# Assessment of Micro Pollution in Mumbai, India: A Comparative Study

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## ABSTRACT

The National Science Foundation (NSF) funded a 3-year project to conduct micro-level pollution investigations in Mumbai and New Delhi, India. The first data set was collected in December 2022 – January 2023 by 13 students selected across City University of New York (CUNY) institutions.

The primary focus of this research was to conduct a comparative micro-level analysis of particle count distributions between Dharavi (slum) and an upper-middle-class area (Santa Cruz). These students were equipped with mobile backpacks with sensors to collect particulate loading and gas concentrations. We examine daily variations in average pollution levels by matching pollution histograms to sources and performing pattern analysis. Visual representation, such as plotting route averages and daily variations of average pollution levels, is used to investigate the relationship between air pollution and meteorological factors like wind and boundary layer height. An analysis was conducted to compare surface aerosol optical depth and satellite aerosol optical depth to boundary layer height. Linear regression is used to extract variations in urban temperature as a function of vegetation and building spacing averages for specific days. The findings of this research project pertain that the air quality in Santa Cruz is relatively better compared to Dharavi. There were more green spaces and pollution-reducing infrastructure in Santa Cruz while Dharavi experienced a disproportionate burden of pollution from industrial facilities, outdoor cooking, burning trash, densely populated, and lack of green space. Access to clean air is a fundamental right, but socioeconomic factors often result in significant disparities in air quality between poor and wealthy neighborhoods.

The endeavors of this project will lay the groundwork for the upcoming data collection field campaign and will provide valuable insights into the complex interplay of environmental factors, socioeconomic disparities, and their impact on the health and well-being of urban populations in Mumbai.

## Background

This was the first session of a three-year study, so the data sets are not yet conclusive. By design, data is collected in January to avoid the effects of precipitation (which clears out pollution particles) and crop burning. A low-cost custom-designed instrument package was created for this project. The project team had tight connections with the State of Maharashtra government and researchers at the Indian Institute of Technology and SNDT Women's College of Technology, ensuring the continuation of data collection and policy development.

## Objectives

- Relate pollution measurements averaged every 100 meters along each route to observed pollution sources. For this poster, we display particle counts and accumulated particle mass (PM2.5).
- Compare particulate matter distributions between the Santa Cruz (upper middle class) and Dharavi (slum) neighborhoods.
- Demonstrate if weather variables such as Planetary Boundary Layer Height (PBL H) and Wind speed are related to ground-level measurements of pollution (PM2.5).
- Examine if PBL height affects the ratio between ground and satellite observations of Aerosol Optical Depth.
- Apply linear regression to see if local Temperature Variation can be related to vegetation indices observed by satellite and estimates of building density.

## Data Sets and Methods

Mobile sensor packs consist of two sets of instruments. An off-the-shelf data logger (Vernier LabQuest) recorded GPS, temperature, and RH readings. A custom-designed package (MCCI corporation) consisted of an optical particulate matter counter in bins of 0.1, 0.3, 0.5, 1.0, 2.5, 5 and 10-micron diameter and gas detectors measuring concentrations of ozone, carbon monoxide, $NO_2$, and $SO_2$. The gas measurements are not addressed in this poster.

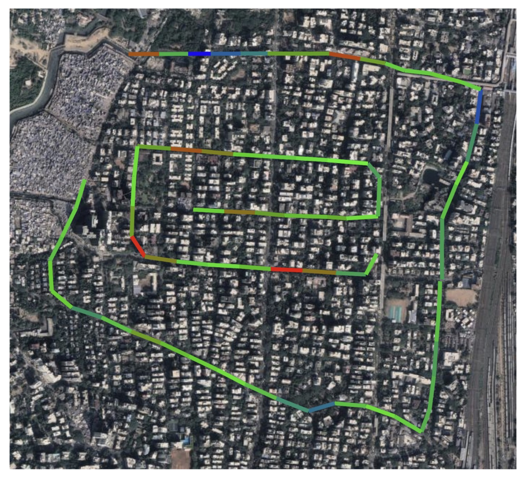
Satellite data was used for Aerosol Optical Depth (AOD) and vegetation density. The MODIS MAIAC 1 km AOD data uses multiple view angles from the MISR instrument across 16 days to establish surface reflectance. 30-meter Landsat reflectance data was used to calculate the Normalized Difference Vegetation Index (NDVI) which was converted to an estimate of the Leaf Area Index (LAI).

