Chapter 4: Experiment 2—Application of Personal Ozone Exposure Monitoring in Urban Parks

Introduction

This study was part of a program of research investigating recreation activity, health benefits, and risks across socioeconomic differences in the City of Los Angeles, California. The scope of this research is designed to investigate multiple dimensions of community vulnerability and resilience under changing climate conditions in this socially complex metropolis (Winter et al. 2019). Potential study communities were evaluated for their percentage of residential land use (with an aim to stay away from zones that were primarily commercial or industrial), attributes of disadvantage and affluence, and amount of tree canopy cover (in this step, drawing primarily from McPherson et al. 2008 and the community profiles from a Los Angeles Times website called “Mapping L.A. Neighborhoods” [http://maps.latimes.com/neighborhoods]). The communities of Sun Valley and Brentwood were selected as case examples of a disadvantaged (DAC) and an affluent (AFF) community, respectively. In each community, two public parks were identified for focused study (fig. 4.1A). Each of the four parks chosen had similar physical amenities, including play areas for children; restrooms; open space for unstructured activities; at least one ballfield for soccer, baseball, or another sport; and picnic areas (fig. 4.1B).

Within the affluent community of Brentwood, Crestwood Hills Park (AFF) is tucked into a largely residential area consisting of single-family homes (fig. 4.2A). Barrington Recreation Center (AFF) is situated within a mixed development of multi-family housing, single-family homes, and commercial properties (fig. 4.2B). The two parks selected in Sun Valley were Sun Valley Recreation Center (DAC) (fig. 4.3A) and Fernangeles Recreation Center (DAC) (fig. 4.3B). Both were surrounded by a mix of commercial and residential land uses, and both had industrial centers nearby, including an active quarry and a battery recycling center (US Census Bureau 2014).

The Brentwood community (AFF) was characterized as having greater anticipated resilience to climate change effects as a result of its relative social, economic, and environmental attributes. Brentwood had a higher proportion of service and entertainment businesses, including health care services. In contrast, Sun Valley (DAC) had a higher percentage of manufacturing and other industrial sites as well as trucking and warehousing services. Sun Valley was anticipated to have greater vulnerability to climate change, owing primarily to socioeconomic disadvantages and other factors typical of low-income communities (see Winter et al. 2019). The Sun Valley population has less than half the median income of
Brentwood and a notably higher population density. Sun Valley had markedly less tree canopy cover, and residential areas were closer to major roadways.

Several differences between the Sun Valley area and Brentwood are evident (fig. 4.1B). Both Sun Valley parks are located near major highways and therefore are at greater risk of degraded air quality (O’Neill et al. 2003). Tree canopy cover appears more prevalent in the Brentwood community, and neither of the Brentwood parks appear to have industrial activity nearby. These characteristics (proximity to highways and industrial areas and tree canopy cover) confirm structural differences
between the two communities. Our aim was to understand if these contrasting communities had different levels of environmental risk from impaired air quality, particularly from greater exposure to ozone.

Affluent and disadvantaged communities may be differently sensitive to environmental shifts associated with climate change, and furthermore, we might anticipate people with higher exposure to air pollution to make more use of urban parks on high-heat days (see Winter et al. 2019). This could result in an increased risk from elevated ozone, given the synergistic relationship between extended heat spells and ozone production.

Figure 4.1B—Satellite views of the case study parks.
Figure 4.2—Satellite view of (A) Crestwood Hills Park and (B) Barrington Recreation Center in the affluent community of Brentwood. Note the presence of tree and vegetation cover.
Figure 4.3—Satellite view of (A) Sun Valley Recreation Center and (B) the Fernangeles Recreation Center in the disadvantaged community of Sun Valley. Note the nearby presence of major roadways.
Approach and Methods

