard T.H. Chan School of Public Health's Human Subjects Committee, Office of Regulatory Affairs and Research Compliance. The data collection methods in this study were determined by the Committee to not be Human Subjects research, as no identifying information was collected at any point in the study.

Air sampling methods

Air sampling was conducted at all four fire stations in the spring of 2016. Sampling included integrated and continuous measurements of particulate matter ($PM_{2.5}$) and continuous measurements of particle-bound polycyclic hydrocarbons (PAHs) in three primary areas in and around the fire station: the truck bay, the kitchen, and outside. $PM_{2.5}$ and PAHs were selected as exposures of interest as they represented good proxies for diesel exhaust and other potential exposures from station-related activities (e.g. off-gassing from bunker gear, cooking). Diesel exhaust has been recognized as being *probably carcinogenic to humans (Group 2A)* by the International Agency for Research on Cancer (IARC). [15] Additionally, IARC has reviewed the literature on numerous PAHs and has classified many of these chemicals into various categories.[25] For example, benzo[*a*]pyrene has been recognized as *carcinogenic to humans (Group 1)*, whereas other as other PAHs such as dibenzo[*a,l*]pyrene and dibenz[*a,h*]anthracene have been recognized as *probably carcinogenic to humans (Group 2A)*. PAHs such as chrysene and naphthalene have been designated as *possibly carcinogenic to humans (Group 2B)*. Furthermore, particulate matter from outdoor air pollution (and $PM_{2.5}$ in particular) has been determine to be *carcinogenic to humans (Group 1)* by IARC. [26]

$PM_{2.5}$ was measured two ways. Gravimetric $PM_{2.5}$ samples were collected using Teflon filters (47mm, Pall Life Sciences, Port Washington, NY, USA) used with an impactor cassette to measure $PM_{2.5}$. The cassette was connected to a pump operated at 30 lpm and samples were collected for 2-5 hours. Flow rates were checked at the beginning and end of sample collection. Before and after use, the filters were equilibrated with an atmosphere maintained at 72-74 °F and 39-41% relative humidity and weighed using a Mettler Micro-Gravimetric No. M5 electronic microbalance (Mettler Instruments Corporation, Hightstown, NJ). The difference (net μg) between the pre- and post-weights was calculated to determine the amount of $PM_{2.5}$ collected.

Continuous-readings of $PM_{2.5}$ were measured with a SidePak Aerosol Monitor AM510 (TSI, Minneapolis, MN). The device uses a laser photometer based on light scattering technology, fitted with an impactor to estimate mass concentrations with an aerodynamic diameter of less than 2.5 μm. For all continuous measurements, gaps in the data (due to power failures or changes in deployment protocol) were not used in the final averaging and analysis. Data were collected continuously for approximately 5 days in the truck bay and outside in one-minute intervals for analysis. These data were used to examine changes in $PM_{2.5}$ levels throughout each day of sampling and were standardized using temporally and location matched gravimetric $PM_{2.5}$ samples. These corrections were necessary due to variability in particle composition and ambient conditions (e.g., temperature and relative humidity) that may influence the accuracy of laser photometry.[27-28] Specifically, the ratios of gravimetric $PM_{2.5}$ to matched time-averaged continuous readings from the SidePak were calculated for every sampling session. All continuous data were multiplied by the appropriate ratio to give a continuous, gravimetric-corrected time series. The time series information was used to investigate relative differences between and within stations.

Particle surface bound PAHs were monitored using an Ecochem PAS 2000CE (EcoChem Analytics, League City, TX). The PAS is a photoelectric aerosol sensor that uses an irradiation wavelength specific to excitation of all PAHs, with a demonstrated linear response to surface-bound total PAH levels.[29] The charge of the photoionized particles is measured and reported as a mass concentration of total PAHs (1-4000 ng/m^3). Air was continuously sampled at 1 L/min, with readings recorded at one-minute intervals, each consisting of six 10-second averaged measurements. Before deployment, PAS units were co-located on site and simultaneously run for cross-calibration. These tests generated linear correction factors between units that were applied to raw data before analysis. In the event that the cross-calibration gave unfeasible correction values due to low signal, the results were discarded, and the cross-calibration was repeated on-site immediately after deployment. Data were collected continuously for approximately 5 days in the truck bay, kitchen, and outside.

