

**Port of Oakland Particulate Matter Emissions and Prevalence of  
Asthma Hospitalizations in Bay Area Communities**

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**ABSTRACT**

This study consists of a comparison between ambient particulate matter (PM) concentrations and incidence of asthma in eight San Francisco Bay Area communities – West and East Oakland, San Francisco, Redwood City, Vallejo, Point Reyes Station, and San Jose, all of which are in California. West Oakland, predominantly African American, may be at risk of dangerous levels of diesel particulate matter emissions because of its close proximity to the Port of Oakland. The purpose of this study is to investigate an association between three variables: PM<sub>2.5</sub> concentrations, asthma incidence, and demographic/socioeconomic status in each community. A map was created using Geographic Information System (GIS) to observe spatial autocorrelative effects that the Port may have on West Oakland's health, compared to neighboring communities. West Oakland shows the highest risk for asthma out of all the other evaluated Bay Area communities. Racial associations seem to exist between asthma prevalence and socioeconomic status. The results of this study suggest that West Oakland residents are disproportionately exposed to PM and are disproportionately burdened with asthma.

**KEYWORDS**

Particulate Matter, Asthma Hospitalizations, Port of Oakland, Bay Area, Socioeconomic

## INTRODUCTION

Many studies have shown that ambient air pollution can cause health problems for residents living in exposed areas. For instance, the U.S. EPA has linked exposure to PM to a series of health problems, including increased respiratory symptoms, such as irritation of the airways, coughing, and difficulty breathing (EPA, 2004). Epidemiologic studies have demonstrated an association between ambient PM<sub>2.5</sub> exposure and the presence or extent of atherosclerosis in humans, which is the build-up of a waxy plaque on the inside of blood vessels that increases the risk of cardiovascular diseases (Brook, 2010). Furthermore, other studies show common links between air particulates, and lung cancer and asthma (Pingkuan, 2008). PM<sub>2.5</sub> can cause health hazards because of its small size and the toxicity of its chemical components (Bailey, 2004). All of these studies show important research into human health that involves ambient air pollution, but it is also important to know the source of the pollution.

Seaports are major hubs of economic activity and of environmental pollution in coastal urban areas (Bailey, 2004). The Port of Oakland (Port) operates with cranes, trains, ships, and container trucks that carry goods to and from the Port, transporting them through businesses and people in the entire United States (Palanianppan et al., 2003). It was concluded that trucks entering the Port of Oakland contribute to 71 percent of the Port's toxins, which includes PM pollution (Pingkuan, 2008). Facilities like the Port of Oakland are often located in areas near minority communities that tend to have higher levels of air pollution (UCCCRJ, 1987; Bullard, 1994). West Oakland, which is a predominantly African American population, consists of significantly elevated concentrations of air pollution than in other parts of the San Francisco Bay Area (Palanianppan et al., 2003). Since the Port neighbors the West Oakland community, the Port's PM emissions may have a significant impact on respiratory diseases for West Oakland residents.

Leading causes of hospitalization vary among different racial/ethnic groups. West Oakland consists of 51% African Americans and the leading cause of hospitalizations among African Americans in West Oakland is respiratory disorders at an estimated 232 hospitalizations per 3-year period, as opposed to the rate of Hispanic/Latinos at 11 hospitalizations per 3-year period in West Oakland (Witt et al. 2001). Although Hispanic/Latinos only make up 13% of the population in West Oakland, this suggests that there may be an association with race and

respiratory disorders. PM pollution from Port operations can disperse up to a very large area, reaching to about 550,000 acres (Pingkuan, 2008). Although other Bay Area communities are further away from the Port as to West Oakland, PM from the Port should still have a health impact on other Bay Area residents (Pingkuan, 2008). The level of susceptibility to PM pollution in Bay Area communities can be assessed by analyzing the association with race as well as analyzing each community's incidence of asthma. Although there have been various studies on Port emissions and subsequent environmental concentrations of PM, few studies have looked at the relationship between environmental concentrations of PM arising from the Port and asthma hospitalizations of the West Oakland community. Even fewer studies have compared West Oakland asthma incidence to asthma incidence in other Bay Area communities, such as East Oakland, San Francisco, Vallejo, Redwood City, Point Reyes, San Jose, and Livermore, that may have lower ambient concentrations of PM, and may show differences in the associations to PM across racial backgrounds. The purpose of this study is to evaluate the association between environmental concentrations of PM and asthma hospitalization rates for the above eight Bay Area communities, and to study the impact the Port may have on West Oakland residents.

