Mapping the Cumulative Impacts of Point-Source Air Pollution in West Oakland

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ABSTRACT

High levels of ambient air pollution in dense urban communities are associated with negative health outcomes to exposed populations. Environmental justice studies have focused on the disproportionate siting of air pollution sources in low income and communities of color. Beyond justice concerns, potential cumulative impacts from multiple sources create additive toxicity and compounding effects from multiple chemicals. This is a concern for mixed-use communities such as West Oakland, a residential neighborhood and industrial zone. This study focuses on the children at schools and childcares of West Oakland, whose health may be particularly negatively affected by air pollution. I used GIS to analyze the proximity of schools and childcare to point-source air pollution emission sites in West Oakland compared to the city of Oakland. From a buffer analysis of a radius of 0.5 miles, I found schools in West Oakland had an average of 5.3 point-sources emitting 62 lbs/year of toxic air pollutants within 0.5 miles compared to Oakland with an average of 4.7 sources emitting 509 lbs/year. For criteria air pollutants, I found schools in West Oakland had an average of 10.5 point-sources emitting 10.37 tons/year of criteria air pollutants compared to Oakland with an average of 7.8 sources emitting 33.3 tons/year. I found a similar comparison for childcares. This suggests that during the time at schools and childcare centers, children of West Oakland are less burdened by stationary point-source air pollution relative to Oakland. However, this does not translate to a lack of adverse human health effects.

KEYWORDS

air pollution emissions, children's health, schools and childcare centers, geographic information systems, buffer analysis

INTRODUCTION

Ambient air pollution has negative health and economic implications for exposed communities. In the developing world alone, more than 1.5 billion people live in polluted cities (World Health Organization 2000). High ambient air concentrations are associated with negative health effects such as asthma exacerbation, reduce lung function, neurological and reproductive disorders, and cancer (California Air Resources Board 2009). The World Health Organization (WHO) estimates ambient air pollution is responsible for 1.4% of all deaths (WHO 2002). In addition to costs to public health, there are potential economic costs as well. A study of one coal mining city in China determined that if health costs associated with air pollution were internalized into the price of coal, then price for coal would triple; these health costs are equivalent to 10% of the city's GDP (Wang and Mauzerall 2006). Despite these established public health and economic costs associated with human exposure to air pollution, polluting sources still occur frequently near dense populations.

Environmental justice studies have repeatedly found associations of disproportionately high occurrences of air toxic hazards in low income and minority communities such as Toxic Release Inventory facilities, toxic waste facilities, and more recently high traffic corridors (Ringquist 1997; Anderton et al. 1994; Boer et al. 1997; Jerrett 2009). Not only are these communities more likely to be home to environmental hazards, but these communities are more vulnerable to the negative health effects of air pollution because of compromised health status resulting from lack of access to nutritional foods and medical care and lessened ability resist the placement of such facilities (O'Neill et al. 2003; Pastor et al. 2002).

Beyond the equity concern in the disproportionate siting of environmental hazards in low income and communities of color, is the potential for cumulative exposure to air pollution. Because these communities are usually home to many ambient air pollution sources, individuals are often exposed to multiple types of pollution from many sources. Exposure to multiple hazards may have cumulative affects, magnifying health risks in humans (National Research Council 2009). The extent of these health effects depends on the total exposure of chemicals (Xia and Tong 2006). Even more concerning is there are health effects due to cumulative exposure to air pollutants blow national ambient air quality standards (Xia and Tong 2006).

Although people of any age can be negatively affected by air pollution, there can be particularly devastating effects for children. Children are particularly vulnerable to the toxicity of air pollution due to increased breathing rates compared to adults, and thus intaking greater quantities of air pollution (Poets et al. 1993, Dixon 2002). Children's lungs are still developing, and damage to their systems may have permanent effects on respiratory health (Bateson and Schwartz 2007). Increased air pollution has been linked to reduced lung function, increased acute respiratory disease morbidity, and aggravation of asthma in children (Liu and Zhang 2009, Dixon 2002, Bates 1995, Searing and Rabinovitch 2011). There are even associations with lowered birth weight and prematurity from maternal exposures and also has been linked to sudden infant death syndrome (Bobak 2000; Dales et al. 2004). Pollution levels below the EPA standards have also been linked to aggravating asthma in children (Gent et al. 2003).