Statistical analysis included descriptive statistics and regression analysis. Time-series plots were generated for all continuous instruments to visually explore exposure patterns. Descriptive statistics were calculated overall and by work location and station. Linear mixed models were used to determine differences daily mean average exposure to $PM_{2.5}$ and particle-bound PAH by location and site. All analyses were completed in SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) and were considered statistically significant at $P<0.05$.

Qualitative methods

To complement the air sampling, we also conducted interviews with officers at each of the four fire stations (two interviews each at Stations #1, 2, and 3; one interview at Station #4).

The purpose of the interviews was to understand the daily activities of firefighters, along with the policies and practices (both written and enacted) regarding engine idle-time, return and washing of contaminated clothing, and any other station-related health and safety activities. Each of the seven interviews lasted approximately 30 minutes and were completed with the lieutenant on duty within each company at the fire station during the first day of air sampling. Interviews were transcribed and analyzed for thematic content using Nvivo (QSR International [Americas] Inc., Burlington, MA, USA).

Results

Air sampling findings

At each of the four stations, we examined the variability of particle-bound PAH and $PM_{2.5}$ observed within a single location throughout the day. Figure 1 shows a plot of the exposure levels in Station #1 throughout a day of sampling (patterns were similar at the other stations and not shown here) (Figure 1). These figures show that levels of exposures vary from minute to minute within a station, which may be related to station activities (such as trucks idling and entering/leaving the station, or cooking activities). The graph of $PM_{2.5}$ demonstrated that levels outside also vary throughout the day, which could be related to changes in weather or local neighborhood activities (e.g. traffic patterns).

We also compared the levels of particle-bound PAHs and $PM_{2.5}$ between the truck bay and outside environments (Table 2). Mean and median daily levels of PAHs and $PM_{2.5}$ in the truck bay were higher than the outside measurements at each station and were similar across all stations. At stations #1 and #2, levels of PAHs in the kitchen were approximately double of what they were outside. The observed average levels of PAHs and $PM_{2.5}$ in Station #4's truck bay were much higher than any of the Boston stations (Figure 2) and had a much wider range of values.

We compared the levels of PAHs in the kitchen between Stations #1, 2, and 4 (the equipment failed at Station #3 rendering the data invalid). The kitchen of Station #4 (the newest station) had levels of PAHs that were approximately 20% of that found in the two older stations, despite having higher levels of PAHs measured in the truck bay. Visual observation of differences in building design revealed the pole holes in Stations #1 and 2 connected the living quarters to the truck bay, allowing air to move easily between areas within the station. Pole holes were not present in Station #4, as the living quarters and truck bay were located on the same level. Furthermore, the building was designed to have an effective separation between the truck bay and living quarters with doors remaining shut at all times.

The results of the PAH regression model (Table 3) indicated that average daily PAH levels in the truck bays were higher when compared to outside, adjusting for station differences, and this association was statistically significant (β=23.68ng/m^3; p-value <0.0001). In contrast, the average daily levels of PAHs in the kitchen were not statistically different than outside (β=0.7 ng/m^3; p-value = 0.89), when adjusting for station differences. The average daily $PM_{2.5}$ levels (using the gravimetric data) in the truck bay were also higher than outside, when adjusting for the other stations, and this association was statistically significant (β=10.74μg/m^3; p-value = 0.028).

Qualitative findings

The interviews helped us understand more about the daily activities of firefighters and to explore variability in organizational policies and practices among stations. Two primary themes surrounding practices that may influence air quality at the station emerged from the interviews: use of the systems designed to ventilate truck exhaust and the washing of bunker gear after a fire. Other topics related to firefighter health and organizational policies and practices such as scheduling, work breaks, nutrition, and physical activity were also discussed but are not included here, as there was little variability from station to station and these areas did not appear to influence air quality.

In all four stations, the ventilation system in place involved flexible ducts that attach directly to the truck in order to transmit the exhaust out of the truck bay. These systems require a firefighter to attach it as the truck backs into the fire station and is then automatically released as the truck pulls out of the fire station. In written policy, these exhaust systems are intended to be connected to the truck as the truck backed in; however, in practice, this happened more often at some stations than others. For example, at two of the stations (which were located in parts of the city with higher pedestrian and vehicle traffic) all members of the company were often required to be on the street in order to hold the public back and help the driver in. In those instances, the exhaust reduction system was attached to the truck only after the truck entered the station.

