Particulate Matter 2.5 Concentrations in Underground Bay Area Rapid Transit Stations

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Introduction

In the Summer of 2012, an East Bay Academy for Young Scientists (EBAYS) research team found high concentrations of particulate matter (PM) in underground Bay Area Rapid Transit (BART) stations relative to the above ground stations that they studied. In the Summer of 2013, we focused on analyzing fine PM solely in underground BART stations to understand the dynamics of concentrations in different stations and the areas within them. PM, defined by its size, is a combination of metals, compounds, and complex mixtures that can take form in either liquid droplets or solid particles. PM is divided into two groups: fine "$PM_{2.5}$" (diameter < 2.5 μm) and coarse "PM_{10}" (2.5 μm < diameter < 10 μm).[3] Fine PM is of particular health concern in that it can more readily enter the bloodstream causing damage to one's respiratory health with effects such as asthma, sight impairment, long-range transport of toxins, and mortality.[4] Additional health issues beyond the respiratory system are being documented and continuing to be understood.[1] Annually 14,000 - 24,000 deaths in California are associated with $PM_{2.5}$.[4]

Methods and Materials

We measured $PM_{2.5}$ using a DustTrak II 8530 Aerosol Particulate Concentration Monitor, a machine that takes in air samples to calculate, display, and record $PM_{2.5}$ concentrations in mg/m^3 every second. We collected data on three different routes departing from the West Oakland BART station: 1) **San Francisco**: Embarcadero, Montgomery, Powell, and Civic Center stations; 2)**Berkeley**: 12th street, 19th street, Ashby, and Downtown Berkeley stations; 3) **Oakland**: Lake Merritt, Fruitvale, and Coliseum stations. Over the course of four days; July 17, July 18, July 22, and July 23, we went to each station three times in small groups. We sampled the BART stations' different levels between the hours of 3:00-5:00 P.M. collecting $PM_{2.5}$ readings and taking notes for more detailed data analysis. Sampling time varied from 1 to 10 minutes inside the stations; more time was spent at the three stations where we went outside. We went above ground at one station on each route: Embarcadero, 12th street, and Lake Merritt.

Data and Results

Graphical representations of our raw data ($PM_{2.5}$ concentration versus time) are shown in Figures 2 and 3, which both show $PM_{2.5}$ recordings on July 17 along the San Francisco route. EPA Air Quality Index categories (Figure 8) are superimposed onto the graphs to give a sense of the data, and should not be taken as understood as actual health ratings. Location information is also shown on the graphs.
We also calculated average concentrations of each station and additional locations for each day. One bar graph for each route displays this data (Figures 5-7). Note that the scales of these graphs are not uniform, so to compare data between routes one must account for the range differences on the graphs.

Figure 1: BART Station Map.[2]

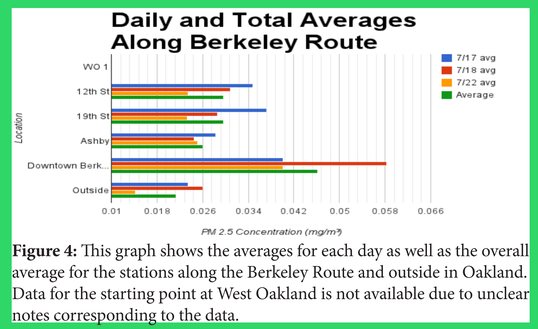

Figure 4: This graph shows the averages for each day as well as the overall average for the stations along the Berkeley Route and outside in Oakland. Data for the starting point at West Oakland is not available due to unclear notes corresponding to the data.