I expect to find higher ambient concentrations of PM in West Oakland, and lower concentrations of ambient PM in the other seven communities. I also expect to find lower asthma hospitalization counts in each Bay Area city except for a higher asthma hospitalization count in West Oakland. If these patterns are found, PM emissions from the Port to be causing higher asthma incidence in West Oakland is highly suggested to be the case. I also expect to find a relationship between race/ethnicity and hospitalization for asthma symptoms between the eight communities as West Oakland and East Oakland are predominantly African American and the other six populations are a combination of various ethnic roots.

## **METHODS**

### **Data Collection**

### *Demographic Information*

I used the “Census 2000 Demographic Profile Highlights” ([www.factfinder.census.gov](http://www.factfinder.census.gov)) that displays information for each zipcode to collect demographic and socioeconomic variables for each study site for zip codes in West Oakland, East Oakland, San Francisco, Livermore, Redwood City, San Jose, Point Reyes, and Vallejo. Variables that I included in my study are race/ethnicity percentages, percentages of families below the poverty level, and educational attainment above the high school and bachelors’ level.

### *Asthma Hospitalization Counts*

I obtained asthma hospitalization counts for each zipcode from the Office of Statewide Health Planning and Development (OSHPD) for the calendar years 2005-2009. Frequency counts of admission to hospitals were categorized by five International Classification of Diseases codes for asthma, ICD-9-CM, each representing the severity of the asthma diagnosis during admission to the hospital. For each asthma hospitalization, the year in which the hospitalization occurred and the race, ethnicity, and zipcode of residence of the patient were documented and included in the dataset. In order to summarize the data into total number of hospitalizations per zipcode per year, each occurrence was counted and the sum equaled the total number for that zipcode and year.

### *Ambient PM<sub>2.5</sub> Concentration*

Ambient concentrations of PM<sub>2.5</sub> were populated with hourly ambient PM monitoring data in micrograms per cubic meter (ug/m<sup>3</sup>) from the California Air Resources Board’s (CARB) Air Quality Meteorological Information System (AQMIS) (CARB 2009). I downloaded data from PM monitoring locations for 2005-2009 in Livermore, East and West Oakland, Point Reyes, Redwood City, San Francisco, San Jose, and Vallejo as hourly concentrations. I categorized observed ambient PM concentrations by summarizing the hourly data into an average of yearly concentrations.

### *Data Analysis*

I used GIS to construct maps in order to visualize spatial associations between ambient PM concentrations, asthma hospitalizations, and demographic/socioeconomic variables between my study sites. GIS software ArcMap 9.3.1 was used for all GIS procedures. A choropleth map was created for all eight zipcodes that included their zipcode boundary filled with graduated colors, bar graphs, and graduated symbols that each represent data for the year 2009, because 2009 was the only year with thorough data for all three datasets. Graduated colors of black, gray, and white were used to show variation in asthma hospitalizations, the size differences of the green circles used as a graduated symbol were used to depict variation in yearly PM<sub>2.5</sub> concentration, and bar graphs were used to show demographic/socioeconomic variables. A basemap layer of streets and expressways was also included in each map figure. All map figures were placed into one document to observe any difference between the eight neighborhoods and to see how the Port might be associated with higher environmental concentrations of PM in West Oakland.

## **RESULTS**

### *Demographic Information*

Socioeconomic, racial, and ethnic demographics varied between the communities. West Oakland (94607) and East Oakland (94603) communities share similar socioeconomic and demographic variables compared to any other study site (Table 1). African Americans make up the majority of each population. Sixty Percent of each population extend their educational attainment past high school, while 15% and 7% have completed a bachelors degree or higher. West Oakland and East Oakland also have the most families below the poverty level, with 29% and 21% of its population in this category, which is the most out of the eight communities. On the other hand, Redwood City (94063) and San Francisco (94107) express higher levels in education with 36% and 58% of their populations completing a bachelors degree or higher, and 4% and 15% of families below the poverty level.

