Magnetic Biomonitoring of Polluted Trees in South Seattle

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Magnetic Biomonitoring of Polluted Trees in South Seattle

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Project Dates: March 29 - August 19 2016

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Magnetic Biomonitoring of Polluted Trees in South Seattle

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Introduction

Particulate matter (PM) air pollution is a major public health issue across the United States. PM air pollution is sourced from a variety of industrial, transportation, and fuel combustion processes (EPA 2016). Through increases in regulation standards, PM air pollution has been gradually decreasing over the past twenty years (Appendix 1.1). Between 1990 and 2011 air toxins and toxicants in the United States decreased by over 60% according to the EPA (2016). Unhealthy air quality days, caused by ozone and particulate matter 2.5 microns (PM$_{2.5}$), also decreased from 2,076 days in 2000 to 675 days in 2014 (EPA 2016). Many of these reductions have been from changes in the National Ambient Air Quality Standards (NAAQS) through the Environmental Protection Agency (EPA). Unfortunately, EPA’s PM$_{2.5}$ health standard goals still are not being met. In the Puget Sound region, three counties are still exceeding NAAQS PM$_{2.5}$ standard goals (PSCCA 2014). While the EPA’s most recent air quality assessment has shown positive results in air quality mitigation (Appendix 1.2), the results fail to recognize the continued public health issues and disparities of air pollution in neighborhoods within cities. Research has shown less affluent communities and communities of color are exposed to higher levels of air pollution than the wealthier and whiter communities (Bell 2012). This trend is clearly shown in Seattle, Washington.

Seattle is located in King County where PM air pollution has been decreasing since 2006 (PSCCA 2014). While overall air quality is improving, the Duwamish Valley in South Seattle is still affected by poor air quality (PSCCA 2010). The South Park and Georgetown neighborhoods are situated in the Duwamish Valley on the Duwamish River, the most industrialized region of Seattle. The region suffers from high PM concentrations from an increased amount of gas and diesel traffic, industrial practices, and wood smoke burning according to one Puget Sound Clean Air Agency study (PSCCA 2016). In an earlier analysis, the PSCCA (2010) found that Diesel PM contributes to 73% of the average potential cancer risk in the Duwamish Valley. The combination of a highly industrialized region and its location in a valley has caused Georgetown and South Park to be disproportionately exposed to the worst air pollution than any other Seattle neighborhood. The Duwamish River is also listed as a National Priority Superfund site (EPA 2001) and has three of the four highest air polluting Toxic Release Inventory (TRI) facilities (Abel, Rodriguez and Clauson 2016) in Seattle. A more recent study monitored particulate matter air pollution in King County, Seattle, and the Duwamish Valley and found the average annual particulate matter concentrations to be higher in the Duwamish Valley compared to the King County average and Greater Seattle average (Schulte et al. 2015).

These two neighborhoods are also home to higher rates of low-income, minority, and Native American populations, as well as higher elderly populations. Over 70% of the residents in Georgetown and South Park are non-white, over 20 languages are spoken, and the median household income is lower than the rest of Seattle (city-data.com). A Cumulative Health Impact Analysis (CHIA) funded through an EPA Environmental Justice Research Grant and the University of Washington created an impact score of disproportionate impacts based on social, environmental, and public health criteria. The study found South Park and Georgetown to be
encompassed within the zip code with the highest disproportionate cumulative impact score in Seattle, scoring a 106 compared to a 13 in Magnolia, one of Seattle’s wealthiest neighborhoods (Gould & Cummings 2013). The Duwamish Valley was also characterized as a highly impacted community by PSCAA, ranking it in the highest five percent of neighborhoods in King, Pierce, Kitsap, and Snohomish counties (Park 2014).

The Duwamish Valley’s high concentration of industry has led to the highest number of contaminated sites and some of the worst air pollution in Seattle. The combination of severe air pollution and higher rates of vulnerable populations, like elderly and children, has led to worse public health issues than other Seattle neighborhoods. For example, the life expectancy in Georgetown and South Park was estimated to be 8 years lower than the Seattle average and childhood asthma hospitalizations were higher than any other neighborhood in King County (Gould & Cummings 2013).