As described in previous chapters, Ogawa badge-type passive monitors were used to estimate exposures to ozone by park visitors. In experiment 2, two observers visited each park five times between late August and late September. Timing was determined by field team availability and months when ozone levels are typically high. We intentionally selected months expected to have higher ozone loads to increase the probability that we would be able to distinguish patterns of exposure between the two communities. Park observations took place between 10 a.m. and 3 p.m. on weekends and weekdays. During each visit, observers worked together to identify and record recreational use while following a prescribed path through the park. Observation sweeps occurred upon arrival at 10 a.m., 12 p.m., and 2 p.m. Between sweeps, observers remained in the park, outdoors. Each observer wore two badges, which resulted in the use of four filters per person and eight filters per
sampling day. A field blank was used during each park visit to check for systematic errors and correct for any effects of time and travel. The field blank was kept sealed in the container and carried in the field by one of the observers. The badges were pinned or clipped to clothing on the upper torso; one badge on the front and one badge on the back as shown in figures 4.4A and 4.4B. Specific placement on the torso varied based on garment and observer comfort.

The protocol for ozone monitoring and paired recreation observations was strictly prescribed and followed. The protocol ensured consistency of exposure methods across days, proper handling to prevent unintended contamination of collector badges and filter pads, and the ability to contrast data collected by different pairs of observers. Prior to deployment, the badges were stored in small sealable plastic bags placed in sealed plastic jars. Upon arrival, observers adhered to the protocol as shown in box 1.

Regional, Real-Time Ozone Monitoring

Los Angeles and much of the southern California region have a network of electronic ozone monitoring stations maintained by a colloquium of agencies including the U.S. EPA, California Air Resources Board, and South Coast Air Quality Management District (data are available online at http://www.epa.gov/airdata/ad_data.html). Monitoring locations are indicated by the triangles in figure 4.1A. The sites closest to each of the parks were selected both for comparisons of the passive ozone data and for comparisons of diurnal ozone concentration patterns. Search parameters were entered into the online data repository: state = California; county = Los Angeles; amount of ozone across range of dates; 24-hour period each day.1

Data and Results

**Passive ozone monitors**—

Ozone exposures determined by passive sampling differed widely across sampling days from a low of 29 ppb on September 5 to a high of 83 ppb on September 30 (fig. 4.5). The average across all days in parks in affluent versus disadvantaged communities was not significantly different: 46 ppb in the Brentwood (AFF) parks (black) as compared to 50 ppb (gray) in the Sun Valley (DAC) parks. In comparing the parks individually, Sun Valley Recreation Center (DAC) had the highest average value across sampling days, which was significantly higher than Barrington

1 Investigators who want to replicate this procedure may benefit from knowing that there is a lag time between the days of interest and availability of the online data.
Recreation Center (AFF) (table 4.1). However, exposure at Fernangeles Recreation Center (DAC) was similar, on average, to that recorded at Barrington Recreation Center (AFF). Three days of measurement revealed ozone exposures that exceeded the U.S. EPA threshold for deleterious health effects, suggesting that limited outdoor activities would have been advisable on these days, especially for sensitive populations.

<table>
<thead>
<tr>
<th>Location and date</th>
<th>Brentwood parks</th>
<th>Sun Valley parks</th>
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<tbody>
<tr>
<td>25 Aug.</td>
<td>Brentwood</td>
<td>Sun Valley</td>
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<tr>
<td>27 Aug.</td>
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<td>4 Sept.</td>
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<td>11 Sept.</td>
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<td>27 Sept.</td>
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<tr>
<td>28 Aug.</td>
<td>Fernangeles</td>
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<tr>
<td>30 Aug.</td>
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<tr>
<td>21 Sept.</td>
<td></td>
<td>Fernangeles</td>
</tr>
<tr>
<td>24 Sept.</td>
<td></td>
<td>29 Sept.</td>
</tr>
<tr>
<td>31 Aug.</td>
<td>Sun Valley</td>
<td>10 Sept.</td>
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<tr>
<td>10 Sept.</td>
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<tr>
<td>22 Sept.</td>
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<td>26 Sept.</td>
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Figure 4.5—Personal ozone exposures as measured by passive samplers. Average exposure of two observers each wearing 4 filters (n = 8). Light grey bars are data from the affluent community parks (Barrington and Crestwood Hills); dark grey bars are from the parks in disadvantaged communities (Fernangeles and Sun Valley). Error bars = standard error of the mean; ppb = parts per billion.
Active ozone monitors—
A common approach when calibrating passive monitoring systems is to compare the calculated data derived from the passive technique to the data produced from electronic monitoring instruments. Los Angeles has four ozone monitoring stations in relative proximity to the parks. For the Brentwood (AFF) parks, hourly ozone concentrations for each sampling day were downloaded from station number 0113 (fig. 4.1A). Two monitoring stations were available for the Sun Valley (DAC) parks—1201 and 1002. Linear regression analysis was conducted to determine if the data from the two active monitoring stations differed. Analysis of the two data
sources revealed that the average ozone concentrations on the 8 days monitored had a slope of 0.886 and an R\(^2\) of 0.881, indicating a slight bias between the two, but a good correlation. As there was no way to determine which of the two monitoring stations was correct, we chose to use an average of the two stations for comparison to the passive monitor data.