West Oakland is a prime example of a low income and predominately black community that is exposed to many sources and types of air pollution. These sources include the activity from the Port of Oakland, diesel trucks on the three highways that border the neighborhood transporting goods, and surrounding industrial facilities supporting port activity (Mendoza 2011)**.** The Port of Oakland, the fourth largest container port in the United States, brings 73,000 jobs to the region and $462.7 in taxes **(**Port of Oakland**).** Although this port and associated businesses are of high economic value to the community, it comes at a potentially high health cost to the residents of this community. Kidney disease, neurological damage, cancer, asthma, and other respirator diseases are likely impacts from this pollution (Global Community Monitor.). Children in West Oakland are seven times more likely to be hospitalized for asthma symptoms than the average child in California (Pacific Institute and 7th street McClymonds Corridor 2002).

Assessing the outcomes of cumulative exposures of air pollution to public health is fairly new in the science and governmental monitoring effects have not yet caught up. In the Bay Area, the Bay Area Air Quality Management District has 28 permanent ambient air monitor stations. West Oakland has one active monitor (BAAQMD.). A singular monitor captures only the immediate air pollution levels, not the nuanced neighborhood level air pollution levels which residents are more realistically exposed to.

This study overcomes the possibly misleading representation by a singular air pollution monitor by examining the exposure of air pollution to our most vulnerable population—children. Schools and childcare centers are important to examine because children may spend a majority of their waking day at these locations, thus their exposures at these sites are an important factor for risk. The objectives of this study are 1) assess the spatial proximity and cumulative impacts of point-source polluting facilities to schools and childcare centers and 2) create a finer-grain picture of the air pollution emissions of point-sources in West Oakland. I used ArcGIS to analyze the stationary point-source air polluting sources in the vicinity (0.5 miles) of schools and childcare centers and created maps of potential cumulative exposure to point-source air pollution.

METHODS

Geographic Information Systems (GIS) is often used to answer environmental justice questions in communities like West Oakland regarding proximity of environmental hazards to the characteristics of potentially exposed populations (Charkaroborty and Maantay 2011). This study uses the same principles of these studies, but focuses on the proximity of point-source polluting facilities to children in schools and childcare centers. I used the buffer analysis method, in which circular buffers are created around point-sources of hazards to identify exposed populations. For this study's purpose, West Oakland was defined as the area bordered by Highway 580 and 980 (See Appendix A for a map).

Data collection and preparation

First, I started with collecting data for air pollution. I found data for point-source air pollution emitting facilities from California Air Resources Board (CARB) and Bay Area Air Quality Management District (BAAQMD). From the CARB website, I used the stationary emissions facility finder to generate a list of polluting facilities in Oakland which emitted any of the criteria air pollutants (total organic gases, reactive organic gases, carbon monoxide, nitrogen oxides, sulfur oxides, and particulate matter) (CARB). From the BAAQMD website, I found a list of facilities in Oakland which self-reported their toxic emissions, as apart of the Toxic Air Contaminate Control Program (BAAQMD). Toxics reported include diesel-particulate matter, formaldehyde and benzene. The lists I obtained from CARB and BAAQMD included the address of point-source emission facilities, type of pollutant, and pollutant emissions estimates.

Second, I collected data for schools and childcare centers (referred to as sensitive sites). To find data on childcare centers in Oakland, I used the California Department of Social Service's (CDSS) licensed care finder to search for currently licensed child care centers, defined to be "non-medical care and supervision for infant to school age children in a group setting for periods of less than 24 hours" (CDSS). Then to find data on schools, I used InfoAlamedaCounty, a website which aggregates government and corporate datasets for public use (InfoAlamedaCounty). From a list of private and public schools in Alameda, I extracted the schools in Oakland. Only schools that contained kindergarten to fifth grades were included. Foreclosed schools also appeared on this list, and were excluded.