The Duwamish Community Action for Clean Air project was created to mitigate air pollution in the Duwamish Valley. This includes the implementation of two green facades, one in South Park and one in Georgetown, to improve air quality. Just Health Action funds the green façade project through a $45,000 grant from King County’s green grant program for the Duwamish region. A green façade is a stand-alone trestle structure that grows vegetation, creating a green screen-like result (http://greenscreen.com/products/elements/). Green space in urban environments has been shown to improve air quality and decrease many public health issues (Nowak 2014). To determine where to place the facades and to continue monitoring air pollution, there needs to be a clear and accurate representation of the air pollution in the two neighborhoods. Unfortunately, the neighborhoods lack a spatial analysis of the air pollution within South Park and Georgetown. There is only one air pollution monitor in each neighborhood (PSCAA 2010), making it difficult to determine the variation in air pollution. This project provides a spatial analysis using leaf samples to help the decision-making process of the green façade implementation and further air pollution mitigation.

**Literature Review**

Disproportionate exposure to toxic pollutants on minority and low income communities is a common trend throughout the United States (Collins et al. 2016). One study found that low-income and minority populations were disproportionately exposed to “hyper-polluters” and a polluters ability to affect these neighborhoods could be based on less power to resist within the exposed community (Collins et al. 2016). A study characterizing air pollution in the Duwamish Valley found worse air pollution near busier roadways, as well as disparities in diesel air pollution in South Park and Georgetown compared to other Seattle neighborhoods (Schulte et al. 2014).

This research was also informed by a growing body of work that uses leaves as a biocollector of particulate matter that can help identify particulate matter air pollution. Particulate matter (PM) is a form of air pollution that can be in both liquid and solid form. PM is categorized as either PM 10 microns or smaller (PM$_{10}$) or PM 2.5 microns or smaller (PM$_{2.5}$). PM
is harmful to human health because it can be inhaled easily and enter the lungs or bloodstream (EPA, Particulate Matter Pollution, 2016). A study found that an increase in exposure to PM is directly correlated to an increase in asthma hospitalizations in Seattle (Schwartz et al, 1993). Anthropogenic PM can contain high levels of magnetic properties, so testing the magnetic susceptibility of urban leaf samples can help characterize a spatial distribution of air pollution (Rai and Chutia, 2016). PM attaches to, and is slightly absorbed by, tree leaf surfaces, making them a useful biocollector (Nowak, 2014).

Tree leaves, moss, and lichens are increasingly being recognized as an effective and inexpensive biocollector of particulate matter pollution to help identify air toxics hotspots. In Portland Oregon for instance, two air toxic hotspots led the state’s health department to issue an advisory against eating garden vegetables for residents living within a half-mile of two facilities (Terry, 2016). These elevated levels of arsenic, lead, and nickel particulate matter were identified by analyzing moss samples collected by US Forest Service scientists (Zarkhin, 2016). A study in Rome, Italy found that tree leaves with higher magnetic concentrations and larger grain size were located in close vicinity to high traffic roads and railways (Moreno et al., 2003). A study in Bellingham, WA used biomonitors of PM and found that magnetic concentrations increased two to eight times when in close vicinity to vehicle PM sources (Housen, 2014). Likewise, other researchers have also used magnetic hysteresis of tree leaves to identify vehicle-derived particulate matter pollution variations in India (Rai, 2014), Finland (Bucko et al., 2010), and Portugal (Sant’Ovaia, Lacerda, Gomes, 2012).

Seattle’s air pollution riskscape has never been analyzed with leaf samples and this pilot project builds on a two-year Collaborative Problem Solving and Environmental Justice project funded by the EPA. Participants included the Duwamish River Cleanup Coalition (DRCC), Just Health Action (JHA), the Washington Chapter of the American Lung Association (ALA), the Puget Sound Clean Air Agency (PSCAA), Western Washington University’s (WWU) Huxley College of the Environment’s Peninsulas Program, and the Georgetown and South Park Neighborhood Associations.

