Quantifying the temporal and spatial variation of atmospheric particles on Dalhousie Campus – a pilot study

Honours Thesis

April 23, 2009

Student Investigator: Caitlin Owens
Environmental Science Major
Dalhousie University
Tel: 902 440-9766
email: cowens@dal.ca

Supervisor: Dr. Mark D. Gibson
Research Scientist, Atlantic RURAL Center
Community Health and Epidemiology
Dalhousie University
Room401, 5790 University Avenue
Halifax, Nova Scotia, B3H 1V7
Tel: 902 494-7019, Fax: 902 494-7019
Email: mark.gibson@dal.ca

DALHOUSIE UNIVERSITY
Inspiring Minds

Table of Contents

INTRODUCTION
Review

Outdoor air pollution is a broad and complicated issue that poses a real threat to human health and the environment. Past research demonstrates a link between urban air pollution and increased rates of mortality and morbidity (Vigotti *et al*, 1996; Ostro *et al*, 2000; Metzger *et al,* 2004; Curtis *et al,* 2006; Bell *et al,* 2008; Stieb *et al,* 2002). It has also shown to be detrimental to the environment (United States Environmental Protection Agency (EPA), 2008a; Health Canada, 2003, Health Canada, 2006b). Such findings have only continued to strengthen the concern that outdoor air pollution continues to pose a threat to public health (Samet *et al,* 2000). As this area of research continues to receive ongoing attention it also proves to be a difficult area to study. What makes researching outdoor air pollution so complicated and broad is that air pollution is a heterogeneous mixture of gaseous and particulate components that vary through the seasons, diurnally and spatially (Davidson *et al*, 2005; Bell *et al*, 2008, Gibson *et al*, 2009) Additionally, since the industrial revolution, the air pollutant mix has changed and so have their sources (but not uniformly on a global scale, e.g. developed versus developing world). Pollutants that received a large amount of attention for their impact on the environment include sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) both of which led to the formation of acid deposition (Health Canada, 2003, 2006b) and carbon dioxide (CO_2), which is a greenhouse gas (Health Canada, 2006b). Air pollutants of health concern include ground-level ozone (O_3), carbon monoxide (CO), oxides of sulphur (SO_X) - a mixture of SO_3 & SO_2 , nitrogen oxides (NO_X) volatile organic compounds (VOCs), and Particulate Matter (PM) - $PM_{2.5}$ & PM_{10} (the subscript indicates what aerodynamic diameter is in consideration). $PM_{2.5}$ indicates those particles that are 2.5 microns and smaller where as, PM_{10} indicates aerodynamic diameter 10 microns and below; this classification is split into two fractions; coarse particles ($PM_{2.5-10}$) and fine particles ($PM_{2.}$) (EPA, 2008a; Health Canada, 2006b).

Research over the last decade has shown that ambient concentrations of these pollutants are declining in Canada (Curtis *et al*, 2006). This is due to tighter emissions regulations and the retro fitting of scrubbers on power stations in the NE USA, which have been particularly effective at reducing NO_x and O_3 seen in Eastern Canada (Kim *et al*, 2006). However, in recent years some pollutants, especially PM, are being exacerbated by our increased use of vehicles and industrial chemicals (Curtis *et al*, 2006).

Background

In North America $PM_{2.5}$ is a "criteria" pollutant for which the Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS) (EPA, 2008b, Environment Canada, 2007). PM is made of a complex mixture of tiny airborne particles of solid or liquid suspended in a gas (EPA, 2008a, WHO, 2008). These particles are as mentioned complex and as a result can have a range of toxic effects. One characteristic that changes PM toxicity is particle size. Those that are considered fine particulate matter, <2.5 microns in diameter ($PM_{2.5}$), are small enough that when they are breathed they have the ability to penetrate deep into the lung and cause damage to the aveoli (EPA, 2008a). Coarse PM ($PM_{2.5-10}$) does not have as damaging effects to the lungs but are considered irritants and exasperators to the upper respiratory tract. Research on $PM_{2.5}$ suggests that these small airborne particles are a toxic component of urban air pollution (Samet *et al*, 2000). Other studies have provided evidence that $PM_{2.5}$ in the ambient air is associated with increases in eye nose and throat irritation, daily mortality, and respiratory and cardiovascular diseases (Health Canada, 2006a). The effects of particle pollution don't stop with the negative health effects; PM can also have adverse effects on vegetation and structures, and contributes to visibility deterioration, acid deposition and regional haze.

Purpose

Increased levels of PM have shown to degrade the built and natural environment by soiling of buildings and works of art due to soot, by acid particle weathering of lime stone buildings, and by making acidic waters, and by depleting soils (EPA, 2008a). They are also related to increase hospital visits, morbidity and mortality and in turn increase social costs (health care, infrastructure) (Stieb *et al*, 2002). Therefore, ambient air pollution is a global issue and of major concern from a health, environmental, infrastructure and national heritage perspective.

In the Halifax area there have been no published research on PM but there has been research competed. Gibson *et al.* (2008, 2009) has conducted several studies on PM and has presented the findings at peer review conferences and will present at CMOS in May. There are many factors like population and population density, vehicle an industrial density, ship emissions, transboundary air movements telling us that outdoor PM pollution in an area like Halifax would be of concern (Environment Canada, 2007). The outdoor air quality health research (Gibson *et al*, 2008, 2009) has been valuable but more research is needed to establish a baseline of PM data. This baseline is needed in order to make further and just recommendations in areas where continued research is warranted.

The purpose of this study is to measure and compare the concentration levels of particulate matter ($PM_{2.5}$) in order to find out the spatial and temporal variations across the Dalhousie Campus. This study specifically targets those who may be exposed on campus. The target populations of this study included Students, Faculty, Staff, as these are the populations that are most likely to be exposed to the air pollution on campus routes. A secondary aim was to develop a winter season baseline of $PM_{2.5}$ concentrations on the Dalhousie campus.

It is the goal of this research to 1) Identify spatial variations, 2) Identify temporal variations, 3) investigate the concentrations of $PM_{2.5}$ on campus during peak traffic flows in order to estimate a worst case exposure scenario and 4) possibly identify any "hot spots and "cold spots" on campus, e.g. identify where the highest or lowest concentrations are located.

Scope

This study was impacted by severe time constraints. Due to unforeseen circumstances the period in which I had to conduct the study was limited to four months. Therefore, the area of investigation was limited to the Dalhousie campus. This includes the Studley, Carlton, and Sexton campuses. Also given the time constraint only particular sampling times will be chosen, this is to allow the estimate of the a worst case exposure scenario. Additionally, there were financial constraints combined with limited availability of the monitoring equipment (due to it being used for a Health Canada funded study of indoor air quality in Halifax). Therefore, $PM_{2.5}$, Temperature, Relative Humidity (RH), carbon dioxide and some PM_{10} will be measured. Other temporal limitations include only sampling on sunny weekdays as weather can create dangerous conditions for sampling.

Organization

This Thesis has been organized into four other chapters: Literature Review, Methods, Discussion and Conclusion. The literature review speaks to the extensive scientific background of this topic, what influential results were found, how they influenced the development of this thesis, and how my research fits within this field. The methods section will, in detail, describe the methods that were used to collect and analyze the data. The results section will present the findings and it will be followed by a discussion on what was found. The discussion will address the results in detail and will address any problems or irregularities within the data and the project itself. This Thesis will conclude with an overview of the research and findings and suggest areas for further research.

LITERATURE REVIEW

Purpose

The purpose of this review is to explore the "state-of-the-art" and current air pollution research and to place into context my research in terms of what has already been accomplished in this field. To accomplish this I will identify the articles that contribute the most to the understanding and development of this research, identify the relationships between each work being reviewed, and identify the trends, inconsistencies, and gaps within the existing research.

Topic and Scope

Inhalable atmospheric particulate matter below a median aerodynamic diameter of 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$), collectively abbreviated to PM, is a persisting public health issue that is associated with many negative health affects. PM_{10} when inhaled reach the upper thoracic region of the lung while $PM_{2.5}$ penetrate deeper into the lung reaching the alveoli (Donaldson *et al*, 2001). The early research found that exposure to airborne particles can cause a range of adverse health effects (Vigotti *et al*, 1996; Metzger, *et al*, 2004; Miller *et al*, 2007; Tonne *et al*, 2007). Much of the early work in this subject area is focused on human health and exposure to PM_{10}, and more recently $PM_{2.5,}$ and how these effects vary over time and space. Recent research on $PM_{2.5}$ has evolved to incorporate a broader research spectrum; a more complex area of issues including the source and composition of $PM_{2.5}$ (Harrison *et al*, 2004, Curtis *et al*, 2006). Despite these complexities related to PM characteristics, the significant associations between airborne particles and their negative health effects on humans have necessitated further research in this area. Thus a strict scope and criteria for reviewing the literature was required.

This project addresses, what is the concentration of PM on Dalhousie's campus and how it varies with time and spatially, but reviewing the spatial and temporal literature alone was not enough to focus this research. To accurately contextualize this issue and address its timeliness and importance, a review of the Health literature was necessary. Thus the criteria that were established to identify the relevant literature included those articles that focus on 1) $PM_{2.5/10}$, 2) urban outdoor air quality and the health effects of $PM_{2.5/10}$, and 3) the variation of $PM_{2.5/10}$ through time and space. Research that emphasizes 1) indoor air quality, 2) particle composition, or 3) the sources of $PM_{2.5/10}$ have been omitted from this literature review as it does not constructively contribute to specificity of this subject under review.

The fundamental and key literature that will be reviewed will be examined based on their 1) General objective, 2) Methods of data collection, and 3) Results. I will then identify what areas need further investigation and how this proposed pilot study would contribute to this research.

Review

Examination of the relevant literature on $PM_{2.5/10}$ revealed that many studies shared the general purpose of determining the association(s) between daily urban air pollution ($PM_{2.5/10}$) and acute effects on health (Vigotti *et al,* 1996; Ostro *et al,* 2000, Metzger *et al,* 2004; Miller *et al,* 2007; Tonne *et al,* 2007; Yang *et al,* 2004; Metzger *et al,* 2004; Chen *et al*, 2004; Stieb *et al*, 2002). Aside from this major research objective being the same, the results were also similar, with some exceptions. The individual hypotheses were different in that they varied by disease, population, time, and area. The methods used in each of the studies were also varied and will be addressed later in the review.

Further examination and review of the results highlighted that many studies are finding a similar trend, that PM causes adverse health effects (Bell *et al,* 2008; Curtis *et al,* 2006; Davidson *et al,* 2005; Harrison, *et al,* 2000). To date $PM_{2.5}$ exposure has been linked to cardiovascular disease (CVD) and respiratory hospitalizations (Vigotti *et al*, 1996; Metzger *et al,* 2004; Tonne *et al,* 2007; Bell *et al,* 2008), increased risk of nonfatal and fatal cardiovascular and respiratory events (Schwartz *et al,* 2000; Tonne *et al,* 2007; Miller *et al,* 2007) and mortality (Vigotti *et al,* 1996). In contrast some studies revealed that $PM_{2.5}$ has no significant effect on hospital admissions for respiratory disease (Chen *et al,* 2004; Yang *et al,* 2004). Also $PM_{2.5}$ has been found to have no association with cardiovascular mortality or with respiratory mortality (Ostro *et al,* 2000).

Analysis of the methods used for data collection provides insight into these inconsistencies. The methods used amongst the studies were similar in cases and in others varied. These similarities and variations between methodologies were by 1) duration of study, 2) source of pollutant or health data, and 3) location of study. Therefore these contradictory results may not be as inconsistent as they seem.