### *Asthma Hospitalization Counts*

West Oakland (94607) had a higher asthma hospitalization count among its population compared to any other listed community with 45 asthma hospitalizations per thousand people in 2009 (Table 2). East Oakland (94603) and San Francisco (94107) populations experienced the second and third largest asthma prevalence out of all the communities with 35 and 12 asthma hospitalizations per thousand people, respectively. Livermore (94551) had 5 asthma hospitalizations per thousand people, the lowest out of all communities under study in the San Francisco Bay Area.

### *Ambient PM<sub>2.5</sub> Concentration*

San Francisco (94107) had higher observed ambient PM<sub>2.5</sub> concentrations than any other community with a yearly average of 12.76 micrograms per cubic meter (ug/m<sup>3</sup>). West Oakland (94607) had an annual average of 11.46 ug/m<sup>3</sup> (Table 3). Point Reyes Station (94956) contained the lowest concentration of PM<sub>2.5</sub> with a yearly average of 6.03 ug/m<sup>3</sup>, almost fifty percent lower than the observed values for the zip code areas for West Oakland and San Francisco.

### *Data Analysis*

GIS shows that the West Oakland (94607) population has a greater risk for asthma than the other seven communities (Figure 1). After combining all eight maps into one document to observe any associations between the communities, darker color/larger point size variation was seen on the West Oakland zipcode area, representing the highest proportion of asthma hospitalizations and the highest ambient concentrations of PM<sub>2.5</sub>. Also, West Oakland's bar graph shows a lower socioeconomic/demographic status (SES) in its region. The San Francisco zipcode region shows a large green dot size showing high ambient concentrations of PM<sub>2.5</sub> as well, but its boundary color variation is not as dark as West Oakland's, showing lower asthma hospitalizations in the area. On the other hand, Point Reyes contains the lightest color shading within its zipcode boundary, representing the fewest asthma hospitalizations, as well as the smallest green dot size, showing low levels of PM<sub>2.5</sub> concentration in the area.

**Table 1. Socioeconomic and Demographic Variables.** West Oakland and East Oakland has the highest population of African Americans, the least educational attainment, and the most families below the poverty level.