**Project Activities**

*Site Description*

The leaf samples were collected in the Georgetown and South Park neighborhoods of Seattle. Georgetown and South Park are situated in the Duwamish Valley on the Duwamish River. The region was previously a meandering river, but has transformed into a concentrated industrial hub, turning the river into a very active waterway for Seattle industry.

*Sampling*

The leaves were sampled over three days in the end of June. Using a sampling design tool with ArcGIS, trees were selected from each neighborhood to sample. The tool used spatial sampling to create a randomized selection of trees. The tool used tree inventory data from the Seattle Department of Transportation (SDOT). The tree inventory includes all public trees in
Seattle, with the capabilities to specify neighborhoods. Through the tree inventory, only deciduous trees were selected and then randomized with ArcGIS to provide 27 spatially distributed samples for each neighborhood, Georgetown and South Park (Figure 1). Deciduous trees were used to remove the need to include year-to-year differences in trees and to provide large surface areas on leaves to sample from.

Using the sampling map, five leaves were sampled from each tree. The leaf samples were collected between June 27th and June 29th. Using the ArcGIS mapping tool to determine the correct tree to sample, five leaves were taken from each tree. The samples were chosen based on the height (1-3 meters) and the location on the tree. Leaves should be older leaves on newer branches, located on the outsides of the tree (Rai et al 2014). Choosing older leaves in similar locations on the trees allows for less variability in age and geographic location. The samples were collected using extendable tree trimmers. The height and cardinal direction of each leaf sample was recorded. The leaf samples were labeled and placed into plastic Ziploc bags. The samples were then stored in a refrigerator to help preserve them while prepping and testing the samples.

Figure 1. The sampling data set for Georgetown and South Park. Created using a sample tool and ArcGIS by Stacy Clauson.

Using the sampling map, five leaves were sampled from each tree. The leaf samples were collected between June 27th and June 29th. Using the ArcGIS mapping tool to determine the correct tree to sample, five leaves were taken from each tree. The samples were chosen based on the height (1-3 meters) and the location on the tree. Leaves should be older leaves on newer branches, located on the outsides of the tree (Rai et al 2014). Choosing older leaves in similar locations on the trees allows for less variability in age and geographic location. The samples were collected using extendable tree trimmers. The height and cardinal direction of each leaf sample was recorded. The leaf samples were labeled and placed into plastic Ziploc bags. The samples were then stored in a refrigerator to help preserve them while prepping and testing the samples.
Testing

The leaf samples were then brought back to WWU’s Pacific Northwest Paleomagnetism Lab (PNWPL) to perform a magnetic hysteresis analysis. A MicroMag™ 3900 Vibrating Sample Magnetometer (VSM) was used to perform the magnetic hysteresis analysis (Appendix 2.1). The analysis tested for particulate matter in leaves. Leaves were cut and inserted into gelatin capsules before being placed in the VSM (Appendix 2.2, 2.3). The surface area and mass were measured for each sample before being placed in the gelatin capsules.

A measurement was taken by using a magnetic hysteresis loop. Hysteresis tests for the total particulate matter, including ultrafine particulate matter. Particulate matter is mostly heavy metals, so the more magnetic the sample is, the more PM is present. Magnetic hysteresis measurements are taken by testing the direct magnetic moment versus the field. This forms the hysteresis loop (Princeton Measurements Corporation 2009). Each test provides a hysteresis loop that will give the saturation remanence ($M_r$), saturation magnetization ($M_s$), and coercivity of remanence ($H_c$) (Tauxe et al. 2002). To develop a hysteresis loop that provides the $M_r$, $M_s$, and $H_c$, adjustments were made to the testing software for each sample. The toggle VSM process is the act of the sample vibrating to create a hysteresis loop. For a strong hysteresis loop the averaging time and sensitivity may need to be adjusted. All samples started at a 0.5 second average time and a sensitivity of 500 µemu. The longer the average time, the smoother the sample’s curve will turn out. To make sure every tree had at least one very smooth curve, one sample from each tree was tested with an averaging time of one second or longer. After a viable hysteresis loop was formed, each sample was corrected for dia/paramagnetic characteristics. Each sample was automatically adjusted for 70% Hmax above the assumed saturation for each sample (Princeton Measurements Corporation). The $M_s$, $M_r$, and $H_c$ were collected from the corrected hysteresis loop.