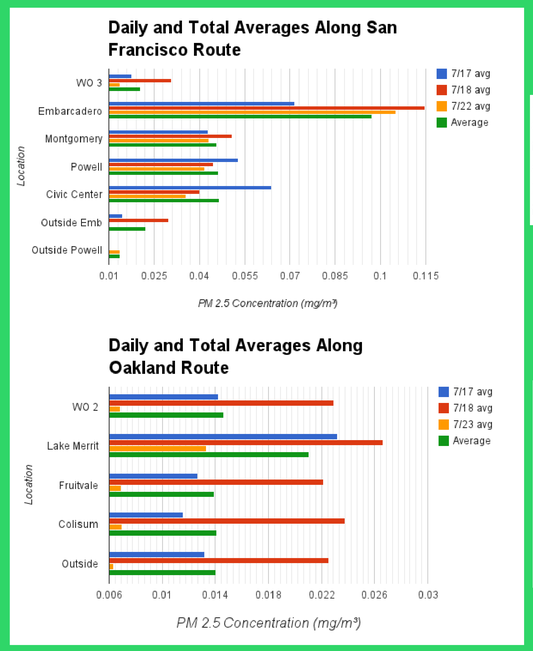

Figure 5: This graph shows each day's averages, as well as the average for all three days, for every station along the SF route, for outside in San Francisco, and for West Oakland. Note that on 7/22 we went outside of Powell instead of Embarcadero.

Figure 6: The graph shows the averages for the stations along the Oakland route for each day and the overall average. Note that PM concentrations were relatively high on 7/18, and that Lake Merrit, the only underground station on the route had the highest average concentration. Also the third day for this route, 7/23, is a day later than the other routes due to equipment failure.

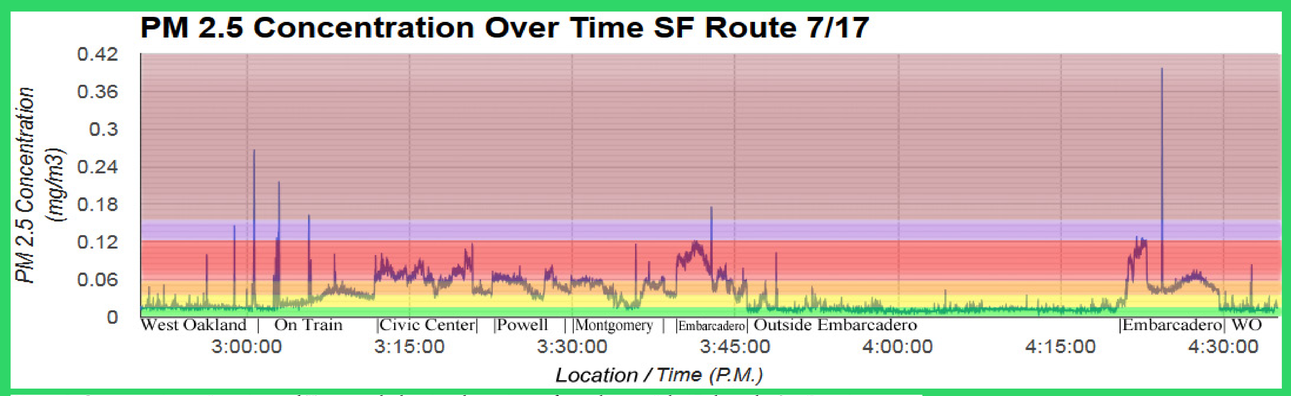

Figure 2: Concentration vs Location and Time graph showing the entirety of sampling on July 17 along the San Francisco route. Colored over the graph is the EPA Air Quality Index categories as shown in Figure 7.

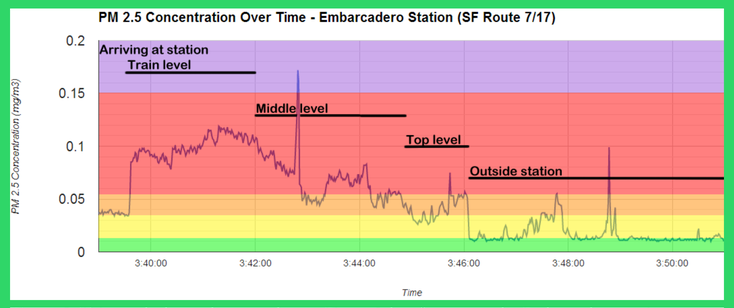

Figure 3: This graph shows the same data as Figure 2, but focuses on the Embarcadero station to emphasize differences in concentration between the levels of the station.