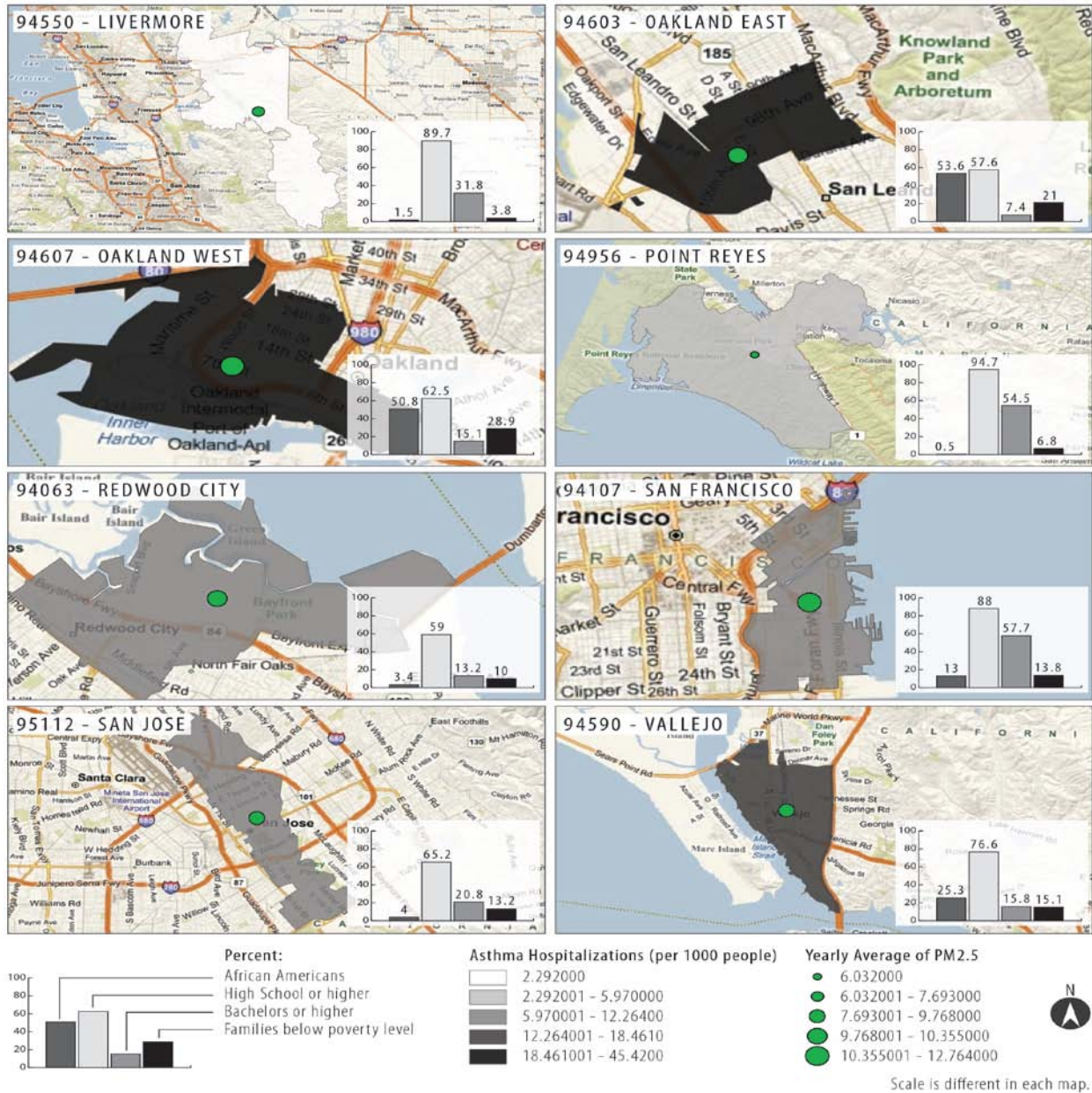
Community	Zip Code	Percent African American (%)	Percent Academic Level (%)		Percent Families Below Poverty Level (%)
			High School or higher	Bachelors or higher	
West Oakland	94607	50.8	62.5	15.1	28.9
East Oakland	94603	53.6	57.6	7.4	21
Vallejo	94590	25.3	76.6	15.8	15.1
San Francisco	94107	13	88	57.7	13.8
San Jose	95112	4	65.2	20.8	13.2
Redwood City	94063	3.4	59	13.2	10
Point Reyes	94956	0.5	94.7	54.5	6.8
Livermore	94550	1.5	89.7	31.8	3.8

**Table 2. Summary of 2009 Asthma Hospitalizations.** West Oakland has the highest number of asthma hospitalizations out of the eight Bay Area communities. Livermore has the least number of asthma counts.

Community	Patient Zip Code	Total Hospitalizations	Population	# of Hospitalizations per 1000 population
West Oakland	94607	956	21048	45.4199924
East Oakland	94603	1088	31389	34.66182421
Vallejo	94590	687	37214	18.46079432
San Francisco	94107	213	17368	12.26393367
Redwood City	94063	331	32350	10.23183926
San Jose	95112	523	52331	9.994076169
Point Reyes Station	94956	11	1874	5.869797225
Livermore	94550	174	75925	2.291735265

**Table 3. Summary of 2009 PM<sub>2.5</sub> Monitoring Site measurements.** San Francisco and West Oakland are the most concentrated communities with PM<sub>2.5</sub>. Point Reyes is the least PM<sub>2.5</sub> concentrated.