Data Analysis

Once the $M_s$, $M_r$, and $H_c$ were collected for each sample, the $M_s$ and $M_r$ were normalized with the mass of the sample. To normalize the samples, the $M_s$ and $M_r$ was divided by the mass in milligrams. The normalized $M_s$ ($N-M_s$) value was then used to determine the total metallic particulate matter concentration in the sample (Housen 2014). The normalized $M_r$ ($N-M_r$) was used to determine the remanent amount of magnetic properties left of the sample. The data was plotted as squareness ($N-M_r / N-M_s$) versus coercivity ($H_c$). This relationship helped determine the size and type of particle that was present in the samples. Samples with a higher coercivity and squareness will be smaller in size, like PM$_{2.5}$ or less. If a sample has a high $M_s$ value as well as a high coercivity and squareness, it could mean that the sample either has a larger amount of small PM or that the PM composition is more magnetic (Tauxe et al. 2002).
Results

Saturation Magnetization

Both neighborhoods show variation in the N-M_s data. The concentrations for each sample were averaged together to produce an average concentration for each tree (Table 1). In Georgetown, the highest concentration is at 7201 E Marginal Way S and the lowest concentration is at 6433 Flora Avenue S (Table 1). In South Park, the highest concentration is at 836 S Sullivan Street and the lowest concentration is at 8437 13th Avenue S.

Table 1. A ranking of the 27 tree samples for each neighborhood based on an averaged Ms concentration for each tree.

<table>
<thead>
<tr>
<th>Ranking*</th>
<th>Tree Number</th>
<th>N-M_s* (µemu/mg)</th>
<th>Address</th>
<th>Ranking*</th>
<th>Tree Number</th>
<th>N-M_s* (µemu/mg)</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GT17</td>
<td>0.1736</td>
<td>6433 Flora Ave S</td>
<td>1</td>
<td>SP17</td>
<td>0.1585</td>
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<td>2</td>
<td>GT8</td>
<td>0.2276</td>
<td>660 S Fidalgo St</td>
<td>2</td>
<td>SP9</td>
<td>0.1735</td>
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<td>0.2309</td>
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<td>3</td>
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<td>0.1735</td>
<td>8420 8th Ave S</td>
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<td>4</td>
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<td>5</td>
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<td>6625 Flora Ave S</td>
<td>5</td>
<td>SP3</td>
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<td>0.3538</td>
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<td>SP20</td>
<td>0.3583</td>
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<td>8</td>
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<td>5700 4th Ave S</td>
<td>8</td>
<td>SP15</td>
<td>0.3741</td>
<td>8457 Dallas Ave S</td>
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<td>9</td>
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<td>0.5100</td>
<td>6020 6th Ave S</td>
<td>9</td>
<td>SP6</td>
<td>0.3855</td>
<td>1007 S Thistle St</td>
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<tr>
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<td>5620 6th Ave S</td>
<td>10</td>
<td>SP4</td>
<td>0.4151</td>
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<tr>
<td>11</td>
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<td>0.6548</td>
<td>660 S Fidalgo St</td>
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<td>SP25</td>
<td>0.4303</td>
<td>702 S Donovan St</td>
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<tr>
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<td>SP12</td>
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<tr>
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<td>SP16</td>
<td>0.7143</td>
<td>1203 S Sullivan St</td>
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<td>17</td>
<td>SP1</td>
<td>0.7365</td>
<td>10th &amp; Dallas Triangle</td>
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<td>SP18</td>
<td>0.7903</td>
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<td>19</td>
<td>SP1</td>
<td>0.7922</td>
<td>7265 2nd Ave S</td>
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<td>0.8618</td>
<td>8110 Dallas Ave S</td>
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<tr>
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<td>SP14</td>
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<td>22</td>
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<td>SP22</td>
<td>1.1411</td>
<td>516 S Concord</td>
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<td>GT21</td>
<td>2.0973</td>
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<td>23</td>
<td>SP27</td>
<td>1.1472</td>
<td>522 S Concord</td>
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<td>6414 Flora Ave S</td>
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<td>1.3378</td>
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<tr>
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<td>3.2228</td>
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<td>SP21</td>
<td>1.7142</td>
<td>836 S Sullivan St</td>
</tr>
</tbody>
</table>