The duration of some studies took place over years (Vigotti *et al,* 1996; Ostro *et al,* 2000; Metzger *et al,* 2004; Yang *et al,* 2004; Chen *et al,* 2004; Miller *et al,* 2007; Tonne *et al,* 2007; Bell *et al,* 2008), while others took months (Schwartz *et al,* 2000). The collection of health data, in some cases, relied on the gathering of outcome data or discharge records from hospitals (Vigotti *et al,* 1996; Metzger *et al,* 2004; Yang, *et al,* 2004; Miller *et al,* 2007; Tonne *et al,* 2007; Bell *et al,* 2008), or identified a group of people in order to acquire health data (Chen, 2004; Schwartz, 2000), or used an areas department of Health services health database (Ostro *et al,* 2000; Miller *et al,* 2007). The pollution data was in some cases collected using central-site real time monitoring stations (Schwartz *et al,* 2000; Ostro *et al,* 2000; Chen *et al,* 2004; Yang *et al,* 2004) others obtained pollutant data from an existing data sources like the U.S. Environmental Protection Agencys' National Emissions Inventory database (Metzger *et al,* 2004; Tonne *et al,* 2007; Miller *et al,* 2007) and in one study used both (Bell *et al,* 2008). Opposite results in association with various methods of obtaining pollutant data collection suggests neither collection method is biased to a particular result. One observation is that the larger scoped studies used existing data sources, which indicate that there is a need to develop a database so that larger more complex studies could be done in the future. Different sample populations were also studied. Sample populations varied by age or gender (Miller *et al,* 2007). Sample populations included children (Schwartz *et al,* 2000; Yang *et al,* 2004) elderly (Chen *et al,* 2004; Bell *et al,* 2008), and all ages (Ostro *et al,* 2000; Metzger *et al,* 2004; Tonne *et al,* 2007; Miller *et al,* 2007). Sample number was also different, but only in one case was statistical power reduced due to low sample number (Ostro *et al,* 2000).

These methods did not seem to have any distinct effect on the results of these studies. However, they may have had some small influence on the results.

Spatial variation, however, seemed to influence the results greatly. These studies took place in different areas around the world and within North America. PM has been studied over large areas (Miller *et al,* 2007; Bell *et al,* 2008) and worldwide (Vigotti *et al,* 1996; Curtis *et al,* 2006) and because it is known to be susceptible to changes in time and space (Bell *et al,* 2008) would therefore have different outcomes in different areas. Also PM composition varies depending upon the geology and prevailing meteorology of the region and anthropogenic emissions (more or less industry etc). The particular phenomenon that was prevalent here was that studies that shared negative associations with $PM_{2.5}$ were conducted in Eastern North America (Schwartz *et al,* 2000; Metzger *et al,* 2004; Tonne *et al,* 2007), where as the insignificant associations with $PM_{2.5}$ where conducted Western North America (Ostro *et al,* 2000; Chen *et al,* 2004; Yang *et al,* 2004). A later study (Bell *et al,* 2008) also found that that the effects of $PM_{2.5}$ on health are higher and more significant in the eastern US than the western US. This trend can be explained by the fact that there are more power stations and industry and greater pop density in the NE US than western US. This combined with prevailing winds carry all the air pollution over the NE USA and then to Nova Scotia (Kim *et al, 2006).*

The literature reviewed revealed the following: $PM_{2.5}$ is a prevalent urban air pollutant associated with negative health effects (Vigotti *et al,* 1996; Schwartz *et al,* 2000; Metzger *et al,* 2004; Davidson *et al,* 2005; Curtis *et al,* 2006; Miller *et al,* 2007; Tonne *et al,* 2007;

Bell *et al,* 2007), that Eastern North America has higher negative associations with $PM_{2.5}$ than Western North America (Bell *et al,* 2008), and that the PM generated in this region of the US is subsequently adverted across the Maritimes by the prevailing wind to impact Nova Scotia (Kim *et al, 2006)*. These overarching factors suggest that doing research on $PM_{2.5}$ in the Maritimes specifically urban centers is important and should be conducted promptly.

Furthermore, the most recent paper reviewed was a pilot comparative study that investigated urban/rural/indoor/outdoor/personal exposure and spatio-temporal concentrations of $PM_{2.5}$ and ground level ozone. What makes this study so significant is it was conducted in Halifax (Gibson *et al,* 2008). This study revealed that urban $PM_{2.5}$ personal exposure is significantly greater than corresponding rural exposure establishing that there is in fact a concern in Halifax with regards to urban $PM_{2.5}$ pollution. These results were also similar to those found in the previously discussed literature as it identified $PM_{2.5}$ as a pollutant of concern in the urban setting. Sampling methods were different used, as compared to those previously discussed studies, as this research only looked at personal exposure to $PM_{2.5}$ and not at the association between PM and health related outcomes. This study also established that further investigation of microenvironments in the Valley and Halifax area is required to get a better understanding of exposure. This pilot study establishes a standard for further study in the Halifax area, and it is from this pilot that I narrowed my projects scope and developed my research methods.

Conclusion

The research and knowledge that describes PM in urban air is well developed and is growing. Research has integrated health with spatio-temporal variables to examine the effects of PM on acute health effect in order to guide further investigation. This research also brings forward the need for additional and extensive investigation on urban $PM_{2.5}$ exposure in Eastern North America.

Examination of existing knowledge and research has indicated that no study has yet looked at comparing the spatio-temporal variation on Dalhousie Campus, which will be the purpose of this project. This project will gather baseline data on $PM_{2.5}$ from Dalhousie's campus by methods already implemented by a pilot study conducted in Halifax (Gibson *et al*, 2008). This will include the use time logs and GPS to track sampling location and TSI Inc. Dust Trak monitors to measure near real-time $PM_{2.5}$ concentrations.

MATERIALS AND METHODS

This section will address the methods that were used for this experiment, the study's sample, the sampling materials, the sampling protocol, and the lab analysis. It also identifies the study protocols put in place and the limitations presented by this research. The research design is an experiment. This particular experiment will examine two study parameters: 1) Temporal PM measurements 2) Spatial gradients of PM concentrations across campus.

Sampling Metrics

The compounds that were chosen for sampling and analysis include particulate matter ($PM_{2.5}$ and PM_{10}), and carbon dioxide (CO_2). These compounds were chosen because they are of health and environmental concern and some of the most commonly measured outdoor air pollutants in Canada and U.S (Health Canada, 2006; EPA, 2008). The EPA has also set national air quality standards for these air pollutants (EPA, 2008). Elevated levels of these outdoor pollutants can impair lung function, irritate the respiratory system, and in some extreme cases lead to premature death (Health Canada, 2006). Temperature and relative humidity (RH) will also be measured because these climatic variables can have effects on the levels of the selected compounds and can also be helpful when comparing one data set to another.

Materials and Methods

The real time air pollution data was collected with the use of the TSI Inc. (Shoreview, Montana, USA) DustTrak PM monitor (See Figure1). This monitor is specifically designed to measure ambient particulate matter in near real-time. Another monitor, the

YES-206 Falcon (See Figure 1), was used to measures CO_2, temperature, and RH. I also used a GPS in order to track my position and a written time log. The equipment that was used is specifically designed to measure the compounds that have been chosen and therefore validate these choices of sampling materials. Furthermore, this equipment has also being used in other ongoing air quality studies (Gibson, M.D. *et al*, 2009, Health Canada, 50 homes Study, 2009).

Figure 1. From left to right: DustTrac PM monitor and the YES-206 Falcon CO_2 monitor.

Sampling Protocol

The near real-time measurements were taken on the three Dalhousie campuses: Studley, Carlton and Sexton. Samples were taken across all Dalhousie so that spatial variations could be measured. Samples were taken along a predetermined route, twice daily, Monday through Friday. The first of the two daily measurements was taken between 07:00 and 08:00 and the second was taken between16:00-17:00. Samples were taken over these times so that temporal variations could be measured and so that the peak traffic regime in Halifax was captured.

The sampling path began at the Sir James Dunn Building and continued down to the Sexton campus via University and Spring Garden, then passing the Student Union Building (SUB), ending at the rear of the Life sciences Center (LSC). The exact path that was sampled is shown in Figure 2. This path was chosen because it passes through each

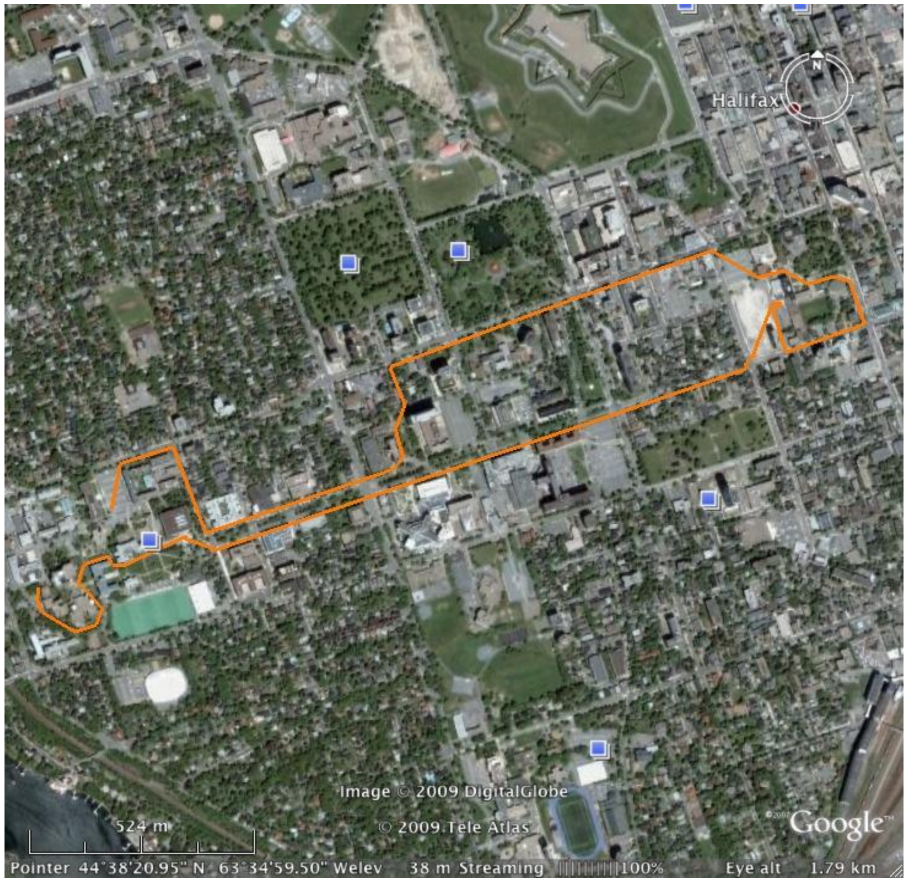

Figure 2. Sampling Path. Picture from Google Earth.

of the Campus' and all of the academic buildings. These buildings include: Sir James Dunn, Marion McCain Arts and Social Sciences building, Weldon Law, Rebecca Cohn, Tupper, Dentistry, Burbridge, Forrest, Goldberg Computer Science, F.H. Sexton Gym, M.M.O'Brien Hall, Building A-D and F, G, and N Buildings, Kenneth C. Rowe Management Building, Student Union Building, Killiam Library, Chemistry Building, Henry Hicks Building, and Life Sciences Centre. This path also incorporates two of the largest residence on campus, Howe Hall and Gerard Hall.