The interviews also indicated that practices surrounding washing of bunker gear varied from station to station. Off-gassing from equipment post-fire might be another source of indoor air contaminants. Differences in policies and practices surrounding gear washing may help explain some of variability observed in the quantitative data. Two of the four stations (Stations #1 & 3) had on-site commercial grade washing machines, and two did not. At the stations without commercial grade washers, gear was rarely washed – typically once per year, likely due to the fact that the gear has to be sent to headquarters, which can be a slow process. At two of the Boston stations in this study, commercial grade washers had been installed within the last year and appeared to have made a substantial difference in the reported frequency of washing the gear. In these stations, firefighters reported that the washers are frequently used, generally after every fire, to clean bunker gear. Firefighters at these stations also reported changes in the practices of washing of other pieces of equipment not directly cleaned in the washing machines (e.g. boots, face pieces, truck seats). The installation of the washing machines appeared to not only impact cleaning of bunker gear in the machines, but also improved awareness and practices related to cleaning of all equipment.

Discussion

The goal of this study was to provide preliminary data on the air quality within a few fire stations in and around Boston, and to investigate some of the factors, both environmental and organizational, that may influence the levels of contaminants in the air. The results demonstrate variability between stations as well as within each station throughout the day. This variability could be attributed to an indoor air source that changes throughout the day (such as diesel exhaust when the trucks enter/exit the station). The results also indicated that building design and layout can help prevent contaminated air from the truck bay from entering the kitchen. Additionally, the results indicated that organizational practices for ventilation and equipment washing do vary, but that the variability is likely connected to the physical environment. For example, it was observed that in parts of Boston where traffic flow is heavier, firefighters may be more likely to stay on the street as the fire truck backs into the bay in order to hold pedestrians and cars back. This means that the flexible duct ventilation system was not attached to the truck until after it enters the station, as opposed to during the reversing into the station (where the exhaust would be captured sooner). A second example relates to the availability of commercial grade washing machines in the station. The presence or absence of these machines in the station appeared to impact frequency of washing of bunker gear as well as other equipment.

The elevated levels of PAH and $PM_{2.5}$ observed in the truck bay of Station #4 may have been the result of firefighters smoking cigars in the truck bay once a week. The tobacco policy in place at Station #4 allowed for some firefighters to smoke while at work. These firefighters had entered the department prior to 1988 and therefore were grandfathered in to the older department tobacco policy. These firefighters planned their shifts together and, while at work, smoked cigars inside the truck bay.

Although the truck bay in Station #4 had the highest exposure levels, it had the lowest concentrations in the kitchen, when compared to the Boston stations. This may be attributed to the building layout, as Station #4 was built within the last ten years and was designed to have a separation between kitchen and the truck bay. The door to the truck bay was observed to be closed at all times, and there was little movement of air in between the truck bay and rest of the station, due to thick walls and no pole holes. Pole holes and open doors between the kitchen and truck bay were observed at the two Boston stations with PAH data in the kitchen, Station #1 and #2, which appeared to provide an opportunity for air to move easily between the kitchens and the truck bay.

There are many studies in the scientific literature that involve an assessment of the adverse exposures firefighters encounter; however, most of the studies focus on exposures experienced while in the field, [11] or at large, one-time events, such as the 9/11 World Trade Center response, [30] or rely on retrospective administrative data to assess risk. [4, 31]

With the exception of Station #4, the average levels of $PM_{2.5}$ in the truck bay were lower than average daily $PM_{2.5}$ levels in other occupational settings, including trucking terminal docks [32] and a shipping container port. [33] However, the layout of these workplaces, the characteristics of the exposures, and the demands of the job vary considerably from those of firefighters. For example, firefighters in Massachusetts work in 24-hour shifts, compared to many people in the occupations included the studies above who work in 8- or 10-hour shifts.

Few studies have measured air quality inside the fire station. One, by Baxter et al (2014), measured $PM_{2.5}$ in fire stations in Cincinnati, Ohio over an 8-hour period on a single day and found values higher than what was observed in this study (average $PM_{2.5}$ in truck bay was $55\mu g/m^3$ compared to our values of $14\text{-}42\mu g/m^3$). [22] Two other recent studies by Oliveira et al [23, 24] examined levels of particle-bound PAHs in breathing zones in firefighters at fire stations in Portugal. They indicated that the likely source of PAHs was the vehicular emissions in the fire stations, although they noted observed levels of PAHs fell below many relevant occupational exposure limits. However, it is possible that the day to day activities of firefighters in Portuguese stations differ from those in the United States in terms of health and safety.