*The ranking is from the lowest N-M_s concentration to the highest N-M_s concentration. N-M_s is an averaged value of the normalized Ms value from 5 samples for each tree.

Georgetown has an absolute difference of 4.234 µemu/mg from the highest N-M_s concentration compared to the lowest N-M_s concentration (Figure 2). South Park shows less variation between the highest sample concentration and the lowest, with an absolute difference of 1.556 µemu/mg (Figure 2). Between neighborhoods, there is more variation between samples in the 75th percentile than the 25th percentile. Georgetown’s average 75th percentile concentrations are 87.99% higher than South Park’s (Table 1). Georgetown’s average concentrations in the 25th percentile are only 9.093% higher than South Park’s concentrations (Table 1).
Figure 2. Averages of the normalized magnetization saturation (N-M_s) for each tree in the Georgetown and South Park neighborhoods, Seattle, WA.

Georgetown’s average concentrations in the 75th percentile are 2.930 µemu/mg, while South Park’s average concentrations are 1.371 µemu/mg, producing a percent difference of 72.51% (Table 1). However, when all concentrations were averaged for each neighborhood, Georgetown’s concentrations were 50.83% higher than South Park’s concentrations (Table 1).

**Squareness and Coercivity**

The N-M_r, N-M_s, and H_c were plotted as squareness versus coercivity to determine the size of the PM. All samples were plotted, excluding negative samples, determining that most of the PM is larger in size. Higher squareness and coercivity mean that the sample is smaller. The majority of the samples have a low squareness and coercivity (Figure 3). The average coercivity for all the samples in Georgetown is 101.5 Oe and the average for South Park is 107.8 Oe, making South Park’s coercivity 6.020% larger. The average squareness for all samples in Georgetown is 0.1309 µemu/mg and the average squareness for all samples in South Park is 0.1187 µemu/mg, making Georgetown’s squareness 9.776% larger.
Figure 3. The squareness versus coercivity of all* samples from Georgetown and South Park. *Samples GT4-5, GT6-2, GT7-3 GT8-1 GT18-2, SP3-5, SP9-1, SP9-2, SP17-2 was excluded from the plot because the samples produced a negative $M_r$ value.

There is little variation between the data from Georgetown and South Park in the 25th percentile. Georgetown has an average coercivity of 96.94 Oe and an average squareness of 0.1113 $\mu$emu/mg (Figure 4).

Figure 4. Samples* from the 25th percentile based on averaged saturation magnetization ($M_s$) plotted for squareness versus coercivity

*Samples GT4-5, GT6-2, GT7-3 GT8-1 GT18-2, SP3-5, SP9-1, SP9-2, SP17-2 were excluded from the plot.
South Park has an average coercivity of 98.77 Oe and an average squareness of 0.1104 µemu/mg (Figure 4). South Park has an average coercivity 1.870% higher than Georgetown and Georgetown has an average squareness that is 0.8119% higher than South Park.

Figure 5. Georgetown samples from the 75th percentile and the 25th percentile based on averaged saturation magnetization (Mₘ) plotted for squareness versus coercivity. *Samples GT4-5, GT6-2, GT7-3, GT8-1, and GT18-2 were excluded from the plot.

Figure 6. South Park samples from the 75th percentile and the 25th percentile based on averaged saturation magnetization (Mₘ) plotted for squareness versus coercivity. *Samples SP3-5, SP9-1, SP9-2, and SP17-2 were excluded from the plot.
A comparison of the average squareness and average coercivity of the 25th and 75th percentile for Georgetown shows that samples in the 25th percentile has an average coercivity 11.95% higher and an average squareness 44.39% higher than samples in the 75th percentile (Figure 5). Samples in the 75th percentile and 25th percentile for South Park show that the average coercivity is 12.43% higher and the average squareness is 16.67% higher for samples in the 25th percentile. (Figure 6).