The sampling equipment was carried in a Knapsack. The DustTrak PM monitor was carried in a backpack with the intake strapped to the shoulder strap and within the breathing zone. The CO_2 monitor was placed in an exterior pocket on the backpack with the intake exposed. The intakes and exhausts were checked regularly to insure that they remained unobstructed throughout the sampling period. The GPS was also carried in the backpack during sampling. During the sampling period a written time log was also kept (See Appendix C). This log noted any events that could potentially have an effect on the measurements, particularly smokers, traffic, idling vehicles, and some weather conditions. This, in combination with the GPS was used to time stamp areas with the real time data. This log also acted as a backup for the GPS, noting the start and end times from the monitors and the times that major buildings were passed.

Analysis

After sampling, the data was uploaded onto a computer. Each monitor had software that could be installed on any Windows 95 or better operating system. The DustTrak particulate monitor used software called TracPro and the YES-206 Falcon CO_2 monitor used software called Trend Reader. These software packages were used to program the monitors and to upload the data. These programs could have been used for graphical display but were not used for this purpose. After the data was uploaded it was then exported into Microsoft excel. In excel the data was manipulated, cleaned, complied, and time coded by day, sample time, and Campus. Data and statistical analysis was then conducted on the complied data files.

Analysis of the data was completed using a program called Sigma Plot (Systat). Sigma Plot 11.0 (latest version) is a state of the art technical graphing program designed for the Windows platform. It’s specifically designed to aid in result analysis and graphing (Sigma Plot Users Guide P1, 2008). This program also features step by step guidance in performing over 50 frequently used statistical tests. The statically tests that were used for analysis include: T-test, Mann-Whitney, ANOVA, Dunn's, Kruskal-Wallis, and Tukeys. These analyses will be considered in more detail in the result section.

Study Design

The study had to be completed by April 2009 in order to meet the course requirements. In light of this fact and the fact that time was a restraint, only outdoor winter measurements were taken. These outdoor measurements were taken only Dalhousie Campus. I did not consider composition of PM nor did I look at sources of PM. Also no ethics review was required as no human subjects were involved.

Study Limitations

The biggest limitation presented by this study is the equipment. The access and the availability of the required equipment was uncontrollable. In order to account for these limitations I delimited the sampling duration within the times that the equipment was available. Also, not only did I place delimitation on this study's duration, but there was also a limitation. Unforeseen circumstances forced me to reduce the amount of time that was available for sampling. Weather was a large limitation presented during this project. Sampling during Halifax's winter months proved difficult, as sidewalk conditions were poor at best. As a result my sampling days were spread over one month as opposed to the anticipated one week.

DATA PRESENTATION/RESULTS

These results are complied according to how they were complied and organized in excel. The first grouping of results is temporal and the second grouping of results is spatial. Within each grouping of results contain different sets. Within the temporal group, data sets include morning vs afternoon and day vs day and campus. Within the spatial group, data sets include campus vs campus. Each data set will be further explained in each section. These results are from running statistical analysis in sigma plot.

Temporal

Morning vs Afternoon

See Appendix A for Full analysis results

This data set compares each day individually. It compares each day's morning measurements to the afternoon's measurements. Initially a t-test was run on each day's data set. It was at this point that the normality test failed ($P < 0.050$). What this determined was that the assumptions of non-linear regression were not true. This data was not distributed normally about the regression, the variance of the dependant variable in the source population was not constant regardless of the value of the independent variable, and that the residuals are not independent of each other. The P value determines the probability of being incorrect in concluding that the data is not normally distributed. The program then suggested that a Mann-Whitney rank sum test would be best suited to this data. The Mann-Whitney rank sum test was then run. This statistical analysis was chosen because the samples were not drawn from normally distributed populations with the same variance.

Table 1. Statistical analysis results from the Mann-Whitney rank sum test. Compares morning and afternoon concentrations of PM2.5 on Monday Jan26.

Group	N	Missing	Median	25%	75%
Morn	66	4	0.0120	0.00910	0.0146
After	69	4	0.0124	0.00952	0.0151

Table 1 sums the statistical analysis results from the Mann-Whitney rank sum test. What was found is that the difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.988).

Table 2. Statistical analysis results from the Mann-Whitney rank sum test. Compares morning and afternoon concentrations of PM2.5 on Wednesday Jan28.

Group	N	Missing	Median	25%	75%
Morn	67	4	0.0152	0.0138	0.0183
After	68	4	0.0114	0.00991	0.0130

Table 2 sums the statistical analysis results from the Mann-Whitney rank sum test. What was found is that the difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.001).

Table 3. Statistical analysis results from the Mann-Whitney rank sum. Compares morning and afternoon concentrations of PM2.5 on Thursday Feb26.

Group	N	Missing	Median	25%	75%
Morn	64	5	0.00900	0.00800	0.01000
After	64	4	0.00400	0.00300	0.00500

Table 3 sums the statistical analysis results from the Mann-Whitney rank sum test. What was found is that the difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.001).

Table 4. Statistical analysis results from the Mann-Whitney rank sum. Compares morning and afternoon concentrations of PM2.5 on Friday Feb27.

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Morn	63	4	0.00700	0.00700	0.00900
After	68	4	0.00400	0.00400	0.00500

Table 4 sums the statistical analysis results from the Mann-Whitney rank sum test. What was found is that the difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference ($P=<0.001$)

Overall there is a statistically significant difference between morning and afternoon PM2.5 concentrations (see Figure 3).

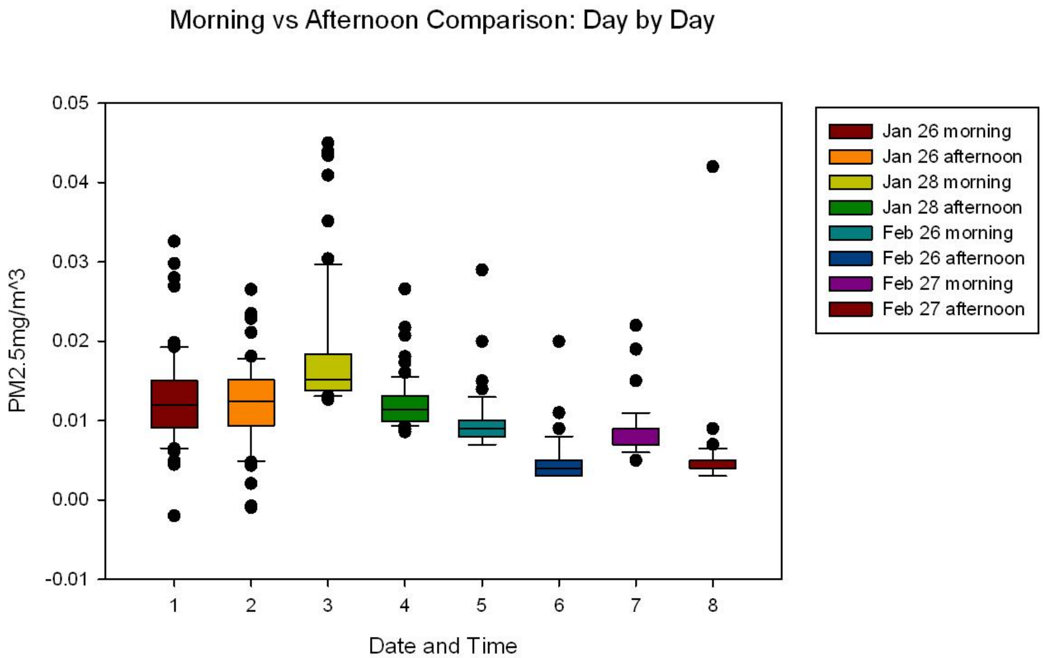

Figure 3. Box plots illustrating the significant differences between morning and afternoon measurements per day. The error bars indicate the 10^{th} and 90^{th} percentiles, the bottom of the box is the 25^{th} 5percentil and the top of the box is the 75^{th} percentile. The line trough the middle of the box is the median.
(Note: this is the same with all successive box plot graphs)

Day vs Day

See Appendix A for Full analysis results

These data sets compare all morning measurements from the five-day week against one another, and do the same for the afternoon measurements. Both Morning and afternoon data sets were run through a One Way Analysis of Variance. Both of which failed the normality test (Failed $P < 0.050$). ANOVA on Ranks was then begun using Kruskal-Wallis. If this test found that there was a statistically significant difference a pairwise multipule comparison was run. This was done in order to isolate the group or groups that differ from the others. In this case all pairwise multiple comparisons used Dunn's Method. Kruskal-Wallis is the same as the Mann-Whitney rank sum test but is used in the case that there are more than two groups to compare. Dunn's method is used because when there are data missing values Dunn is the default. In the event that Sigma Plot suggested more than one analysis method for pairwise multiple comparisons they were all completed. In most cases this was because there was no missing values and the Tukey test is recommended all pairwise comparisons with no missing values. In some of the pairwise comparison the result was "Do Not Test", this occurs for a comparison where no significant difference is found between the two ranks sums that enclose that comparison. Note that not testing the enclosed rank sums is a procedural rule, and a result of Do Not Test should be treated as if there is no significant difference between the rank sums, even though one may appear to exist.

Table 5. All morning measurements compared using the Kruskal-Wallis One Way Analysis of Variance on Ranks. Statistical analysis information.

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Jan 26	66	4	0.0120	0.00910	0.0146
Jan 28	67	4	0.0152	0.0138	0.0183
Jan 30	64	4	0.0111	0.00950	0.0134
Feb 26	64	5	0.00900	0.00800	0.01000
Feb 27	63	4	0.00700	0.00700	0.00900

Table 5 sums the statistical analysis results from the Kruskal-Wallis One Way Analysis of Variance on Ranks. What was found is that the differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Table 6. All Pairwise Multiple Comparison Procedures, Dunn's Method.

Comparison	**Diff of Ranks**	**Q**	**P<0.05**
Jan 28 vs Feb 27	174.278	10.980	Yes
Jan 28 vs Feb 26	135.354	8.527	Yes
Jan 28 vs Jan 30	81.638	5.166	Yes
Jan 28 vs Jan 26	80.381	5.129	Yes
Jan 26 vs Feb 27	93.897	5.893	Yes
Jan 26 vs Feb 26	54.973	3.450	Yes
Jan 26 vs Jan 30	1.258	0.0793	No
Jan 30 vs Feb 27	92.640	5.767	Yes
Jan 30 vs Feb 26	53.716	3.344	Yes
Feb 26 vs Feb 27	38.924	2.413	No

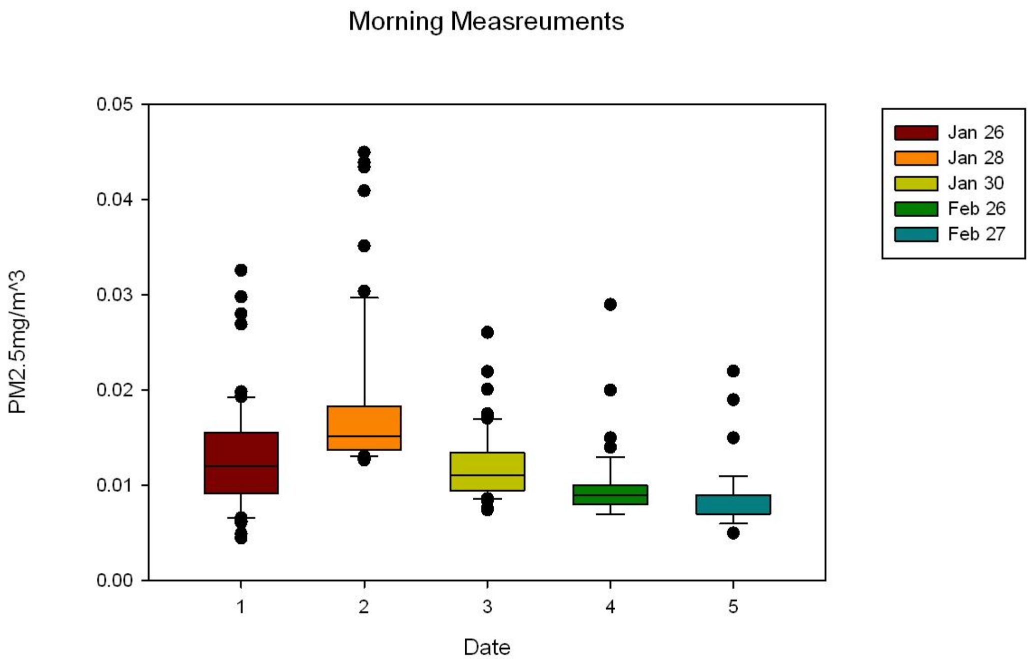

Figure 4. Box plots illustrating the significant differences between morning measurements per day.