Other reasons for the discrepancy between our work and the aforementioned studies could relate to differences in sampling procedures or the fact that samples were collected from fire stations that likely had different ventilation infrastructure. Furthermore, these recent studies collected data from sampling periods of either 4 or 8 hours, much less than the 24-hour shifts experienced by Massachusetts firefighters, which limits the generalizability of these previous studies to our study population. In addition, neither Baxter et al [22], nor the two studies by Oliveria et al [23, 24] include data on contaminant levels outside, which can serve as an important comparison to understand general background levels. There is a lack of information in the scientific literature and limited information available on firefighter exposure to $PM_{2.5}$ and PAHs in the fire station, which highlights the need for further research on this topic.

Limitations and Strengths

While this study provided important insights regarding firefighter health and safety, it was only the first step in a larger research effort to prevent cancer among firefighters. It focused on a small number of stations and contaminants, under a narrow range of weather conditions. A larger study with more sites, greater variability of conditions, and longer time periods of observation would be of value to understand the full range of fire station pollution exposures and the opportunities for mitigation.

Our methods for collecting particle-bound PAHs were consistent across locations and thus valid for making comparisons within our study sample. Although the data has not been standardized to an external gold standard, we did ensure validity of our methods through cross-calibration of the instruments during data collection. Differences in the composition of PAHs across stations could not be detected with this instrument, as the photoelectric excitation wavelength causes all PAH compounds to respond. Therefore, data can only be used for comparing PAH levels among fire stations and between sampling periods with the assumption that the PAH mixture profiles are similar across stations. We also were not able to evaluate PAHs specific to each work location, or to evaluate different mixtures of PAHs that may have been present in each of the areas of each of the stations. While this limitation impacts our ability to compare the data to studies in other populations with measurements of specific PAHs, we can still learn a lot about the patterns of exposure between and within fire stations.

Pilot studies like this one are helpful in that they can help test the feasibility of an approach, collect preliminary data to be used in future work, and identify potential modifications to the research approach for the future work. A larger study could assess the indoor air quality under different weather conditions for a longer period of time and possibly even make a connection with health outcome and/or risk factors for health outcomes. This in turn could help inform a study that evaluates the effect of an intervention in improving the indoor air quality.

Despite the limitations of this pilot study, there were also many important elements of the study that add to its strength. We collected real-time data, allowing us to examine differences in exposures across a work week across different locations. By using a mixed methods approach to data analysis, we were able to further investigate some of the possible reasons behind the patterns observed quantitatively, and expand the scope of this analysis to include some organizational station-related factors. Additionally, by including four sites with different layouts, building age, and run volume, and by sampling over the course of multiple days we were able to capture a range of exposures and show the variability that exists in this work environment. Finally, one of the most important strengths of this study was the partnership between the BFD and the research team. The BFD provided invaluable guidance and access to the fire stations which enabled the success of the pilot, and will set the stage for future work on firefighter cancer prevention.

Conclusions

This pilot study had several important findings. $PM_{2.5}$ and PAH concentrations were higher in the truck bay than outside, suggesting that the fire trucks may be important sources of indoor air contaminants. Levels of contaminants were much lower in the kitchens in Station #4 when compared to the Boston stations, despite the higher levels observed in the truck bay, demonstrating the utility of good separation between quarters through layout and design. The two stations with commercial grade washing machines had remarkably different practices in the washing of bunker gear when compared to those without commercial grade washing machines. By report, the addition of the machines enabled firefighters to wash their gear regularly, demonstrating the potential change that can result from small infrastructure changes. This pilot study represents the first step to understanding exposures firefighters encounter at the fire station and the potential adverse effect these exposures can have on their health. Chronic exposure to the low levels of $PM_{2.5}$ and PAH observed at these fire stations may contribute to firefighter cancer risk. With further understanding of the variability and range of values found, we can begin to inform interventions that aim to improve firefighter cancer prevention efforts.