Georgetown

The saturation magnetization concentrations from the leaf samples seems to be associated with proximity to high traffic corridors. The highest N-Ms values in Georgetown are found on, or near, busy roadways and heavily industrialized areas. One exception is the high Ms value at 6414 Flora Avenue S (GT19). Three trees on Flora Avenue are a part of the 25th percentile of Ms concentrations, but 6414 Flora Avenue S is in the 75th percentile. The high concentration could be from the tree’s close vicinity to Eddy Street. GT19 is located towards the corner of Flora Avenue and S Eddy Street. Two blocks west on Eddy Street is Corson Avenue S, a high traffic road, and a company that services industrial diesel engines (Bloomberg). One block east of Flora Avenue and S Eddy Street is Ellis Avenue and S Albro Place, where the area becomes more industrial (Google Maps). The other 75th percentile concentrations are located on, or near, busy roadways and industry (Figure 7.1). The highest N-Ms concentration came from tree sample GT15 at 7201 E Marginal Way S. Marginal Way is a very high traffic roadway, receiving a lot of traffic air pollution (Appendix 3). The tree is also located next to a railroad, across the street from Boeing Field, and is surrounded by numerous other industrial businesses (Figure 7.2).
The tree with the lowest N-Mₙ concentration, GT17, is located on 6433 Flora Avenue S. The tree is in the center of a residential area covering about three square blocks. The area has a relatively high level of tree cover in comparison to the rest of the Georgetown neighborhood (Figure 7.3).

*South Park*

The N-Mₙ concentrations from South Park show more spatial variability in the tree samples. While there is more spatial variability, the 75th percentile samples are still closer to busier roadways. Four of the top six samples are within two blocks of Highway 99 (Figure 8.1).
Figure 8.1. Map of South Park showing samples in the 75th percentile and 25th percentile of N-M$_s$ concentrations.

Three of the six with the highest N-M$_s$ concentrations are also within one block of the Concord International School. One is directly in front of it (Figure 8.2).

Figure 9.2. Aerial photo of Google Maps showing the close vicinity of The Concord International School and three trees in the 75th percentile N-M$_s$ concentrations.

The Concord International School is within a block of Highway 99, but is also situated in a residential neighborhood. Two of the trees are over two blocks away from Highway 99, but still have some of the highest M$_s$ concentrations. The high concentrations could be from an increase in traffic, from both cars and diesel buses, caused by the school. South Park as some of the
highest childhood asthma hospitalizations in Seattle, so high concentrations of PM air pollution near schools is worrisome.

Most of the lowest concentrations are located on the east side of Highway 99 (Figure 8.1), except for one tree on S Henderson Street. The lowest concentrations are all located in residential neighborhoods. One is directly across the street from South Park Playground. SP19, the tree on S Henderson Street, is one block down from S Concord Street, on the other side of the Concord Elementary School (Figure 8.1). The large difference in N-M\textsubscript{s} concentrations over a 1-2 block radius could depend on the amount of traffic or green space that differs on the two streets.

836 S Sullivan Street (SP21) has the highest N-M\textsubscript{s} concentration out of all the South Park samples. SP21 is located in a residential neighborhood and a block away from 8\textsuperscript{th} Avenue S, a busy roadway. SP21 is also located near the South Park Community Center and South Park Playground. SP7, the fourth highest concentration in South Park, is located a block away from SP21, and is also near the community center and playground. While two of the highest M\textsubscript{s} concentrations are located near the community center and playground, one of the lowest concentrations is as well. A sample taken on 8\textsuperscript{th} Avenue (SP10) is located near both SP21 and SP7, but is the third lowest concentration in South Park. Variation in these concentrations could be based on traffic, bus routes, or surrounding construction.