Table 7. All Afternoon measurements compared using Kruskal-Wallis One Way Analysis of Variance on Ranks. Statistical analysis information.

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Jan 26	69	4	0.0124	0.00952	0.0151
Jan 27	66	4	0.00861	0.00798	0.00935
Jan 28	68	4	0.0114	0.00991	0.0130
Feb 26	64	4	0.00400	0.00300	0.00500
Feb 27	68	4	0.00400	0.00400	0.00500

Table 7 sums the statistical analysis results from the Kruskal-Wallis One Way Analysis of Variance on Ranks. What was found is that the differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Table 8. All Pairwise Multiple Comparison Procedures (Dunn's Method):

Comparison	**Diff of Ranks**	**Q**	**P<0.05**
Jan 28 vs Feb 26	170.396	10.411	Yes
Jan 28 vs Feb 27	161.547	10.034	Yes
Jan 28 vs Jan 27	64.667	3.985	Yes
Jan 28 vs Jan 26	13.597	0.848	No
Jan 26 vs Feb 26	156.799	9.616	Yes
Jan 26 vs Feb 27	147.950	9.225	Yes
Jan 26 vs Jan 27	51.070	3.159	Yes
Jan 27 vs Feb 26	105.728	6.410	Yes
Jan 27 vs Feb 27	96.880	5.969	Yes
Feb 27 vs Feb 26	8.849	0.541	No

Overall there is a significant difference between each morning PM2.5 concentration levels. This is also true with afternoon measurements.

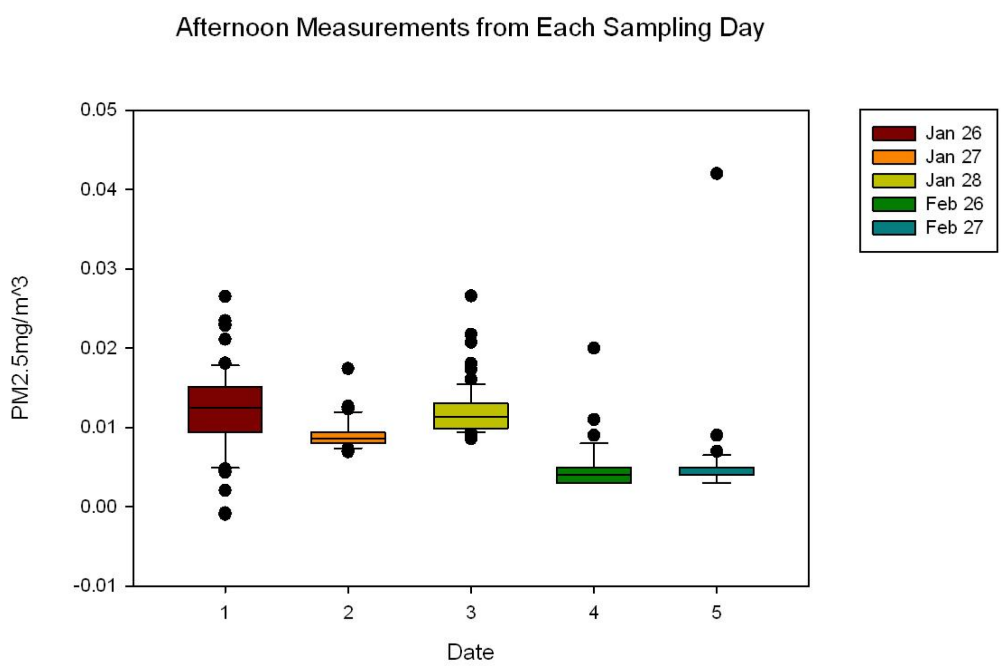

Figure 5. Box plots illustrating the significant differences between afternoon measurements per day.

Campus

See Appendix B for full analysis

These data sets compare single campus information. This includes comparing each campus' morning measurements to its other morning measurements. This was completed for morning measurements and afternoon measurements and for each campus. These data sets were analyzed using the same procedure as day vs day.

STUDLEY:

A comparison of all morning measurements for Studley campus found that the differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001). A Pairwise Multiple Comparison Procedures (Dunn's Method) revealed the following (P<0.05 = YES means there is a statistically significant difference):

Table 9. All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	**Diff of Ranks**	**Q**	**P<0.05**
Jan 28vs Feb 27	105.827	7.509	Yes
Jan 28vs Feb 26	89.786	6.371	Yes
Jan 28vs Jan 26	70.863	5.136	Yes
Jan 28vs Jan 30	51.126	3.667	Yes
Jan 30vs Feb 27	54.702	3.778	Yes
Jan 30vs Feb 26	38.660	2.670	No
Jan 30vs Jan 26	19.737	1.391	Do Not Test
Jan 26vs Feb 27	34.965	2.438	No
Jan 26vs Feb 26	18.923	1.320	Do Not Test
Feb 26vs Feb 27	16.042	1.097	Do Not Test

The same comparison was done for all afternoon measurements. What was found is that the differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001). A Pairwise Multiple Comparison Procedures (Dunn's Method) revealed the following:

Table 10. All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05
Jan 28vs Feb 26	79.566	7.394	Yes
Jan 28vs Feb 27	77.702	7.465	Yes
Jan 28vs Jan 26	30.557	2.993	Yes
Jan 28 vs Jan 27	29.710	2.883	Yes
Jan 27vs Feb 26	49.856	4.559	Yes
Jan 27vs Feb 27	47.992	4.532	Yes
Jan 27vs Jan 26	0.847	0.0814	No
Jan 26vs Feb 26	49.009	4.519	Yes
Jan 26vs Feb 27	47.146	4.492	Yes
Feb 27vs Feb 26	1.864	0.169	No

CARLTON:

The same procedure was used to compare all morning measurements for Carlton campus. What was found is that the differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001). A Pairwise Multiple Comparison Procedures (Dunn's Method) revealed the following:

Table 11. All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05
Jan 28vs Feb 27	30.618	4.624	Yes
Jan 28vs Feb 26	18.550	2.737	No
Jan 28vs Jan 26	11.150	1.645	Do Not Test
Jan 28vs Jan 30	9.982	1.507	Do Not Test
Jan 30vs Feb 27	20.636	3.193	Yes
Jan 30vs Feb 26	8.568	1.294	Do Not Test
Jan 30vs Jan 26	1.168	0.176	Do Not Test
Jan 26vs Feb 27	19.468	2.940	Yes
Jan 26vs Col 8	7.400	1.092	Do Not Test
Feb 26vs Feb 27	12.068	1.823	No

What was found when all afternoon measurements for Carlton campus were compared was is that the differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P=<0.001). A Pairwise Multiple Comparison Procedures (Dunn's Method) revealed the following:

Table 12. All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	**Diff of Ranks**	**Q**	**P<0.05**
Jan 26vs Feb 26	36.250	5.444	Yes
Jan 26vs Feb 27	30.485	4.478	Yes
Jan 26vs Jan 27	15.576	2.288	No
Jan 26vs Jan 28	1.967	0.282	Do Not Test
Jan 28vs Feb 26	34.283	4.909	Yes
Jan 28vs Feb 27	28.518	4.002	Yes
Jan 28vs Jan 27	13.609	1.910	Do Not Test
Jan 27vs Feb 26	20.674	3.037	Yes
Jan 27vs Feb 27	14.909	2.144	No
Feb 27 vs Feb 26	5.765	0.847	No

SEXTON:

A comparison of all morning measurements for Sexton campus found that the differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001). A Pairwise Multiple Comparison Procedures (Dunn's Method) revealed the following:

Table 13. All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	**Diff of Ranks**	**Q**	**P<0.05**
Jan 28vs Feb 27	36.375	5.102	Yes
Jan 28vs Feb 26	26.958	3.781	Yes
Jan 28vs Jan 30	14.833	2.080	No
Jan 28vs Jan 26	9.333	1.309	Do Not Test
Jan 26vs Feb 27	27.042	3.793	Yes
Jan 26vs Feb 26	17.625	2.472	No
Jan 26vs Jan 30	5.500	0.771	Do Not Test
Jan 30vs Feb 27	21.542	3.021	Yes
Jan 30 vs Feb 26	12.125	1.701	Do Not Test
Feb 26 vs Feb 27	9.417	1.321	No

Table 14. All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	**Diff of Ranks**	**q**	**P<0.05**
Jan 28vs Feb 27	436.500	7.215	Yes
Jan 28vs Feb 26	323.500	5.347	Yes
Jan 28vs Jan 30	178.000	2.942	No

Jan 28vs Jan 26	112.000	1.851	Do Not Test
Jan 26vs Feb 27	324.500	5.364	Yes
Jan 26vs Feb 26	211.500	3.496	No
Jan 26vs Jan 30	66.000	1.091	Do Not Test
Jan 30vs Feb 27	258.500	4.273	Yes
Jan 30vs Feb 26	145.500	2.405	Do Not Test
Feb 26vs Feb 27	113.000	1.868	No

The same comparison was completed on all afternoon measurements for Sexton campus. What was found is that the differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001). A Pairwise Multiple Comparison Procedures (Dunn's Method) revealed the following:

Table 15. All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	**Diff of Ranks**	**Q**	**P<0.05**
Jan 26vs Feb 26	39.962	5.446	Yes
Jan 26vs Feb 27	35.390	5.013	Yes
Jan 26vs Jan 27	17.462	2.380	No
Jan 26vs Jan 28	8.712	1.187	Do Not Test
Jan 28vs Feb 26	31.250	4.176	Yes
Jan 28vs Feb 27	26.679	3.700	Yes
Jan 28vs Jan 27	8.750	1.169	Do Not Test
Jan 27vs Feb 26	22.500	3.007	Yes
Jan 27 vs Feb 27	17.929	2.486	No
Feb 27vs Feb 26	4.571	0.634	No

Overall the single campus comparisons were mixed. Further discussion of these results will be addressed in the discussion section.

Spatial

Day and Between Campus'

See appendix B for full analysis results.

These data sets are comparing morning data between each campus, and again with afternoon data. This is done for each day. These data sets were also analyzed with the same procedure as the last two data sets.

MORNING

Morning measurements of $PM_{2.5}$ on Jan 26 were compared between Studley, Carlton, and Sexton. The differences in the median values among the treatment groups (Studley, Carlton, and Sexton) are greater than would be expected by chance; there is a statistically significant difference ($P = 0.026$).

The pairwise multiple comparison procedure found a significant difference ($P<0.05$) between the Sexton and Studley campus, but no other significant differences were found.