Community	Zip Code	PM Monitor Location	Yearly Average of PM <sub>2.5</sub> (ug/m <sup>3</sup> )
San Francisco	94107	San Francisco-Arkansas Street	12.75972382
West Oakland	94607	Oakland-West	11.46215737
Redwood City	94063	Redwood City	10.35347763
East Oakland	94603	Oakland-9925 International Blvd	10.14969781
Vallejo	94590	Vallejo-304 Tuolumne Street	9.761798282
San Jose	95112	San Jose-Jackson Street	9.338131194
Livermore	94551	Livermore-793 Rincon Avenue	7.68320037
Point Reyes Station	94956	Point Reyes	6.066818182



**Figure 1. The association between asthma hospitalizations, PM2.5 concentrations, and socioeconomic/demographic variables in eight Bay Area zipcodes. West Oakland's combination of black shadings, larger green circles, and bar graph information leads West Oakland to have the highest risk for asthma.**





Figure 2. All eight study sites. The eight zipcodes in relation to each other in the San Francisco Bay Area.

## DISCUSSION

My study investigated asthma hospitalizations, PM<sub>2.5</sub> concentration, and demographic and socioeconomic variables in eight Bay Area communities (Figure 2) in order to observe the risk of incidence of asthma. I hypothesized that higher incidences of asthma and higher concentrations of PM<sub>2.5</sub> would be found in West Oakland. Based on the three datasets above, GIS chloropleth maps and bar graphs show that West Oakland residents are more likely to have incidence of asthma than any of the other seven Bay Area communities in my study.

East and West Oakland have the highest percentages of African Americans living in the community, while the other six Bay Area communities hold a substantially fewer amount of African American's in their population. East and West Oakland have lower SES as well, such as lower income and lower educational attainment than residents in the other six communities. In their study on reducing asthma disparities, Lamb et al. (2011) notes that African Americans have disproportionately high rates of asthma and poor health outcomes associated with asthma, compared with the rates for Whites, Latinos, and Asians. Wissow et al. (1988) suggest that asthma disparities exist on the basis of income level, where lower income is associated with higher asthma hospitalization rates. The concentration of racial/ethnic differences only among the very poor suggest that patterns of social and environmental exposures must overshadow any hypothetical genetic risk (Smith et al, 2005). Looking at my data, the percentages of families below the poverty level almost exactly align with the number of asthma counts per thousand population, supporting Wissow's (1988) argument. These findings represent similar results to my study in that the majority of residents in West Oakland are African American, have low levels of income, and low educational attainment.

Already susceptible to asthma on a demographic/SES bases, West Oakland had one of the highest ambient PM<sub>2.5</sub> concentrations, except for San Francisco. Although San Francisco had 1.3 ug/m<sup>3</sup> more PM<sub>2.5</sub> than West Oakland, West Oakland had almost four times the number of asthma hospitalizations. Demographic variables and a higher SES, as explained by the studies above, may be possible reasons why San Francisco residents have lower asthma hospitalization rates than those in West Oakland. The CARB (2008) estimates that exposure to diesel PM from goods movement sources results in 18 premature deaths, 290 asthma attacks, 2,600 days of work loss, and 15,000 minor restricted activity episodes each year in West Oakland. The CARB (2008) predominantly attributes these health impacts the geographic situation of West Oakland among major freeways and the Port of Oakland (CARB, 2008). If I subtract 290 asthma attacks caused by PM exposure from goods movement from my West Oakland data, West Oakland would still have a greater number of asthma hospitalizations per thousand, than any other community, not including East Oakland.

Although there is a paucity of literature describing the relationship between the concentration of PM<sub>2.5</sub> and asthma outcomes, one study suggests that a 1 ug/m<sup>3</sup> increase in traffic particles could be associated with an additional 7,000 additional early deaths per year in the U.S.

(Schwartz et al., 2002). According to Schwartz et al., there seems to be little concern with deaths with a  $1 \text{ ug/m}^3$  increase in relation to the smaller communities, compared to the U.S. Since there is not much literature on the concentration-response associated for asthma, there may still be potential risk. Additionally, the California Air Quality Standard for  $\text{PM}_{2.5}$  is set at  $12 \text{ ug/m}^3$  (CARB, 2011). East Oakland is within  $2 \text{ ug/m}^3$  below the standard, West Oakland is within  $1 \text{ ug/m}^3$  below the standard, and San Francisco is within  $1 \text{ ug/m}^3$  above the standard. According to the CARB, air quality standards are set with the amount that exerts the lowest amount of harm that can be achieved in a cost-effective manner (CARB, 2011), but many critics argue that air quality standards are set somewhat arbitrarily with inconclusive evidence of the specific health benefits and with inadequate considerations of the costs to producers (Neidell, 2004). This suggests that concentrations at or very close to the California standard may still have potential for harm to population health. As discussed earlier, in addition to pollution exposures, asthma is associated with socioeconomic and demographic variables, leaving African Americans more susceptible to incidences of asthma than people in other communities (Lamb et al., 2011). Air quality standards do not take these differential vulnerabilities into consideration.