\textit{Squareness and Coercivity}

The squareness (N-M\textsubscript{r}/N-M\textsubscript{s}) and coercivity (H\textsubscript{c}) helped determine the relative size of the magnetic properties tested. When plotted, the data showed that South Park and Georgetown have similar PM size, both having a few outliers (Figure 3). The majority of the samples showed a trend of larger PM size. Lower coercivity and squareness means that larger PM are present (Tauxe et al 2002). Nine samples were excluded from the graph because they produced negative M\textsubscript{r} values. M\textsubscript{r} is the saturation remanence of the sample (Tauxe et al 2002). While samples cannot have an actual negative saturation remanence, a negative number can be caused by weak samples. A weak sample produces a small curve which can cause negative M\textsubscript{r} values. Figure 10.1 compares a weak hysteresis curve from one of the omitted samples (Figure 9.1) to a strong hysteresis curve from a sample with one of the highest N-M\textsubscript{s} concentrations (Figure 9.2)
The data showed little difference in PM size between Georgetown and South Park. The data did show that PM concentrations in both Georgetown and South Park are larger in size because of the low squareness and coercivity (Tauxe et al. 2002). Further testing of the samples, such as an inductively coupled plasma mass spectrometry (ICP-MS) analysis could help determine what the PM concentrations are composed of and then be able to link them to PM sources.

**Discussion and Conclusion**

The study produced preliminary data providing a spatial representation of particulate matter air pollution in the Georgetown and South Park neighborhoods in South Seattle. The data showed strong correlations of higher PM concentrations in areas with more industry and busier roadways in Georgetown. South Park also showed correlations in higher PM concentrations and more industry and busier roadways, but showed more variation in PM concentrations throughout the area. Adding green space to the areas with the highest PM concentrations could help mitigate the PM air pollution in these neighborhoods. The data showed that the majority of the samples had a low squareness and coercivity, meaning the PM particles are larger in size. Continuing testing for leaf samples over a period of time and sampling more trees within the neighborhoods will help to further determine the variation patterns. An ICP-MS analysis and further tests for the size of PM particles could help determine pollution sources in the region. The preliminary data can be used to assist the communities of South Park and Georgetown on mitigating their current and future air pollution and public health issues.

In comparison to the magnetic hysteresis biomonitoring study in Bellingham, WA, there was a large variation in magnetic concentrations. Bellingham, WA, located north of Seattle has been ranked the least smoggy city in the United States by the American Lung Association (Connelly 2015). The lowest concentrations for both South Seattle and Bellingham ranged between 0.1-0.2 µemu/mg, mostly in residential areas with low traffic. The highest concentrations were much more diverse. The highest concentrations measured in Bellingham ranged between 0.4-0.5 µemu/mg. These samples are located on roadways with the some of the highest traffic in Bellingham. The highest concentrations for Georgetown and South Park ranged between 1.0-5.0 µemu/mg, or between two and ten times as high as the Bellingham concentrations. The highest concentrations in Seattle were also located on busy roadways, but had much higher magnetic concentrations. The difference in the highest magnetic concentrations in Bellingham and South Seattle help characterize how much worse the air pollution is in Georgetown and South Park.

The study characterizing air pollution in Georgetown and South Park in 2013 found similar findings of air pollution concentrations in Georgetown, but more variation in South Park (Schulte 2013), using their August pollution scores. High concentrations along Marginal Way in
Georgetown showed the highest levels of air pollution. It also showed high levels of air pollution along Airport Way and Interstate-5, an area that was not represented in this study, because few trees were randomized near that location. The Schulte et al. (2013) study also showed high levels of air pollution in Northern South Park, an area that also was not represented well in this study with few trees sample. One tree was located in Northern South Park and was ranked in the 50th percentile of high magnetic concentrations, but not in the 75th percentile. A major difference in the Schulte et al. (2013) study and this study is the large difference in concentrations near Concord Elementary School. The Schulte et al. (2013) study showed some of the lowest concentrations near the elementary school, while this study had three of the most polluted trees within a block of the school (Figure 8.1).