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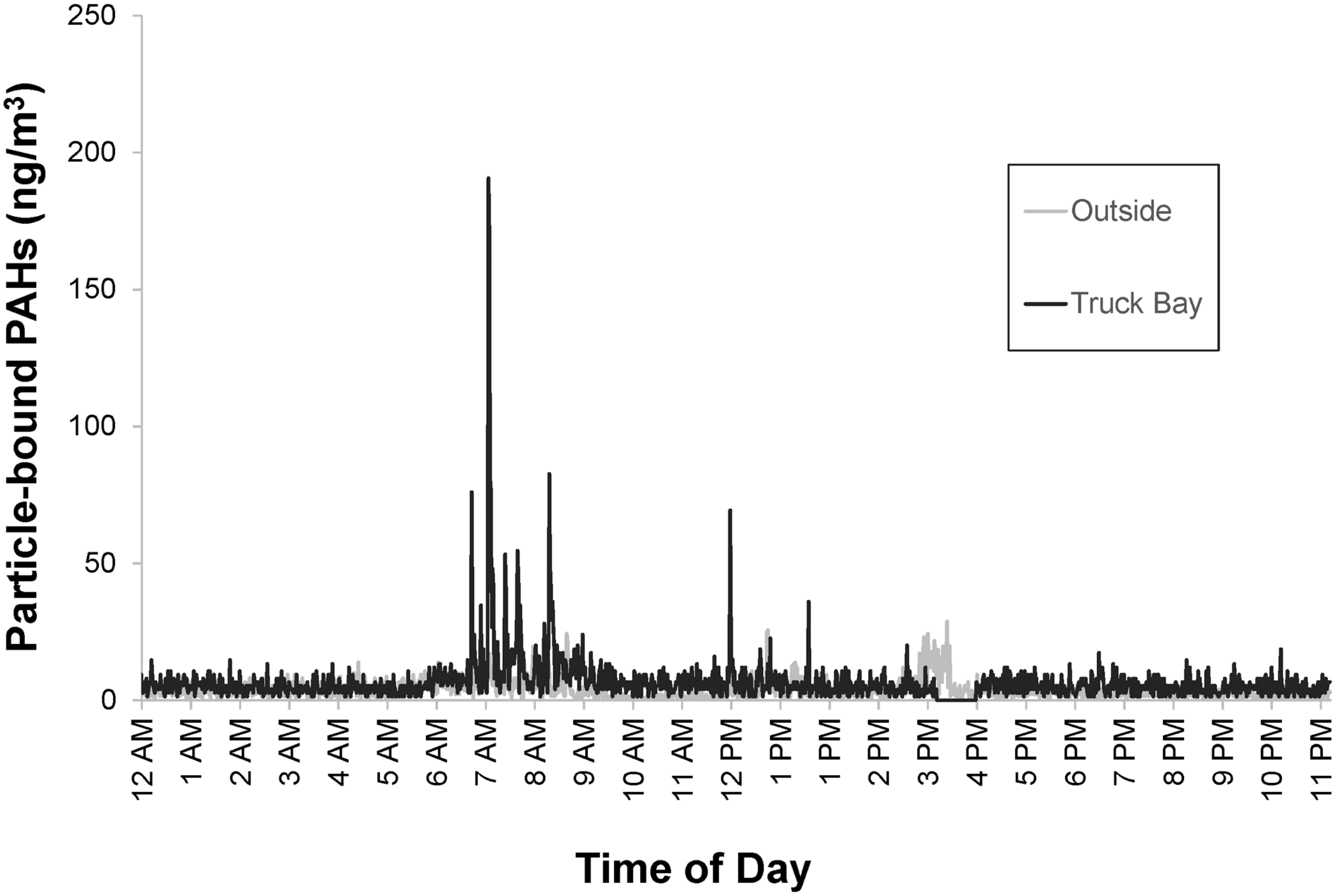
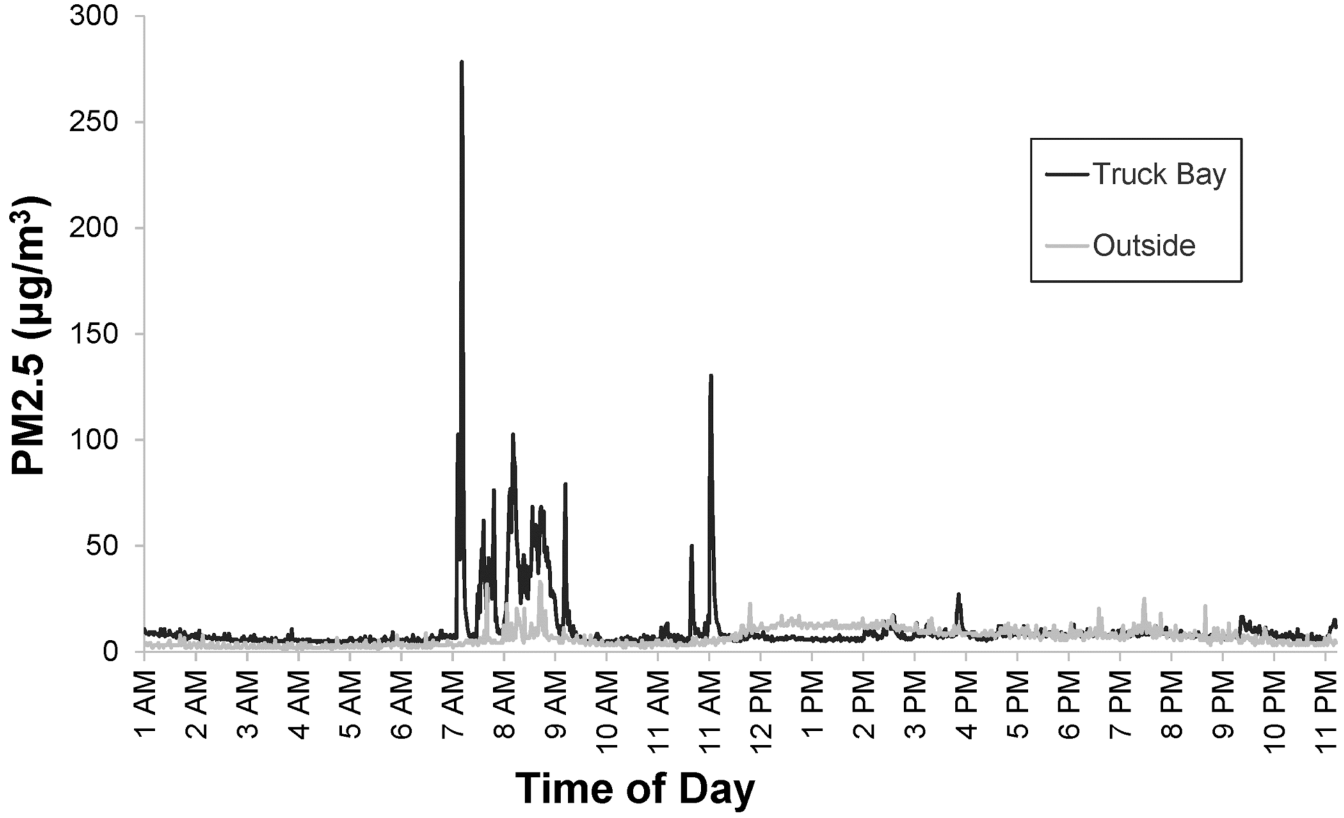