The findings in my study are in line with other related research within West Oakland itself. The West Oakland Indicators project compared Oakland zipcodes and Bay Area zipcodes, and showed that West Oakland has been progressively increasing the air pollution health risk it poses to residents (Hays et. Al, 2002). My study acknowledges this risk and suggests that the air pollution in West Oakland needs to be managed to safer levels, not only because PM levels are highest in this city, but because the population has a greater risk of exposure to a variety of asthma-related factors, such as low SES. Risk should not be based, singularly on the California air quality standard for  $\text{PM}_{2.5}$ , but instead should be based upon a cumulative risk approach that includes the combination of exposure and susceptibility between air pollution and the residents that live in the exposed area (Jerrett et al, 2010).

## **Limitations**

There were some data limitations that could hold implications for the results of my study. First, the location of PM monitoring sites may not have given the most accurate results for the purpose of my study. The existing ambient air quality monitoring network, created to monitor air

pollution at the regional level, is insufficient to provide adequate measures of air quality conditions at the community level because air monitors are not placed in every zip code or neighborhood for each city. Adding more monitors throughout the city would greatly improve the air pollution tracking system and provide higher-resolution data for community-level studies. Further, because of the restricted geographic scope of the available monitoring data, the asthma hospitalization results used for my study are restricted to only zipcodes that contain air monitoring data. One zipcode may not be an accurate representation for the city as a whole or have the high granularity to be an accurate predictor of specific neighborhoods within that city.

I made diagnostic and geographic assumptions that could hold implications for the findings in this study. First, all five asthma diagnostic codes were included for one hospitalization, regardless of their severity. Second, when using GIS, natural breaks were assumed to be adequate in order to create color/point variation for each dataset. Lastly, even though West Oakland may prove to have a higher risk of asthma hospitalizations due to a higher PM concentration, we can only assume that the Port has a large contribution to this. Since the monitor is not placed directly on Port premises and no pollution-source-contribution analysis was undertaken, we do not know definitively what fraction of the overall West Oakland ambient PM concentrations the Port contributes to.

### **Future directions**

Future research should focus on higher resolution ambient PM data throughout the Bay Area. Asthma hospitalizations can be better represented at the neighborhood-scale, rather than the zipcode level. A more accurate representation of the Bay Area can be shown with higher resolution PM concentration data. Also, a focus on the relationship between Port emissions and ambient PM levels in proximate neighborhoods could greatly help to answer my research question of whether or not the Port is culpable for West Oakland's higher concentration of PM. Future studies that include locally-placed PM monitoring networks and source-apportionment methods may increase the chances of answering questions of Port pollution contributions more definitively. Nonetheless, my study provides important information that can be used to weigh in on policy development and other interventions to improve the respiratory health of West Oakland residents.

## Conclusion

My research pertains to the larger problem of environmental injustice. Living in a neighborhood with elevated risks of asthma than in other Bay Area locations, West Oakland residents are not treated equally. If specific neighborhoods are at a disadvantage due to the consumption practices of the greater population, more support should be given to those that suffer disproportionately from the externalities of those consumption practices. The Port of Oakland, major freeways, and other manufacturing facilities are disproportionately distributed throughout West Oakland, and seem to contribute to the greater PM pollution in the city. West Oakland is one of the many cities that are at a disadvantage, and my research helps support the argument that more governmental support and intervention is needed to regulate the amount of air pollution emissions in areas that are most concentrated, especially those that are already susceptible to poor respiratory and cardiovascular health outcomes, such as West Oakland's African American population. When race becomes a factor in areas where air pollution is most concentrated, environmental injustice is apparent and action needs to be taken at the governmental level. People, whether they are African American, White, or Latino, or if they live in urban West Oakland, or rural Point Reyes, should be able to live in an equitable environment, regardless of demographic and socioeconomic differences.