EPA's Air Quality Index for 24-Hour $PM_{2.5}$ Pollution		
	Concentration (mg/m^3)	Rating
	0-.0120	Good
	.0121-.0354	Moderate
	.0355-.0554	Unhealthy for Sensitive Groups
	.0555 -.1504	Unhealthy
	.1505 - .2504	Very Unhealthy
	> .2505	Hazardous

Figure 7: EPA's Air Quality Index[2] adapted to set a color scale for graphs and to match units displayed on the graphs.

Discussion

By analyzing our notes in conjunction with the data, we can determine potential factors that affect $PM_{2.5}$ concentration. For example, the more confined Downtown Berkeley Station had higher concentrations than the Ashby station, which is more open to outside air (Figure 4). Further explanation for this discrepancy can be explained by a direct relation between station depth and $PM_{2.5}$ concentration (see Figure 3 for Embarcadero); we noticed that for most stations as we moved up from the train level the $PM_{2.5}$ concentrations decreased. The Ashby Station is located at ground level while the Downtown Berkeley Station begins further underground and has additional underground floors. We believe this could suggest that the friction between the train and tracks, resulting in wearing of the tracks and subsequent dispersion of particles, is a significant source of $PM_{2.5}$ in underground BART stations.

We also noticed a direct relationship between traffic, in terms of passengers and frequency of train arrivals and departures, and $PM_{2.5}$ concentration. Embarcadero is the busiest station in terms of ridership, and Downtown Berkeley is the busiest station outside of San Francisco.[3] This was especially evident in the Embarcadero Station (Figure 2, 3, and 5), which was the most crowded station that we visited. This is a particularly dangerous relationship because, in turn, larger populations are subjected to poorer air quality. This relationship further supports our hypothesis that train-track interactions are responsible for $PM_{2.5}$ in underground BART stations. More passengers increase the weight of trains, and therefore the friction forces between train and track. A high frequency of trains also contributes to more wearing on the tracks and less time between dispersion and settling of particles onto the tracks.

Conclusion

In general, the results of our research confirm high $PM_{2.5}$ concentrations in underground stations. However, our research consists of limitations. Due to the short sampling time, we cannot directly compare our data to the EPA Air Quality Index Chart, which is for a 24-hour time period (Figure 7). This prevented us from making any definite conclusions regarding health concerns. Additionally we only collected data between 3:00 PM to 5:00 PM on weekdays. Therefore we only have a limited picture of hourly and daily trends.

We recommend future research to be conducted over longer time periods so we can have a clearer picture about potential causes of high $PM_{2.5}$ concentrations, daily and hourly trends, and the populations affected. For stations of immediate concern, such as Embarcadero, we recommend 24-hour monitoring to determine health ratings. Also it would be beneficial to characterize PM from underground BART stations to more directly determine health concerns.

BART can also take steps to improve air quality in underground stations by providing ventilation, filtration (such as electrostatic precipitation systems[8]), access to open air, and track and station cleaning. We also recommend research and implementation of ideas to reduce the wear of wheels and tracks. BART provides service to a great number of passengers[3] and should ensure healthy air for them and especially for employees spending even more time in stations and trains.

References

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Acknowledgements

We want to give special thanks to Tony Marks-Block, Cassandra Martin, Brian Beveridge and Kevin Cuff for their teaching, encouragement, and contributions to our project. We would also like to thank West Oakland Environmental Indicators Project (WOEIP) and the Environmental Protection Agency (EPA) for their support, equipment, and classroom space.

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