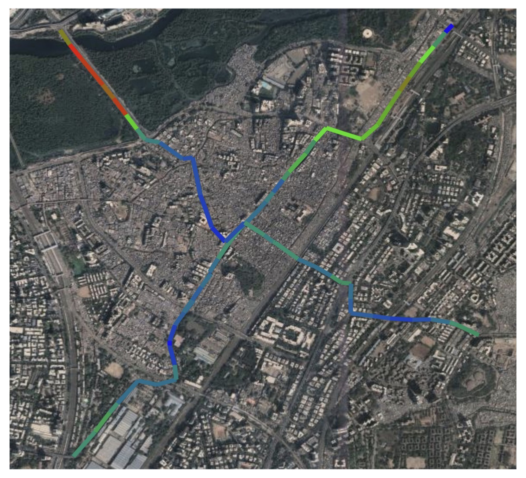
Weather model data is taken from the 25 km resolution US Global Forecast Model (GFS) for boundary layer height and area-wide wind speed (Indian weather model data is not accessible outside India for general research purposes). Mumbai is a peninsula, so ocean and land effects will be mixed within a 25 km grid cell. Therefore, data from a landlocked region to the east of Mumbai was used for comparison.

Pre-planned routes were walked on multiple days in groups of at least 3 students to allow comparison between instruments and swapping of GPS data if needed. The data was averaged into roughly 100 m spatial bins along the routes, with standard deviations calculated to assess pattern stability. These route averages are compared to observed pollution sources such as traffic and wood/coal cooking.

For comparison to satellite data, multiple routes can be combined to form a neighborhood with weighted averages calculated for each day. The daily neighborhood averages are compared to satellite AOD under the assumption that convection pulls pollution away from the surface (as indicated by the PBL height) but the satellite measures the entire column. Under the (unsupported) assumption that pollution sources are constant, we can test the idea that pollution spreads throughout a volume defined by the PBL height and the wind speed.

## Results

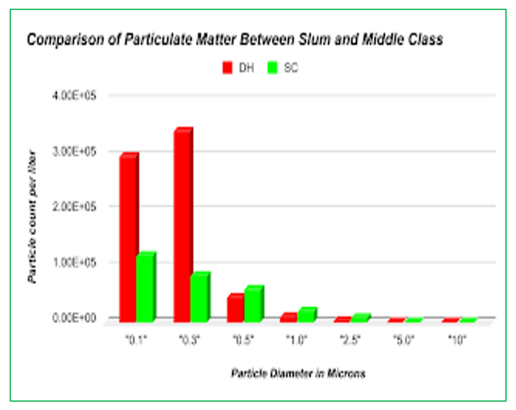


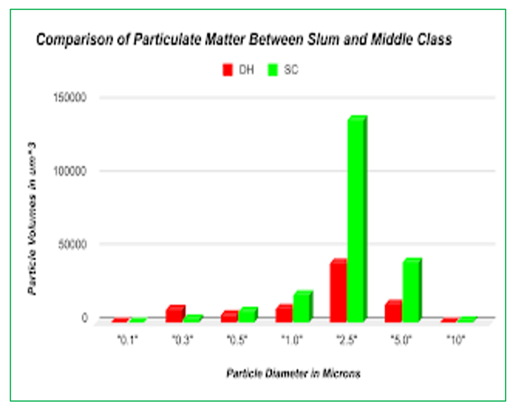


**Santa Cruz PC0.3 Dharavi**
*Blue is low, Red is high*

## Results *(continued)*

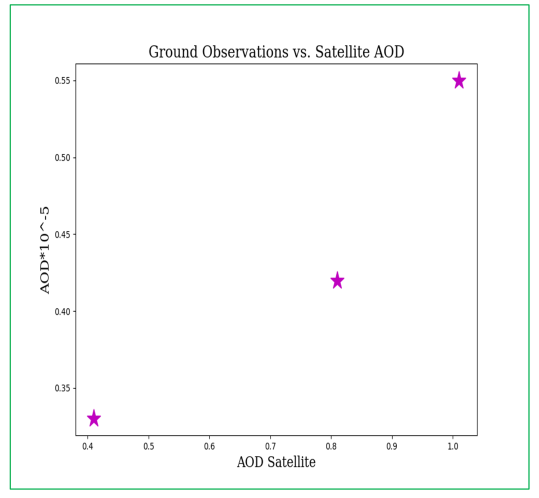
The maps in the previous column show small particle counts in the two neighborhoods. We can see that the NW bridge of Dharavi is dominated by trash burning and heavy traffic (right). The center of Dharavi is residential, and the red area at the top of Santa Cruz is a market. Intersections of SC have high traffic.