Morning measurements of $PM_{2.5}$ on Jan 28 were compared between Studley, Carlton, and Sexton. The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference ($P = 0.180$).

Morning measurements of $PM_{2.5}$ on Jan 30 were compared between Studley, Carlton, and Sexton. The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference ($P = 0.016$). Further analysis using the pairwise multiple comparison procedure found that no actual significant difference existed between the campuses.

Morning measurements of $PM_{2.5}$ on Feb 26 were compared between Studley, Carlton, and Sexton. The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P =

0.016). Further analysis using the pairwise multiple comparison procedure revealed that no actual significance existed between the treatment groups ($P<0.05$).

Morning measurements of $PM_{2.5}$ on Feb 27 were compared between Studley, Carlton, and Sexton. The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference ($P = 0.816$).

Overall it was found these comparisons were not significant. Mornings are not significantly different between campuses. There was one exception; one comparison between Sexton vs Studley that was found to have a statistically significant difference.

AFTERNOON

Afternoon measurements of $PM_{2.5}$ on Jan 26 were compared between Studley, Carlton, and Sexton. The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference ($P=0.012$). Further analysis using the pairwise multiple comparison procedure revealed no significant difference between Sexton and Carlton or Studley but there was a significant difference between Carlton and Studley.

Afternoon measurements of $PM_{2.5}$ on Jan 27 were compared between Studley, Carlton, and Sexton. The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference ($P = 0.393$).

Afternoon measurements of $PM_{2.5}$ on Jan 28 were compared between Studley, Carlton, and Sexton. The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.135).

Afternoon measurements of $PM_{2.5}$ on Feb 26 were compared between Studley, Carlton, and Sexton. The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.092).

Afternoon measurements of $PM_{2.5}$ on Feb 27 were compared between Studley, Carlton, and Sexton. The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.008). Further analysis using the pairwise multiple comparison procedure revealed a significant difference between Carlton and Studley ($P<0.05$). No other comparison was found to be significantly different.

Overall there is no significant difference between campuses in the afternoon. Exception; Carlton vs Studley on two days were significantly different from one another in the afternoon.

Campus vs Campus

See appendix B for full analysis results.

These data sets are comparing cumulative morning data between each campus, and again with afternoon data. This is done for each day. These data sets were also analyzed with the same procedure as the last three data sets.

The differences in the median morning values among the treatment groups (Studley, Carlton, and Sexton) are greater than would be expected by chance; there is a statistically significant difference (P = 0.030). On performing a pairwise multiple comparison procedure it was found the there was no actual significant difference between any of the campuses (P<0.05)(See Figure 6).

The differences in the median afternoon values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.074), (see Figure 7).

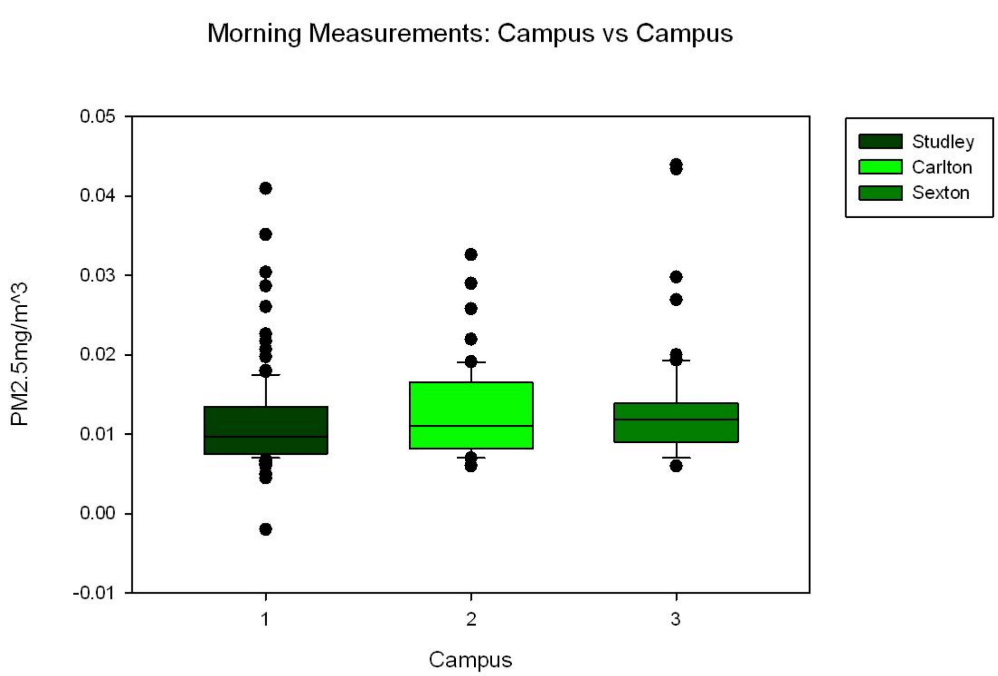

Figure 6. Box plots illustrating that there are no significant differences between campuses during the morning. This takes into consideration all morning data.

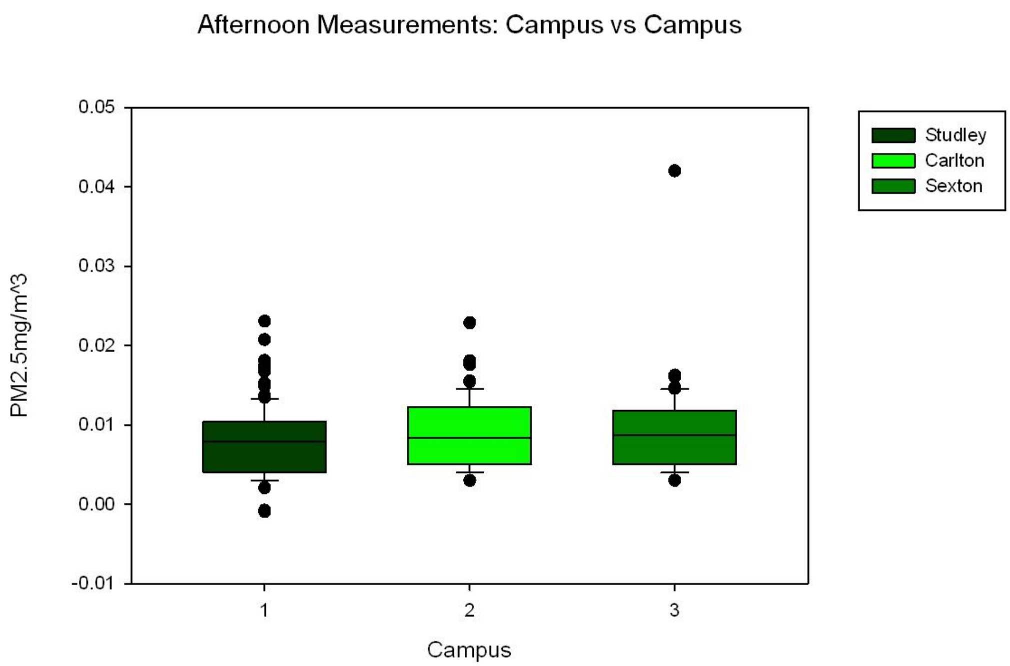

Figure 7. Box plots illustrating that there are no significant differences between campuses during the afternoon.

"HOT SPOTS"

No stastical analysis was conducted for the comparison between $PM_{2.5}/PM_{10}$ or on interior vs exterior (kerbside) campus areas. What this graphical result emphises is that there are possible differences, Figure 8.

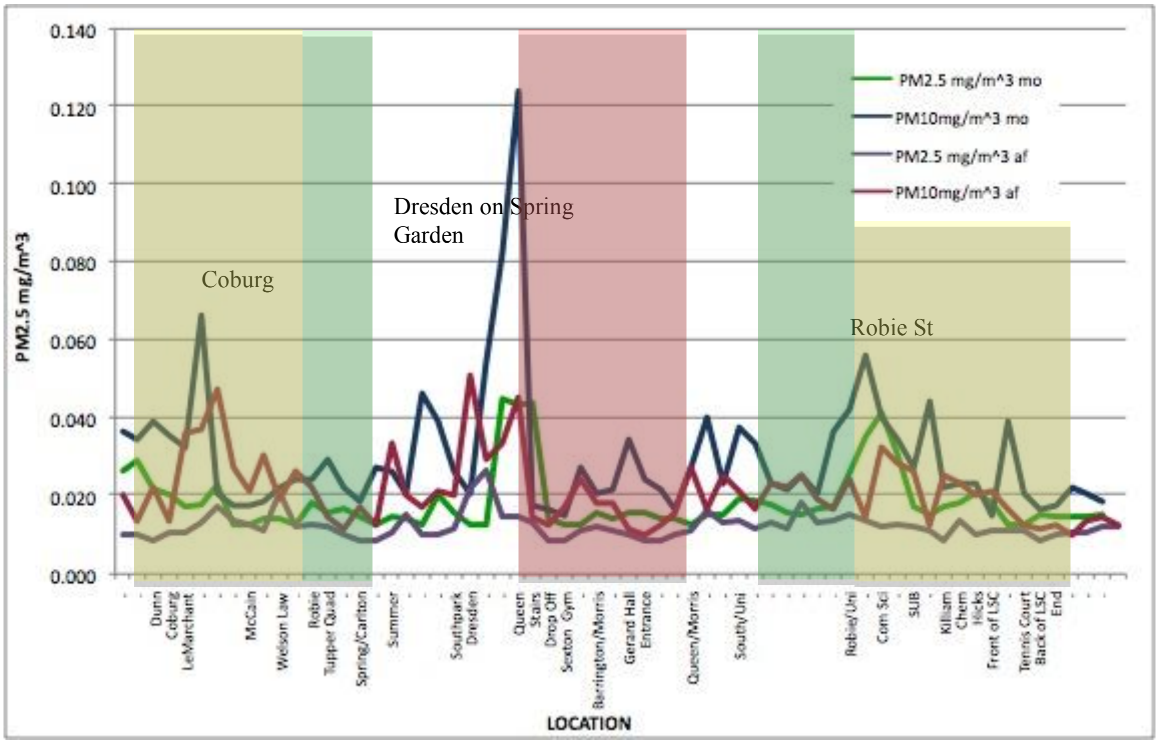

Figure 8. Morning and afternoon $PM_{2.5}/PM_{10}$ concentration levels during sampling on Jan 28. Yellow is Studley, Green is Carlton, and Red is Sexton.

DISCUSSION AND CONCLUSION

The results from this study do provide useful insights into the spatial and temporal variability in $PM_{2.5}$ across the Dalhousie Campus. The study also provides new data with which to adequately test my hypothesis, which is to determine whether there are significant spatial/temporal difference between Dalhousies campuses. I was able to determine the significance of temporal and spatial variations across the Dalhousie campus during the winter. This was achieved by first dividing my analysis into temporal or spatial tests and then by comparison type i.e. morning/afternoon or campus to campus.

The temporal findings show that both hourly and daily temporal differences are significant. Specifically a significant statistical difference was found between mornings and afternoons and morning to morning and afternoon to afternoon. These results suggest that further investigation into temporal variations on Dalhousie campus is necessary, as significant differences were found in all aspects of the temporal analysis.

The analysis of the data showed a mixed result in terms of significant differences in the $PM_{2.5}$ metric observed both spatially and temporally across the Dalhousie Campus. The analysis was based upon spatial and temporal differences between each campus and also morning-to-morning measurements and afternoon-to-afternoon measurements. This analysis used small sample sizes and therefore the results have reduced statistical power. Therefore these results in comparison to the other result are not as significant as the other temporal data.