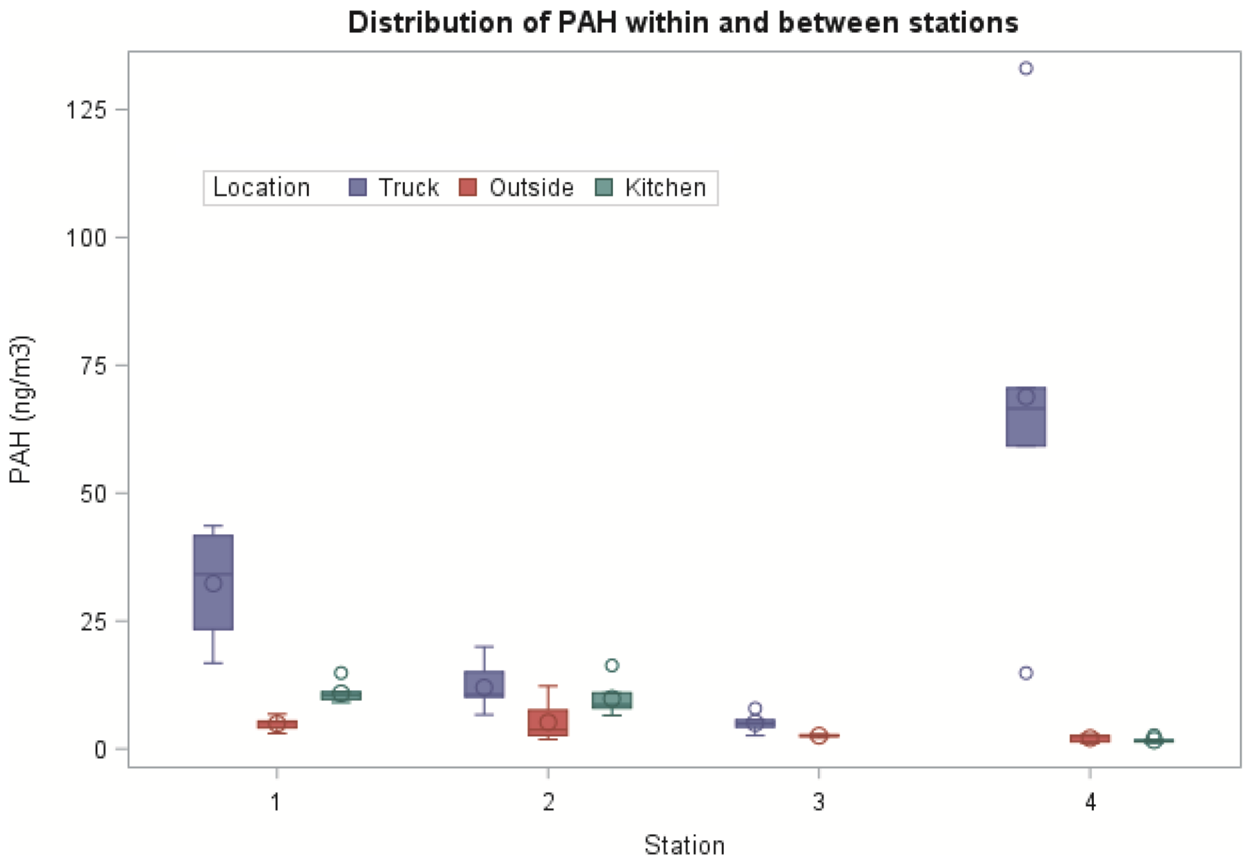
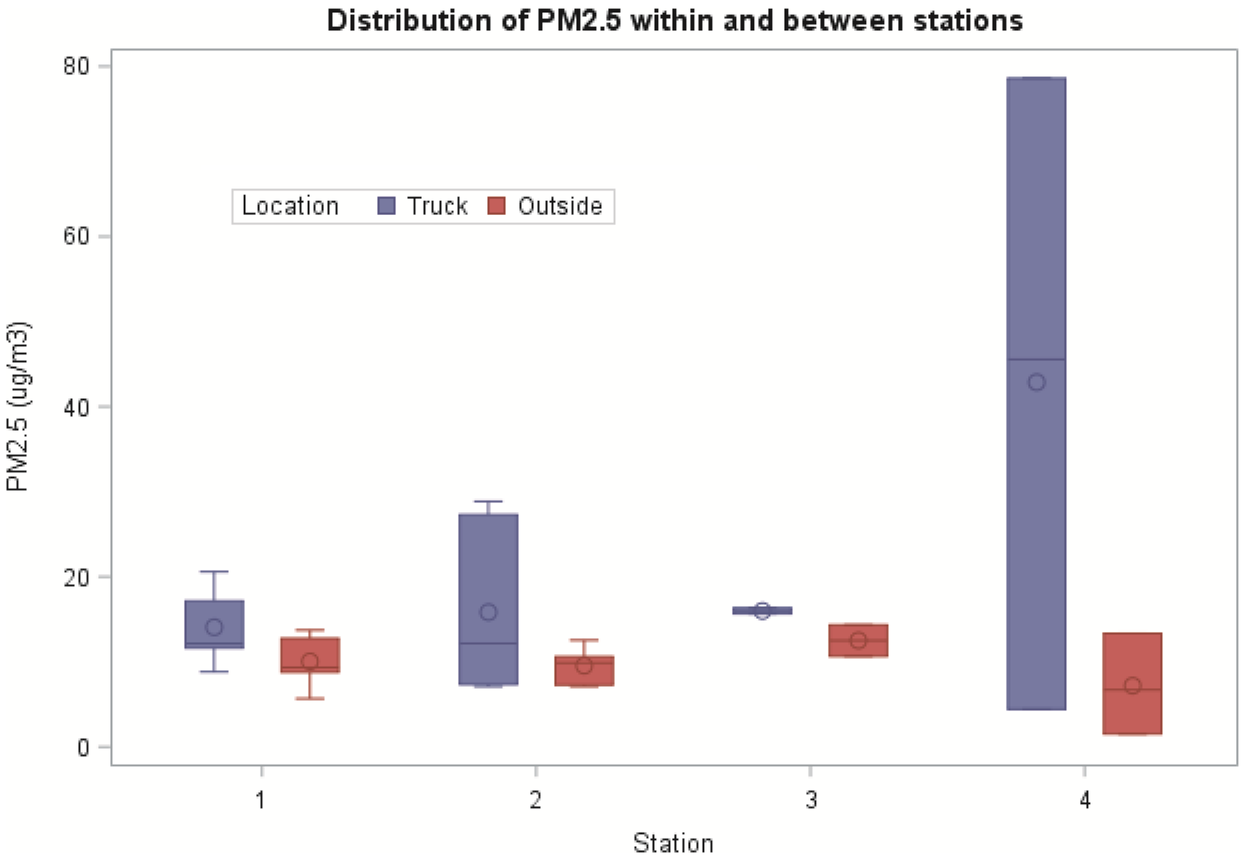