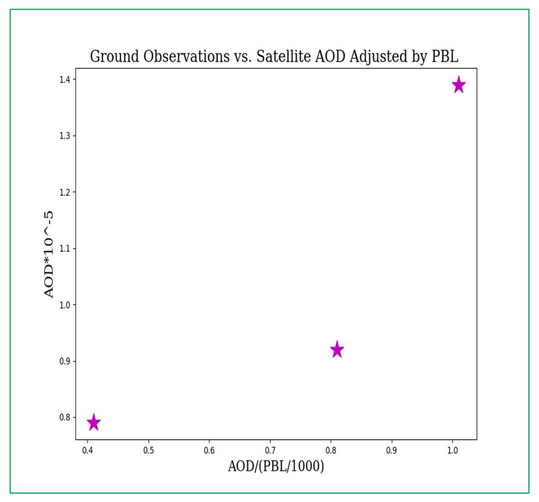



The left histogram demonstrates the particle counts between the two neighborhoods. Dharavi (red) has a higher count of particles with smaller diameters; in contrast, Santa Cruz (green) has a higher count of larger particles. Santa Cruz has a higher volume of traffic causing the particles to be bigger in diameter (dust). Dharavi has more foot traffic, resulting in smaller dust particles; but smoke from cooking with low-grade coal also contributes to small particle loading. However, the small particle counts in Dharavi may be dominated by a single trash-burning event on the NW bridge (image above).

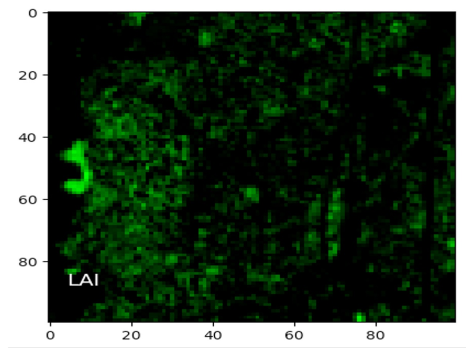
The right histogram is related to the left, but each count is multiplied by particle volume. PM2.5 is the total mass of particles of size up to 2.5 microns, equivalent to summing the volumes. We can see from the figure that PM2.5 would be larger for Santa Cruz, even though the small particle count is much larger in Dharavi. Therefore, the standard health measure of PM2.5 provides a misleading indication of which neighborhood has the greater health impact due to small particles, which are more likely to penetrate the lungs.

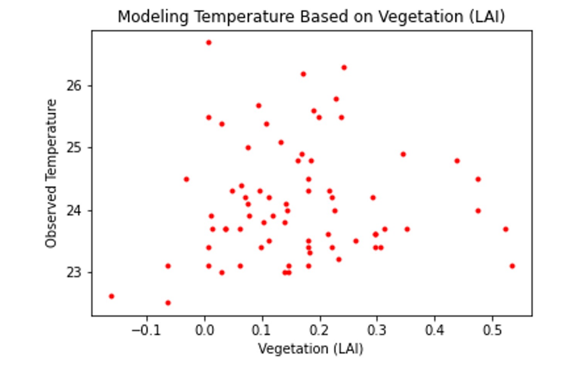



The figure on the left represents the relationship between the observed AOD data and the satellite data over Santa Cruz on January 3, 11, and 15. The graph shows the surface and satellite-measured AOD are not directly proportional. However, when considering PBL height, adjusting the satellite AOD values by PBL (right figure) did not improve the relationship between the observed and satellite AOD values.

The observed values of AOD were also plotted vs values of 1/(PBL*Wind) (not shown), based on the hypothesis that if there is greater wind and a higher boundary layer, the ground AOD would be lower as the aerosol particles are further spread out. This relationship, however, was not effectively represented when plotted. This may be due to the assumption that pollution sources were constant. In addition to this, the time of day the data was collected and whether it was on a weekend or weekday could also influence the outcome of the graphs.




These figures represent the relationship between the amounts of vegetation and the observed temperature along routes in Santa Cruz. The NDVI was derived from Landsat data, which was then converted to Leaf Area Index (LAI) to more accurately represent the amount of vegetation in the neighborhood. As its presence helps to lower surface and air temperatures, it was predicted that temperature would decrease with LAI. However, this relationship is not represented in the figure, perhaps due to limited variability in vegetation, This method of analyzing and plotting NDVI data has been used before for other cities, yet no definite relationship was found for Mumbai in particular.

## Conclusions

- The mapped averages of small particle concentration match observations of trash burning and traffic.
- Perhaps due to cooking smoke and incense a larger concentration of small particles was seen in Dharavi, but traffic in Santa Cruz causes larger PM2.5. This standard measure of air pollution impacts on health may therefore be misleading.
- Simple weather/pollution models based on Boundary Layer Height and wind were unsuccessful in explaining daily pollution trends.
- Though vegetation is generally seen to reduce urban temperatures, this was not seen to be the case in Mumbai. This may be due to pollution diminishing the effects of solar radiation.

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