A side-by-side comparison of active monitors and passive Ogawa badges did not provide definitive results (fig. 4.6). A regression analysis comparing the complete datasets for both passive monitor and active station data determined an R\(^2\) of less than 0.3. However, only Barrington Park (AFF) was within 0.6 km (1 mi) of the active monitoring station; Crestwood Hills Park was 4 km (2.5 mi) from the station (fig. 4.1A); and monitoring stations for the Sun Valley parks (DAC) were more than 8 km (5 mi) away. When each park is analyzed separately, the regression value between the passive monitor and active station data for the Brentwood (AFF) parks is R\(^2\) = 0.68, suggesting that distant active monitoring stations may not yield the most accurate ozone concentrations for the DAC parks (fig. 4.6).

![Figure 4.6](image-url) — A comparison of results from the passive samplers and the electronic monitoring stations. The light gray bars indicate the average hourly concentrations from the passive samplers (n = 8, error bars = standard error of the mean). The dark grey bars are the average hourly values from active monitoring stations for the same period. Note that these data are a single datum for each day.
The passive ozone concentrations do not appear to indicate a substantial exposure difference between the parks in the Brentwood (AFF) and Sun Valley (DAC) communities (figs. 4.5 and 4.6). However, it was clear based on both active and passive monitoring data that there was wide variability among days. It was difficult to draw definitive conclusions from the data either in comparing area type,
or contrasting parks across days, because only one team was deployed each day, none of the observation days were paired, and only one park was visited on any single day. Furthermore, passive samplers can provide only an aggregate measure of the exposure during the 5-hour exposure period, with no indication of hourly variation or peak exposures. As a further validation of the passive sampler data, the daily concentrations from the active monitors were compared (fig. 4.7).

In reviewing ambient ozone concentration data from the nearest active monitoring stations, it is clear that the Sun Valley (DAC) community was at much greater risk from ozone exposure than the Brentwood community (AFF) (fig. 4.7) during the study period. On most days, both locations demonstrated the typical diurnal curves—lower ozone concentrations in the evening and early morning and higher concentrations during daylight hours, peaking between 12 p.m. and 2 p.m. Also notable is the high day-to-day variability. At the Sun Valley (DAC) monitoring station, the peak daily concentration ranged from 55 ppb on September 24 to more than 100 ppb on September 21. At the Brentwood (AFF) monitoring station, the peak concentrations were just over the 65 ppb threshold on September 1 and 7, and just under 40 ppb on September 11.

Conclusions

- All calculated ozone concentration from the passive samples were statistically higher than the field blanks and lab blanks.
- Replication among the four samplers deployed each outing was within the 20 percent standard.
- Ozone levels from the passive samplers were not always well correlated with the active monitors. This may have been a result of the distance between the park and its associated monitoring station.
- As a group, there were no significant differences between Brentwood and Sun Valley, the two areas based on passive data alone; however, the active electronic monitors indicated an overall higher mid-day ozone concentration in the Sun Valley parks.
- Daily ozone variability at the Brentwood and Sun Valley locations and the lack of paired sampling days likely contributed to the absence of statistical significance in comparisons of the passive sampling data.

Proposed Changes for Future Experiments

1. Pair sampling days and times to identify significant differences
2. Move badges from the torso to the head
3. Deploy stationary passive samplers
4. Add an affluent inland community and a disadvantaged coastal community to the study