The results showed that differences in spatial variation are not significant factors in the prediction of $PM_{2.5}$ concentration levels on Dalhousie Campus. This was true in all but three cases. These case had a slightly higher sample size for each campus (n) these were Studley n~30, for Carlton n~14 and Sexton n~15 (See Appendix B) . Two cases showed a significant difference between Studley and Carlton (Afternoon measurements of $PM_{2.5}$ on Jan 26 and Feb 27) and the other between Studley and Sexton (Morning measurements of $PM_{2.5}$ on Jan 26). Due to the sample size (n) these results have lowered statistical significance, however these three cases may have a greater significance as compared to the rest of the comparison as they have larger n value. Overall $PM_{2.5}$ concentrations observed on Studley, Carlton, and Sexton are not significantly different. These findings suggest that only one monitoring site would be needed to explain the $PM_{2.5}$ variation across all three campus (at least during the winter Season), i.e. sampling can take place in one area and can be extrapolated to include the entire campus. An exception to this would exterior (kerbside) sampling locations as they appear to have different PM values and distribution about this area(see Figure 8). This trend is also reported in several other studies (Harrison *et al,* 2004; Jones *et al,* 2005; Lonati *et al,* 2006).

The significance of temporal variation was expected but the lack of a significant difference for the spatial variation was unexpected. In other studies PM was found to have strong seasonal, diurnal and spatial variability (Davidson et al, 2005; Bell et al, 2008). In the case of spatial differences the discrepancy here may be as a result of spatial boundary. In the literature I looked at the research involved considerably larger areas, regional to national, than what was considered in my research, local. Therefore, it appears that spatial scale may play an important role in the concentration gradients of $PM_{2.5}$ observed across a cityscape. This consideration needs further research and would require a larger geographical scope i.e. inter-urban, peri-urban, regional and/or provincial. Additionally, these data sets were small and therefore may be inadequate in describing, with confidence, the true spatial variation across Dalhousie Campus. Never-the-less, this study does provide valuable pilot data with which to base future studies of this nature in Halifax.

Study Confounders

Time was a major limitation on the study design and reduced the number of possible samples taken. This may have impacted the statistical power of the spatial comparison between campuses. Also the analysis and results may have been more rigorous if I was able to compare this data with the Government NAPs data in downtown Halifax. However, the allotted time available for analysis was short and I was uable to complete all desired analysis. Also the Halifax data is not Quality Assured and Quality Controlled (QA/QC).

Another confounder of this research is that the Dust Trak monitor over reads by approximately 2.23 (Heal *et al*, 2000). This error will not in fact have an effect on this research as so long as this error is constant. This is because the differences in the measurements are the same when the error is correct for; therefore the spatial and temporal variations are not affected.

Recommendations

This study provided valuable new data and new insights into the spatial and temporal variation of $PM_{2.5}$ concentration gradients observed across campus. Certain "hot spots" of $PM_{2.5}$ were observed, e.g. Robie Street (see Figure 8) that merit further investigation. Significant temporal variability of $PM_{2.5}$ concentrations was observed. Although spatial variation seemed to have no significance in relation to $PM_{2.5}$ concentration this may not be the case in reality or throughout all seasons. Both these areas warrant more detailed research. Further studies could involve many different steps. The first of which would be identifying the 24h temporal variations on campus. This could then evolve into larger scale temporal investigations i.e. seasonal. The second would be to collect more spatial data on campus in order to support these finding or support the current finding that spatial variations are significant (Davidson et al, 2005; Bell et al, 2008).

Other areas that warrant further investigation on PM include comparing the weather conditions to the data and seeing if that has any significant effect on PM concentration. Looking at the differences between inner and outer campus. Looking at seasonal difference in PM2.5.

Finally it is my recommendation to Dalhousie and Halifax to improve research opportunities within the academic and research community and to invest more time and money into outdoor air pollution research, as it is a significant contributor to human health.

ACKNOWLEDGEMENTS

- Dr. Mark D. Gibson, Research Scientist, Atlantic RURAL Centre, Dalhousie University.
- Gavin H. King, Research Assitant, Atlantic RURAL Centre, Dalhousie University.
- Dr. Judy Guernsey, Director of the Atlantic RURAL Centre and interim Head of the department of Community Health and Epidemiology, Dalhousie University.
- Dr. Daniel Rainham, Elizabeth May Chair in Sustainability and Environmental Health, Professor, Dalhousie University.
- Dr. Tarah Wright Interim Associate Director (Undergraduate), College of Sustainability, Associate Professor, Dalhousie University.

REFERENCES

Bell, M.L., Ebisu, K., Peng, R.D., Walker, J., Samet, J.M., Zeger, S.L., *et al.* (2008). Seasonal and Regional Short-term Effects of Fine Particles on Hospital Admissions in 202 US Counties, 1999–2005. *American Journal of Epidemiology,* 168(11), 1301-1310.

Chen, Y., Yang, Q., Krewski, D., Burnett, R.T., Shi, Y., & McGrail, K.M.(2004), Difference in the Effects of Coarse Particulate Matter on First, Second, and Overall Admissions for Respiratory Disease Among the Elderly in Vancouver, Canada. *Epidemiology,* 15(4), S54.

Curtis, L., Rea, W., Smith-Willis, P., Fenyves, E., & Pan, Y.(2006). Adverse health effects of outdoor air pollutants. *Environment International*, 32, 815-830.

Davidson, C.I., Phalen, R.F., & Solomon, P.A.(2005). Airborne Particulate Matter and Human Health: A Review. *Aerosol Science and Technology*, 39, 737–749.

Donaldson, K., Stone, V., Seaton, A., & MacNee, W.(2001). Ambient Particle Inhalation and the Cardiovascular System: Potential Mechanisms. *Environmental Health Perspectives*, *109*, 523-527.

Douglas W. Dockery, D.W., & Stone. P.H.(2007). Cardiovascular Risks from Fine Particulate Air Pollution. *N Engl J Med*, 356(5), 511-513.

Environmental Canada.(2007). Criteria Air Contaminates and Related Pollutants: Particulate Matter (PM). Available from: http://www.ec.gc.ca/cleanair-airpur/Pollutants/Criteria_Air_Contaminants_and_Related_Pollutants/Particulate_Matter_(PM)-WS2C68B45C-1_En.htm Accessed on April 19, 2009

Gibson, M.D., Guernsey, J.R., Beauchamp, S., Waugh, D., Heal, M.R., Brook, J.R., et al.(2009).Quantifying the Spatial and Temporal Variation of Ground-Level Ozone in the Rural Annapolis Valley, Nova Scotia, Canada Using Nitrite-Impregnated Passive Samplers. *J Air & Waste Manage Assoc*, 59, 310-320.

Gibson, M.D., Guernsey, J.R., Rainham, D., Gould, R., Hore, P., Garand, L., Beauchamp, S., Waugh, D., Brook, J.R., McPherson, J., Bryden, B., Maher, R., King., G. (2008). Pilot Comparative Personal/Indoor/Outdoor/Urban/Rural Exposure Studies for Ground-Level Ozone (GLO) and Fine Respirable Particles ($PM_{2.5}$). Canadian Public Health Association Annual Conference, Halifax, 1st – 4th June 2008.

Gibson, M.D., Guernsey, J.R., Beauchamp, S., Waugh, D., Brook, J.R., Maher, R., Daniel Rainham., McPherson, J., Bryden, B., Gould, R., Gagnon, G. (2008). Air Quality and Health Research in Nova Scotia. Elizabeth May Chair Research Symposium. Dalhousie University, 14th March 2008.

Harrison, R.M., & Yin., J.(2000) Particulate matter in the atmosphere: which particle properties are more important for its effects on health? The Science and the Total Environment, 249, 85-101.

Harrison, R.M., Jones, A.M., & Lawrence, R.G. (2004). Major component composition of PM10 and PM2.5 from roadside and urban background sites. *Atmospheric Environment*, 38, 4531–4538.

Heal, M.R., Beverlan, I.J., McCabe, M., Hepburn, W., & Agius, R.M.(2000). Intercomparison of Five PM10 Monitoring Devices and the Implications of Exposure Measurement in Epidemiological research. *Atmospheric Environment,* 2, 455-461.

Health Canada. (2002). National Ambient Air Quality Standards: proposed decisions on particulate matter and ozone. Available from: http://www.ec.gc.ca/pdb/can_us/qual/matter.html Accessed on March 15, 2009.

Health Canada. (2003). Clean Air Online: Acid Rain. Available from: *http://www.ec.gc.ca/cleanair-airpur/Pollution_Issues/Acid_Rain-WSAA1521C2-1_En.htm* Accessed on March 14, 2009.

Health Canada. (2006a). Healthy living: It's Your Health. http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/environ/smog-eng.php Accessed on March 16, 2009.

Health Canada. (2006b). Environmental and Workplace Health: Air Quality, Outdoor Air. http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/effe/talk-a_propos-eng.php Accessed on March 14, 2009.

Jones, A.M., & Harrison, R.M.(2005). Interpretation of particulate elemental and organic carbon concentrations at rural, urban and kerbside sites. *Atmospheric Science*, 39, 7114-7126.

Kim, S., Heckel, A., McKeen, S.A., Frost, G.J., HsieE.-Y., Trainer, M.K., et al. (2006). Satellit-Observed U.S. Power Plant NO_x Emissions Reductions and their Impact on Air Quality. Geophys. Res. Lett, 33

Lonati, G., & Giugliano, M. (2006).Size distribution of atmospheric particulate matter at traffic exposed sites in the urban area of Milan (Italy). Atmospheric Environment, 40, S264-S274.

Liu, S., Box, M., Kalman, D., Kaufman, J., Koenig, J., Larson, T., et al.(2003). Exposure Assessment of Particulate Matter for Susceptible Populations in Seattle. *Environmental Health Perspectives*, 111(7), 909-918.

Metzger, K.B., Tolbert, P.E., Klein, M., Peel, J.L., Flanders, W.D., Todd, K., et al.(2004). Ambient Air Pollution and Cardiovascular Emergency Department Visits, *Epidemiology,* 15(1), 46–56.

Miller, K.A., David, S., Siscovick, D.S., Sheppard, L., Shepherd, K., M.S., Sullivan, J.H., et al. (2007). Long-Term Exposure to Air Pollution and Incidence of Cardiovascular Events in Women. *N Engl J Med*, 356(5), 447-58.

Ostro, B., Brosdwin, R., & Lipsett, M.J. (2000). Coarse and fine particles and daily mortality in the Coachella Valley, California: a follow-up study. *Journal of Exposure Analysis and Environmental Epidemiology*, 10, 412-419.

Ostro, B., Feng, W., Broadwin, R., Green, S., & Lipsett, M.(2007). The Effects of Components of Fine Particulate Air Pollution on Mortality in California: Results from CALFINE. *Environmental Health Perspectives*, 115(1), 13-19.

Samet, J.M., Dominici, F., Curriero, F.C., Coursac, I., & Zeger, S.L.(2000). Fine Particulate Air Pollution and Mortality in 20 U.S. Cities, 1987-1994. *The New England Journal of Medicin*e, 343(24), 1742-1749.

Stieb, D.M., Judek, S., & Burnett, R.T.(2002). Meta-Analysis of Time-Series Studies of Air Pollution and Mortality: Effects of Gases and Particles and Influence of Cause of Dealth, Age, and Season. *J. Air & Waste Manage. Assoc.,* 52, 470-484.