The datasets for criteria air pollutants, toxic pollutants, schools, and childcares contained addresses that needed to be geocoded in ArcGIS 10's Street Locator to assign a geographic location to the listed address (ESRI). Addresses that were not automatically recognized by the Streets Locator on ArcGIS were located by a search on Bing Maps and manually located (Bing Maps).

Analysis

Calculating cumulative emissions

To find the potential cumulative exposure of air pollution from point-sources for each childcare center and school, I first identified the point-source polluting facilities near each sensitive site. Environmental justice studies have often utilized varying distances from 0.5 mile to 1 mile radius surrounding a point-source pollution emission site and used this buffer radius to characterize the population, often times finding higher proportions of low-income and colored populations compared to populations outside this radius (Charkarobotry and Maantay 2011). I tended to the conservative side by only looking at polluting facilities within a 0.5 mile radius of each sensitive site, capturing a smaller number of polluting facilities (See Appendix B for example). I generated a list of polluting facilities within a specified 0.5 mile radius for each sensitive site (Near Table tool on ArcGIS). I used this list to calculate for within each 0.5 mile radius of a sensitive site: the number of polluting facilities, total amount of criteria air pollutants, and total amount of toxic air pollutants from all polluting facilities. Summing the amount of air pollution from each polluting facility was used as a metric for quantifying the cumulative risk from multiple sources of exposure for sensitive sites. These calculations were also done for the entire city of Oakland as a means for comparison.

Suitability map analysis

Suitability maps are often used in urban land-use planning for decision-making, by weighting favorable against unfavorable land factors (i.e. proximity to amenities versus geological hazards) (Dia et al. 2001). I used this approach to identify the most unsuitable places to site a school or child care center in relation to cumulative impacts of point-source air pollution by creating a suitability map for West Oakland. I first identified unfavorable factors, air polluting facilities by extracting the top 25 criteria air polluting facilities with a 0.5 mile buffer within the borders of West Oakland and weighted these polygons by the amount of emissions. When these buffer polygons were drawn, the circles overlapped each other. The overlapping area represents a space in which there may be contributing emissions from multiple facilities, indicating cumulative impacts. For the areas that overlapped, I summed the amount of emissions as a cumulative emission amount for the particular area using ArcGIS. I repeated this suitability analysis for toxic air polluting point-sources.

RESULTS

Toxic Air Pollutants

For toxic air pollutants and elementary schools, I found West Oakland had a higher average count of polluting facilities within a 0.5 mile radius of each school, of 5.33 compared to 4.68 in Oakland (Table 1). The average amount of emissions was 62.38 lbs/year in West Oakland compared to 509 lbs/year in Oakland. As for childcare centers, West Oakland had an average count of 4.78 facilities within a 0.5 mile radius of each center compared to Oakland, with a 5.51 average count. The average emission was 97.02 lbs/year in West Oakland, compared to 627.60 lbs/year in Oakland.

Table 1. Toxic Air Pollutants. West Oakland and Oakland averages counts of point-source air polluting facilities and pollution emissions for within 0.5 miles of elementary schools and childcare centers.

	West Oakland elementary schools	Oakland elementary schools	West Oakland childcare centers	Oakland childcare centers
Average count of polluters	5.33	4.68	4.78	5.51
Average emissions (pounds/year)	62.28	509.00	97.02	627.60

Criteria Air Pollutants

For criteria air pollutants and elementary schools, I found West Oakland had a higher average count of 10.50 facilities within a 0.5 mile radius of each school compared to 7.82 in Oakland (Table 2). The total average emission per 0.5 mile radius of each school was 10.37 tons/year for West Oakland compared to 33.27 tons/year in Oakland. As for childcare centers, West Oakland had a higher average count of 9.75 facilities within a 0.5 mile radius of each center compared to Oakland, with a 8.79 average count. Average total emissions within a 0.5 mile radius of each school was 10.31 tons/year compared to 33.47 tons/year in Oakland.

Table 2. Criteria Air Pollutants. West Oakland and Oakland averages counts of point-source air polluting facilities and pollution emissions for within 0.5 miles of elementary schools and childcare centers.