250
200
150
100
50
0
Particle-bound PAHs (ng/m³)
Outside
Truck Bay
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
11 PM
Time of Day



Figures 1a and b.

Levels of contaminants throughout one day of sampling at Station #2 in the truck bay and just outside of the station. Figure 1a shows particle-bound PAHs (ng/m^3), Figure 1b shows PM$_{2.5}$ (µg/m^3).


Distribution of PAH within and between stations
Location
Truck
Outside
Kitchen
PAH (ng/m3)
0
25
50
75
100
125
Station
1
2
3
4



Figures 2a and 2b.

Box plots showing the range of daily averages in each area sampled within the fire station (truck bay, outside, and kitchen). Figure 2a shows particle-bound PAHs (ng/m^3), Figure 2b shows PM$_{2.5}$ (μg/m^3).

Table 1

Overview of fire stations included in study

Station Name	Companies at station	Average number of calls	Neighborhood description	Date of building construction
Station #1	1 ladder, 1 engine	Around 40 per shift for each company	Urban, near bus terminal	1974
Station #2	1 ladder, 1 engine	Around 8-10 per shift for each company	Urban, near commercial area	1948
Station #3	1 ladder, 1 engine	Around 12-14 per shift for each company	Urban, residential	1959
Station #4	1 engine	On average, 5-7 calls per shift	Suburban, residential	2007

Table 2

Overview of average daily differences between air quality in truck bay, outside, and the kitchen

		Truck				Outside				Kitchen			
PAHs	**Number of days sampled**	**Avg (ng/m3)**	**Std dev**	**Median**	**IQR**	**Avg (ng/m3)**	**Std dev**	**Median**	**IQR**	**Avg (ng/m3)**	**Std dev**	**Median**	**IQR**
Station #1	8	32.35	10.72	34.13	18.27	4.92	1.24	5.26	1.27	10.84	1.78	10.55	1.39
Station #2	7	11.98	4.28	10.63	4.88	5.20	3.63	3.72	4.95	9.81	1.78	8.64	2.89
Station #3	6	5.03	1.76	4.89	1.38	2.55	0.26	2.57	0.32				
Station #4	5	68.83	42.25	66.54	11.33	2.07	0.78	2.50	1.16	1.69	0.60	1.55	0.33
$PM_{2.5}$ (Gravimetric)	**Number of days sampled**	**Avg (μg/m3)**	**Std dev**	**Median**	**IQR**	**Avg (μg/m3)**	**Std dev**	**Median**	**IQR**				
Station #1	5	14.06	4.72	12.14	5.51	10.04	3.24	9.33	3.95				
Station #2	6	15.82	9.92	12.16	19.95	9.54	2.09	9.86	3.31				
Station #3	2	15.99	0.48	15.99	0.68	12.50	2.60	12.50	3.67				
Station #4	3	42.87	37.16	45.56	74.18	7.18	5.93	6.70	11.82				

Table 3

Results of the Linear Mixed Effects Regression Models

PAHs	β coefficient (ng/m3)	Standard Error	p-value
Location			
Truck	23.68	5.04	<.0001
Kitchen	0.71	4.55	0.89
Outside	Ref		
Station			
Station #1	-8.16	5.04	0.14
Station #2	-15.20	5.40	0.0079
Station #3	-24.12	5.55	0.0005
Station #4	Ref		
$PM_{2.5}$ (Gravimetric)	**β coefficient (μg/m3)**	**Standard Error**	**p-value**
Location			
Truck	10.74	4.64	0.028
Outside	Reference		
Station			
Station #1	-12.97	6.77	0.066
Station #2	-12.35	6.56	0.071
Station #3	-10.78	8.46	0.21
Station #4	Reference		