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## REFERENCES

Bailey, Diane, and Solomon, Gina. (2004). *Pollution Prevention at Ports: Clearing the Air*. San Francisco, CA: Elsevier.

- Brook, Robert D., and Rajagopalan, Sanjay. (2010). Particulate Matter Air Pollution and Atherosclerosis. Published online: *Springer Science*. 12:291–300. DOI 10.1007/s11883-010-0122-7.
- Bullard, R., (1994). *Environmental justice for all: it's the right thing to do*. Journal of Environmental Law and Litigation 281.
- California Air Resources Board. Air Quality and Meteorological Information System. Assessed December 6<sup>th</sup>, 2009. <<http://www.arb.ca.gov/aqmis>>
- California Air Resources Board. (2009). *California ambient air quality standards: particulate matter - overview*. Assessed March 27, 2011, from <http://www.arb.ca.gov/research/aaqs/caaqs/pm/pm.htm>.
- Census 2000. "Census 2000 Demographic Profile Highlights". American Fact Finder.
- Hays, J., Landeiro, C., Rongerude, J. (2002). *Neighborhood Knowledge for Change: The West Oakland Environmental Indicators Project*. Oakland, CA: Pacific Institute for Studies in Development, Environment, and Security.
- Jerrett, M., Gale, S., & Kontgis, C. (2010). Spatial modeling in environmental and public health research. *International Journal of Environmental Research and Public Health*, 7, 1302-1329. Doi:10.3390/ijerph7041302.
- Lamb, A. K., Ervice, J., Lorenzen, K., Prentice, B., & Shannon, W. (2011). Reducing asthma disparities by addressing environmental inequities: A case study of regional asthma management and prevention's advocacy efforts. *Family & Community Health*, 34(1), S54-S62.
- Neidell, M.J. (2004). Air pollution, health, and socio-economic status: the effect of outdoor air quality on childhood asthma. *Journal of Health Economics*, 23, 1209–1236.
- Palaniappan, Meena, Wu, Diana, Kohleriter, Jacki. (2003). *Cleaning the Air: Reducing Diesel Pollution in West Oakland*. Oakland, CA: Pacific Institute.
- Pingkuan, Di. (2008). *Diesel Particulate Matter Health Risk Assessment for the West Oakland Community*. California: Air Resources Board, Environmental Protection Agency.
- Schwartz, J., Laden, F., & Zanobetti, A. (2002). The Concentration–Response relation between PM<sub>2.5</sub> and daily deaths. *Environmental Health Perspectives*, 110(10).
- Smith, L. A., Hatcher-Ross, J. L., Wertheimer, R., & Kahn, R. S. (2005). Rethinking race/ethnicity, income, and childhood asthma: Racial/ethnic disparities concentrated among the very poor. *Public Health Reports*, 120(2), 109-116.
- United Church of Christ Commission on Racial Justice. (1987). *Toxic Wastes and Race in the United States*. New York, CA: United Church of Christ.
- U.S. Census Bureau. (n.d.). Fact Sheet: Census 2000 Demographic Profile Highlights - Zip Code Tabulations for 94601 and 94606. Retrieved October 11, 2010, from <http://factfinder.census.gov>. U.S. EPA. (2004). Air Quality Criteria for Particulate

Matter. Washington, DC: U.S. Environmental Protection Agency.

Wissow, L. S., Gittelsohn, A. M, Szklo, M., Starfield, B., Mussman., M. (1988). Poverty, race, and hospitalization for childhood asthma. *American Journal of Public Health*. 78, 777-782.

Witt, Sandra, Cho, Sangsook, Jain, Sonia, Le, Gem, Martin, Jane, and Nobuko Mizoguchi. (2001). *West Oakland: Community Information Book 2001*. Oakland, CA: Alameda County Health Care Services Agency.