Schwartz, J., & Neas, L.M. (2000). Fine Particles Are More Strongly Associated Than Coarse Particles with Acute Respiratory Health Effects in Schoolchildren. *Epidemiology*, 11(1)**,** 6-10.

Systat Software, Inc.(2008). Sigma Plot 11.0 software.

Systat Software, Inc.(2008). Sigma Plot 11.0 User's Guide.

Tonne, C., Melly, S., Mittleman, M., Coull, B., Goldberg, R., & Schwartz, J.(2007). A Case–Control Analysis of Exposure to Traffic and Acute Myocardial Infarction. *Environmental Health Perspectives,* 115(1), 53-57.

United States Environmental Protection Agency (EPA).(2008a).Particulate Matter: Health and Environment. Available from: http://www.epa.gov/air/particlepollution/health.html Accessed on March 14, 2009.

United States Environmental Protection Agency (EPA).(2008b).Six Common Air Pollutants: What Are the Six Common Air Pollutants? Available from: http://www.epa.gov/air/urbanair/ Accessed on March 14, 2009.

Vigotti, M.A., Rossi, G., Bisanti, L., Zanobetti, A., & Schwartz, J.(1996). Short term effects of urban air pollution on respiratory health in Milan, Italy, 1980-89. *Journal of Epidemiology and Community Health,* 50, S71-S75.

World Health Organization (WHO).(2008).Air quality and health. Available from: http://www.who.int/mediacentre/factsheets/fs313/en/index.html Accessed on March 15, 2009.

Yang, Q., Chen, Y., Krewski, D., Shi, Y., Burnett, R.T., & McGrail, K.M.(2004). Association Between Particulate Air Pollution and First Hospital Admission for Childhood Respiratory Illness in Vancouver, Canada. *Archives of Environmental Health*, 59 (1), 14-21.

APPENDIX A

SIGMA PLOT DATA

DAY TO DAY

Morning Afternoon Pm2.5Day: Jan26

t-test Wednesday, March 25, 2009, 11:00:01 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Wednesday, March 25, 2009, 11:00:01 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 3	66	4	0.0120	0.00910	0.0146
Col 14	69	4	0.0124	0.00952	0.0151

Mann-Whitney U Statistic= 2011.500

T = 3964.500 n(small)= 62 n(big)= 65 (P = 0.988)

The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.988)

Morning Afternoon Pm2.5Day: Jan28

t-test Wednesday, March 25, 2009, 11:08:54 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Wednesday, March 25, 2009, 11:08:54 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 5	67	4	0.0152	0.0138	0.0183

Col 18	68	4	0.0114	0.00991	0.0130

Mann-Whitney U Statistic= 462.000

T = 5586.000 n(small)= 63 n(big)= 64 (P = <0.001)

The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

Morning Afternoon PM2.5Day: Feb26

t-test Wednesday, March 25, 2009, 11:05:38 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Wednesday, March 25, 2009, 11:05:38 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 9	64	5	0.00900	0.00800	0.01000
Col 20	64	4	0.00400	0.00300	0.00500

Mann-Whitney U Statistic= 215.500

T = 5094.500 n(small)= 59 n(big)= 60 (P = <0.001)

The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

Morning Afternoon Pm2.5Day: Feb27

t-test Wednesday, March 25, 2009, 11:07:21 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Wednesday, March 25, 2009, 11:07:21 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 11	63	4	0.00700	0.00700	0.00900
Col 22	68	4	0.00400	0.00400	0.00500

Mann-Whitney U Statistic= 216.000

T = 5330.000 n(small)= 59 n(big)= 64 (P = <0.001)

The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

DAYS: Morning

One Way Analysis of Variance Wednesday, March 25, 2009, 11:12:11 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Wednesday, March 25, 2009, 11:12:11 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 3	66	4	0.0120	0.00910	0.0146
Col 5	67	4	0.0152	0.0138	0.0183
Col 7	64	4	0.0111	0.00950	0.0134
Col 9	64	5	0.00900	0.00800	0.01000
Col 11	63	4	0.00700	0.00700	0.00900

H = 138.192 with 4 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05
Col 5 vs Col 11	174.278	10.980	Yes
Col 5 vs Col 9	135.354	8.527	Yes
Col 5 vs Col 7	81.638	5.166	Yes
Col 5 vs Col 3	80.381	5.129	Yes
Col 3 vs Col 11	93.897	5.893	Yes
Col 3 vs Col 9	54.973	3.450	Yes
Col 3 vs Col 7	1.258	0.0793	No
Col 7 vs Col 11	92.640	5.767	Yes
Col 7 vs Col 9	53.716	3.344	Yes
Col 9 vs Col 11	38.924	2.413	No

Note: The multiple comparisons on ranks do not include an adjustment for ties.

DAYS: Afternoon

One Way Analysis of Variance Wednesday, March 25, 2009, 11:15:43 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Wednesday, March 25, 2009, 11:15:43 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 14	69	4	0.0124	0.00952	0.0151
Col 16	66	4	0.00861	0.00798	0.00935
Col 18	68	4	0.0114	0.00991	0.0130
Col 20	64	4	0.00400	0.00300	0.00500
Col 22	68	4	0.00400	0.00400	0.00500

H = 196.991 with 4 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05
Col 18 vs Col 20	170.396	10.411	Yes
Col 18 vs Col 22	161.547	10.034	Yes
Col 18 vs Col 16	64.667	3.985	Yes
Col 18 vs Col 14	13.597	0.848	No
Col 14 vs Col 20	156.799	9.616	Yes
Col 14 vs Col 22	147.950	9.225	Yes
Col 14 vs Col 16	51.070	3.159	Yes
Col 16 vs Col 20	105.728	6.410	Yes
Col 16 vs Col 22	96.880	5.969	Yes
Col 22 vs Col 20	8.849	0.541	No

Note: The multiple comparisons on ranks do not include an adjustment for ties

APPENDIX B

SIGMA PLOT DATA

CAMPUS COMPARISONS:

Campus Morning PM2.5 Jan26

One Way Analysis of Variance Friday, March 27, 2009, 9:38:48 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 9:38:48 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Studley	30	4	0.0102	0.00659	0.0126
Carlton	14	4	0.0112	0.00800	0.0189
Sexton	16	4	0.0129	0.0117	0.0167

H = 7.335 with 2 degrees of freedom. (P = 0.026)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.026)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05	
Sexton vs Studley	12.878	2.636	Yes	Sexton and Studley are different
Sexton vs Carlton	5.717	0.954	No	
Carlton vs Studley	7.162	1.375	No	

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Campus Morning PM2.5Jan28

One Way Analysis of Variance Friday, March 27, 2009, 10:06:26 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:06:26 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Studley	30	2	0.0168	0.0141	0.0212
Carlton	12	2	0.0168	0.0154	0.0179
Sexton	14	2	0.0139	0.0134	0.0153

H = 3.435 with 2 degrees of freedom. (P = 0.180)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.180)

Campus Morning PM2.5Jan30

One Way Analysis of Variance Friday, March 27, 2009, 9:57:07 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 9:57:07 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Studley	27	2	0.00973	0.00883	0.0114
Carlton	13	2	0.0142	0.00966	0.0166
Sexton	14	2	0.0121	0.0115	0.0132

H = 8.295 with 2 degrees of freedom. (P = 0.016)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.016)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05
Carlton vs Studley	11.853	2.340	No
Carlton vs Sexton	0.398	0.0681	Do Not Test
Sexton vs Studley	11.455	2.330	Do Not Test

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Morning Campus PM2.5Feb26

One Way Analysis of Variance Friday, March 27, 2009, 10:02:09 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:02:09 AM

Data source: Data 1 in Notebook1

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Studley	27	3	0.00800	0.00700	0.00950
Carlton	12	2	0.01000	0.00900	0.0110
Sexton	14	2	0.00950	0.00900	0.0105

H = 8.315 with 2 degrees of freedom. (P = 0.016)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.016)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	**Diff of Ranks**	**Q**	**P<0.05**
Carltonvs Studley	11.204	2.218	No
Carltonvs Sexton	0.0167	0.00290	Do Not Test
Sexton vs Studley	11.188	2.357	Do Not Test

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Campus Morning PM2.5 Feb 27:

One Way Analysis of Variance Friday, March 27, 2009, 10:04:18 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:04:18 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Studley	26	2	0.00750	0.00700	0.00800
Carlton	13	2	0.00700	0.00625	0.00875
Sexton	14	2	0.00700	0.00700	0.00900

H = 0.408 with 2 degrees of freedom. (P = 0.816)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.816)

CAMPUS AFTERNOON PM2.5:

Col2 Studley
Col4 Carlton
Col6 Sexton

Campus AfternoonPM2.5 Jan 26

One Way Analysis of Variance Friday, March 27, 2009, 10:19:13 AM

Data source: Data 1 in Notebook1

Normality Test: Passed (P = 0.097)

Equal Variance Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:19:13 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 8	30	2	0.00801	0.00513	0.0128
Col 19	14	2	0.0127	0.0118	0.0155
Col 30	15	2	0.0130	0.0110	0.0146

H = 8.831 with 2 degrees of freedom. (P = 0.012)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.012)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05	
Col 19 vs Col 8	13.155	2.469	Yes	Studley and Carlton are different
Col 19 vs Col 30	1.054	0.171	No	

Col 30 vs Col 8	12.100	2.335	No

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Campus Afternoon PM2.5 Jan 27

One Way Analysis of Variance Friday, March 27, 2009, 10:25:00 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:25:00 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 2	27	0	0.00843	0.00793	0.00901
Col 4	11	0	0.00867	0.00768	0.00978
Col 6	12	0	0.00877	0.00815	0.00990

H = 1.870 with 2 degrees of freedom. (P = 0.393)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.393)

Campus Afternoon PM2.5 Jan 28

One Way Analysis of Variance Friday, March 27, 2009, 10:28:06 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:28:06 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 2	29	0	0.0111	0.0103	0.0126
Col 4	10	0	0.0122	0.0116	0.0129
Col 6	12	0	0.0103	0.00944	0.0124

H = 4.003 with 2 degrees of freedom. (P = 0.135)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.135)

Campus Afternoon PM2.5 Feb26

One Way Analysis of Variance Friday, March 27, 2009, 10:32:01 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:32:01 AM

Data source: Data 1 in Notebook1

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Col 2	23	0	0.00400	0.00300	0.00400
Col 4	12	0	0.00400	0.00300	0.00450
Col 6	12	0	0.00400	0.00400	0.00500

H = 4.779 with 2 degrees of freedom. (P = 0.092)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.092)

Campus Afternoon PM2.5 Feb27:

One Way Analysis of Variance Friday, March 27, 2009, 10:33:13 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:33:13 AM

Data source: Data 1 in Notebook1

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Col 2	26	0	0.00400	0.00300	0.00500
Col 4	11	0	0.00500	0.00400	0.00600
Col 6	14	0	0.00450	0.00400	0.00600

H = 9.586 with 2 degrees of freedom. (P = 0.008)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.008)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	**Diff of Ranks**	**Q**	**P<0.05**	
Col 4 vs Col 2	14.052	2.628	Yes	Studley and Carlton are different
Col 4 vs Col 6	3.377	0.564	No	
Col 6 vs Col 2	10.676	2.166	No	

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Ledgend

Morning Data Sets	
Col 2	Jan26
Col 4	Jan28
Col 6	Jan30
Col 8	Feb26
Col 10	Feb27

Afternoon Data Sets	
Col 2	Jan26
Col 4	Jan27
Col 6	Jan28
Col 8	Feb26
Col 10	Feb27

All days Studley Campus Afternoon Comparisons

One Way Analysis of Variance Friday, March 27, 2009, 10:43:33 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:43:33 AM

Data source: Data 1 in Notebook1

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Col 2	32	4	0.00801	0.00513	0.0128
Col 4	30	3	0.00843	0.00793	0.00901

Col 6	32	3	0.0111	0.0103	0.0126
Col 8	26	3	0.00400	0.00300	0.00400
Col 10	29	3	0.00400	0.00300	0.00500

H = 84.310 with 4 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	**Diff of Ranks**	**Q**	**P<0.05**
Col 6 vs Col 8	79.566	7.394	Yes
Col 6 vs Col 10	77.702	7.465	Yes
Col 6 vs Col 2	30.557	2.993	Yes
Col 6 vs Col 4	29.710	2.883	Yes
Col 4 vs Col 8	49.856	4.559	Yes
Col 4 vs Col 10	47.992	4.532	Yes
Col 4 vs Col 2	0.847	0.0814	No
Col 2 vs Col 8	49.009	4.519	Yes
Col 2 vs Col 10	47.146	4.492	Yes
Col 10 vs Col 8	1.864	0.169	No

Note: The multiple comparisons on ranks do not include an adjustment for ties.