This study has provided preliminary spatial characterization of the PM air pollution riskscape in Georgetown and South Park using biomonitoring data. The Duwamish Valley only has two consistent air monitoring stations and this study showed that there is a diverse range of PM concentrations within each neighborhood. One monitoring station near each neighborhood may not provide an accurate representation of the distribution of PM in the Duwamish Valley. The range of PM concentrations and the environmental injustice issues surrounding these two neighborhoods make Georgetown and South Park important areas for air pollution mitigation and further testing. With such contrasting results in the central South Park neighborhood between this study and Schulte et al. (2013), and a lack of representation near Interstate-5 and Northern South Park, further biomonitoring should be conducted in this region. Hopefully this data can be helpful for the decision-making process of the implementation of the green facades and future air pollution mitigation, but also to develop an understanding of the variation in PM concentrations both within each neighborhood and among other regions.

**Huxley & Fairhaven Connections**

Being a Fairhaven student with a Huxley minor has given me a unique skill set that has benefited my process of developing and implementing my senior project. As a Fairhaven student, I have become accustomed to an interdisciplinary process, independent study, and a social justice lens. Having already completed three independent studies (Elwha Dam Removal, Environmental Justice, and an internship with Sustainable Connections) during my time at Fairhaven, it has helped me hone my study skills for working alone. The interdisciplinary process and social justice lens has also helped a lot while working on my senior project. While the research was primarily science focused, it included some important social and community components that have helped me better understand the environmental issues in South Seattle, as well as learn how environmental issues and social issues are so closely connected. Having already developed a social justice lens and having written a concentration that connected research, policy, and justice, I felt like I came into my project with a better understanding of the connections in environmental and social issues. While my education at Fairhaven helped me with the overall process of my senior project, my education at Huxley has helped me much more with the technical process.
My classes at Huxley lacked a lot of the social justice, interdisciplinary, and independent study skills that Fairhaven helped me with, but overall I think Huxley was much more beneficial in the completion of my project. Through my environmental science classes at Huxley, I developed a stronger understanding of the research process. Knowing quality assurance/quality control steps, turning my data into helpful information, and writing a research lab report are all skills I have learned through Huxley. More specifically, I strengthened these skills, that I had been working on since my freshman year, in Huxley’s Water Quality with Lab class. A major component of the class was collecting field samples, practicing QA/QC, and writing a final lab report. While my project worked with leaf samples, not water, the skills I learned in Water Quality made me much more confident in the research process.

Huxley & Fairhaven Disconnections

I think all of the skills I developed in both Fairhaven and Huxley were incredibly helpful in my ability to produce my senior project. Without the combination of these two educational paths, I think I would have had more personal challenges. One area that both Huxley and Fairhaven lacked was environmental justice themes. I know that Huxley is trying to improve on this, and Fairhaven has a more overarching social justice theme, but if it wasn’t for the Political Science Environmental Injustice class, I wouldn’t have had a solid understanding of environmental injustice or known about this project. Overall, this process has been an incredibly beneficial and enjoyable learning experience. Although Huxley and Fairhaven provided me with a strong set of skills coming into the project, working on this project independently has only strengthened them more.

Appendices

Appendix 1.1 EPA 2016 report findings on national air quality concentrations.
Appendix 1.2 EPA 2016 report findings of national air emission trends

Appendix 2.1. MicroMag™ 3900 Vibrating Sample Magnetometer (VSM) located in the PNW Paleomagnetism lab at WWU.
Appendix 2. Sequence of steps for testing leaf samples (1) cut leaf into rectangular shape then (2) measure the height and width of leaf then (3) role into gelatin capsule then (4) measure the sample then (5) place capsule on metal rod and then (6) place sample in the VSM and use computer software to develop magnetic hysteresis loop.

Appendix 3. Photo taken of tree GT15 on June 29th, when the tree was sampled. The close vicinity to the railroad and a major roadway are shown clearly.

References


Bell, Michelle L., and Ebisu Keita. 2012/ "Environmental Inequality in Exposures to Airborne Particulate Matter Components in the United States.” *Environmental Health Perspectives* 120.12: 1699-704.