All days Carlton Campus Afternoon Comparisons:

One Way Analysis of Variance Friday, March 27, 2009, 10:45:55 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:45:55 AM

Data source: Data 1 in Notebook1

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Col 2	16	4	0.0127	0.0118	0.0155
Col 4	15	4	0.00867	0.00768	0.00978
Col 6	14	4	0.0122	0.0116	0.0129
Col 8	16	4	0.00400	0.00300	0.00450
Col 10	15	4	0.00500	0.00400	0.00600

H = 46.087 with 4 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	**Diff of Ranks**	**Q**	**P<0.05**
Col 2 vs Col 8	36.250	5.444	Yes
Col 2 vs Col 10	30.485	4.478	Yes
Col 2 vs Col 4	15.576	2.288	No
Col 2 vs Col 6	1.967	0.282	Do Not Test
Col 6 vs Col 8	34.283	4.909	Yes
Col 6 vs Col 10	28.518	4.002	Yes
Col 6 vs Col 4	13.609	1.910	Do Not Test
Col 4 vs Col 8	20.674	3.037	Yes
Col 4 vs Col 10	14.909	2.144	No
Col 10 vs Col 8	5.765	0.847	No

Note: The multiple comparisons on ranks do not include an adjustment for ties.

All days Sexton Campus Afternoon Comparisons:

One Way Analysis of Variance Friday, March 27, 2009, 10:47:41 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:47:41 AM

Data source: Data 1 in Notebook1

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Col 2	17	4	0.0130	0.0110	0.0146
Col 4	16	4	0.00877	0.00815	0.00990
Col 6	16	4	0.0103	0.00944	0.0124
Col 8	16	4	0.00400	0.00400	0.00500
Col 10	18	4	0.00450	0.00400	0.00600

H = 44.758 with 4 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	**Diff of Ranks**	**Q**	**P<0.05**
Col 2 vs Col 8	39.962	5.446	Yes
Col 2 vs Col 10	35.390	5.013	Yes
Col 2 vs Col 4	17.462	2.380	No

Col 2 vs Col 6	8.712	1.187	Do Not Test
Col 6 vs Col 8	31.250	4.176	Yes
Col 6 vs Col 10	26.679	3.700	Yes
Col 6 vs Col 4	8.750	1.169	Do Not Test
Col 4 vs Col 8	22.500	3.007	Yes
Col 4 vs Col 10	17.929	2.486	No
Col 10 vs Col 8	4.571	0.634	No

Note: The multiple comparisons on ranks do not include an adjustment for ties.

All days Studley Campus Morning Comparisons:

One Way Analysis of Variance Friday, March 27, 2009, 10:53:25 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:53:25 AM

Data source: Data 1 in Notebook1

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Col 2	30	4	0.0102	0.00659	0.0126
Col 4	33	5	0.0168	0.0141	0.0212
Col 6	30	5	0.00973	0.00883	0.0114
Col 8	30	6	0.00800	0.00700	0.00950
Col 8	30	6	0.00800	0.00700	0.00950
Col 8	30	6	0.00800	0.00700	0.00950
Col 10	29	5	0.00750	0.00700	0.00800

H = 81.024 with 6 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	**Diff of Ranks**	**Q**	**P<0.05**
Col 4 vs Col 10	105.827	7.509	Yes
Col 4 vs Col 8	89.786	6.371	Yes
Col 4 vs Col 2	70.863	5.136	Yes
Col 4 vs Col 6	51.126	3.667	Yes
Col 6 vs Col 10	54.702	3.778	Yes
Col 6 vs Col 8	38.660	2.670	No
Col 6 vs Col 2	19.737	1.391	Do Not Test
Col 2 vs Col 10	34.965	2.438	No
Col 2 vs Col 8	18.923	1.320	Do Not Test
Col 8 vs Col 10	16.042	1.097	Do Not Test

Note: The multiple comparisons on ranks do not include an adjustment for ties.

All days Carlton Campus Morning Comparisons:

One Way Analysis of Variance Friday, March 27, 2009, 10:57:05 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:57:05 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 2	14	4	0.0112	0.00800	0.0189
Col 4	13	3	0.0168	0.0154	0.0179
Col 6	14	3	0.0142	0.00966	0.0166
Col 8	13	3	0.01000	0.00900	0.0110
Col 10	14	3	0.00700	0.00625	0.00875

H = 23.825 with 4 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05
Col 4 vs Col 10	30.618	4.624	Yes
Col 4 vs Col 8	18.550	2.737	No
Col 4 vs Col 2	11.150	1.645	Do Not Test
Col 4 vs Col 6	9.982	1.507	Do Not Test
Col 6 vs Col 10	20.636	3.193	Yes
Col 6 vs Col 8	8.568	1.294	Do Not Test
Col 6 vs Col 2	1.168	0.176	Do Not Test
Col 2 vs Col 10	19.468	2.940	Yes
Col 2 vs Col 8	7.400	1.092	Do Not Test
Col 8 vs Col 10	12.068	1.823	No

Note: The multiple comparisons on ranks do not include an adjustment for ties.

All days Sexton Campus Morning Comparisons:

One Way Analysis of Variance Friday, March 27, 2009, 10:59:30 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 10:59:30 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 2	16	4	0.0129	0.0117	0.0167
Col 4	15	3	0.0139	0.0134	0.0153
Col 6	15	3	0.0121	0.0115	0.0132
Col 8	15	3	0.00950	0.00900	0.0105
Col 10	15	3	0.00700	0.00700	0.00900

H = 32.580 with 4 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	Diff of Ranks	q	P<0.05
Col 4 vs Col 10	436.500	7.215	Yes
Col 4 vs Col 8	323.500	5.347	Yes
Col 4 vs Col 6	178.000	2.942	No
Col 4 vs Col 2	112.000	1.851	Do Not Test
Col 2 vs Col 10	324.500	5.364	Yes
Col 2 vs Col 8	211.500	3.496	No
Col 2 vs Col 6	66.000	1.091	Do Not Test
Col 6 vs Col 10	258.500	4.273	Yes
Col 6 vs Col 8	145.500	2.405	Do Not Test
Col 8 vs Col 10	113.000	1.868	No

Note: The multiple comparisons on ranks do not include an adjustment for ties.

A result of "Do Not Test" occurs for a comparison when no significant difference is found between the two rank sums that enclose that comparison. For example, if you had four rank sums sorted in order, and found no significant difference between rank sums 4 vs. 2, then you would not test 4 vs. 3 and 3 vs. 2, but still test 4 vs. 1 and 3 vs. 1 (4 vs. 3 and 3 vs. 2 are enclosed by 4 vs. 2: 4 3 2 1). Note that not testing the enclosed rank sums is a procedural rule, and a result of Do Not Test should be treated as if there is no significant difference between the rank sums, even though one may appear to exist.

One Way Analysis of Variance Friday, March 27, 2009, 11:00:12 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)
Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 11:00:12 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 2	16	4	0.0129	0.0117	0.0167
Col 4	15	3	0.0139	0.0134	0.0153
Col 6	15	3	0.0121	0.0115	0.0132
Col 8	15	3	0.00950	0.00900	0.0105
Col 10	15	3	0.00700	0.00700	0.00900

H = 32.580 with 4 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	**Diff of Ranks**	**Q**	**P<0.05**
Col 4 vs Col 10	36.375	5.102	Yes
Col 4 vs Col 8	26.958	3.781	Yes
Col 4 vs Col 6	14.833	2.080	No
Col 4 vs Col 2	9.333	1.309	Do Not Test
Col 2 vs Col 10	27.042	3.793	Yes
Col 2 vs Col 8	17.625	2.472	No
Col 2 vs Col 6	5.500	0.771	Do Not Test
Col 6 vs Col 10	21.542	3.021	Yes
Col 6 vs Col 8	12.125	1.701	Do Not Test
Col 8 vs Col 10	9.417	1.321	No

Note: The multiple comparisons on ranks do not include an adjustment for ties.

One Way Analysis of Variance Friday, March 27, 2009, 11:01:43 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 11:01:43 AM

Data source: Data 1 in Notebook1

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Col 2	16	4	0.0129	0.0117	0.0167
Col 4	15	3	0.0139	0.0134	0.0153
Col 6	15	3	0.0121	0.0115	0.0132
Col 8	15	3	0.00950	0.00900	0.0105
Col 10	15	3	0.00700	0.00700	0.00900

H = 32.580 with 4 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Student-Newman-Keuls Method) :

Comparison	**Diff of Ranks**	**q**	**P<0.05**
Col 4 vs Col 10	436.500	7.215	Yes
Col 4 vs Col 8	323.500	6.670	Yes
Col 4 vs Col 6	178.000	4.877	Yes

Col 4 vs Col 2	112.000	4.572	Yes
Col 2 vs Col 10	324.500	6.691	Yes
Col 2 vs Col 8	211.500	5.795	Yes
Col 2 vs Col 6	66.000	2.694	No
Col 6 vs Col 10	258.500	7.083	Yes
Col 6 vs Col 8	145.500	5.940	Yes
Col 8 vs Col 10	113.000	4.613	Yes

Note: The multiple comparisons on ranks do not include an adjustment for ties.

All Campus by time of day MORNING:

One Way Analysis of Variance Friday, March 27, 2009, 11:07:09 AM
Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 11:07:09 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 1	131	4	0.00965	0.00755	0.0135
Col 2	56	4	0.0110	0.00833	0.0165
Col 3	64	4	0.0119	0.00905	0.0138

H = 7.013 with 2 degrees of freedom. (P = 0.030)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.030)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05
Col 3 vs Col 1	24.917	2.301	No
Col 3 vs Col 2	2.802	0.214	Do Not Test
Col 2 vs Col 1	22.115	1.943	Do Not Test

Note: The multiple comparisons on ranks do not include an adjustment for ties.

All Campus by time of day AFTERNOON:

One Way Analysis of Variance Friday, March 27, 2009, 11:11:53 AM

Data source: Data 1 in Notebook1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, March 27, 2009, 11:11:53 AM

Data source: Data 1 in Notebook1

Group	N	Missing	Median	25%	75%
Col 1	137	4	0.00792	0.00400	0.0104
Col 2	60	4	0.00837	0.00500	0.0122
Col 3	67	4	0.00875	0.00500	0.0116

H = 5.209 with 2 degrees of freedom. (P = 0.074)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.074).

APPENDIX C

(Time Log Dairy)