		West Oakland elementary schools	**Oakland elementary schools**	**West Oakland childcare centers**	**Oakland childcare centers**
Average count of polluters		10.50	7.82	9.75	8.79
Average emissions (Tons/year)	*Total organic gases*	3.26	9.94	3.47	9.96
	Reactive organic gases	2.21	8.81	2.47	8.53
	Carbon monoxide	1.08	1.77	0.92	1.97
	Nitrogen oxides	2.47	5.16	2.43	6.85
	Sulfur oxides	0.03	2.60	0.03	2.55
	PM (particulate matter)	0.86	3.05	0.62	2.16
	PM 10 (Particulate matter smaller than 10 micrometers)	0.48	1.93	0.36	1.45
	Total	**10.37**	**33.27**	**10.31**	**33.47**

Suitability Map

I created a map to display the places in West Oakland near the highest emissions of criteria air pollutants and toxic air pollutants (Fig. 3, Fig. 4). In this map, the colors represent different levels of pollution, green indicating lower and red indicating higher levels of total criteria pollution. Each color level represents a tenth of a quantile in tons of emissions per year. The areas with the highest emissions are indicated by the areas in red. For criteria air pollutants, the area of highest emissions is along I-888 between Grand Avenue and West MacArthur Boulevard, in which the emissions for all 0.5 radius buffer zones overlapping this area sum to greater than 670 tons of pollution per year. For toxic air pollutants, the area of highest emissions is in the same area, with 79,000 pounds of toxic air pollution per year (64,000 pounds are ammonia).

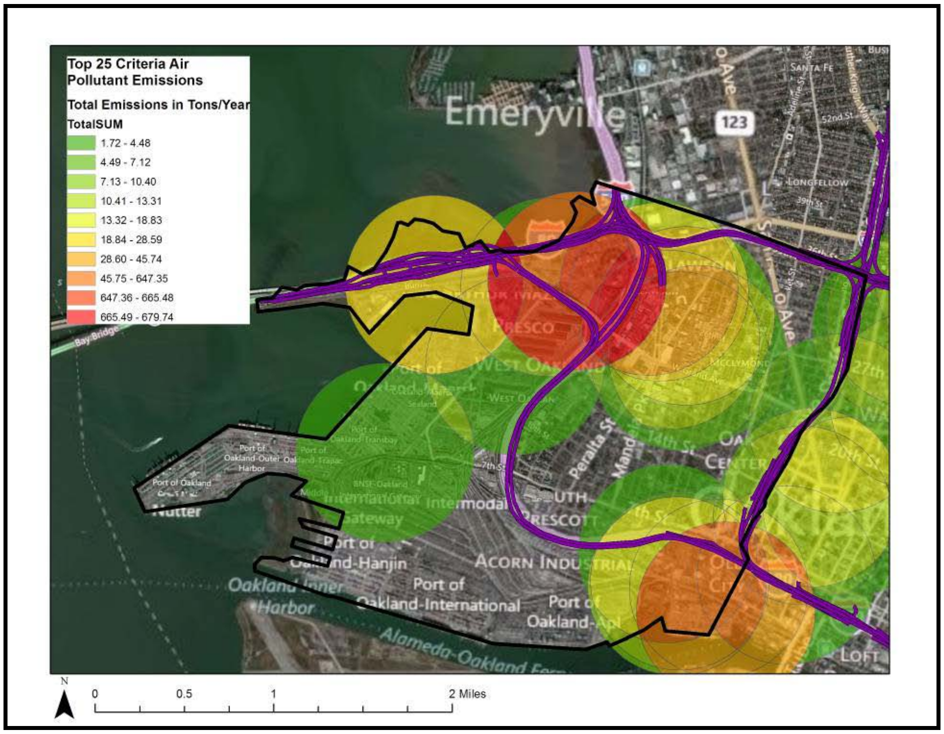

Figure 3. Suitability analysis map for top 25 criteria air pollution emission facilities. The area shaded red indicates high potential cumulative exposure to criteria air pollutants.

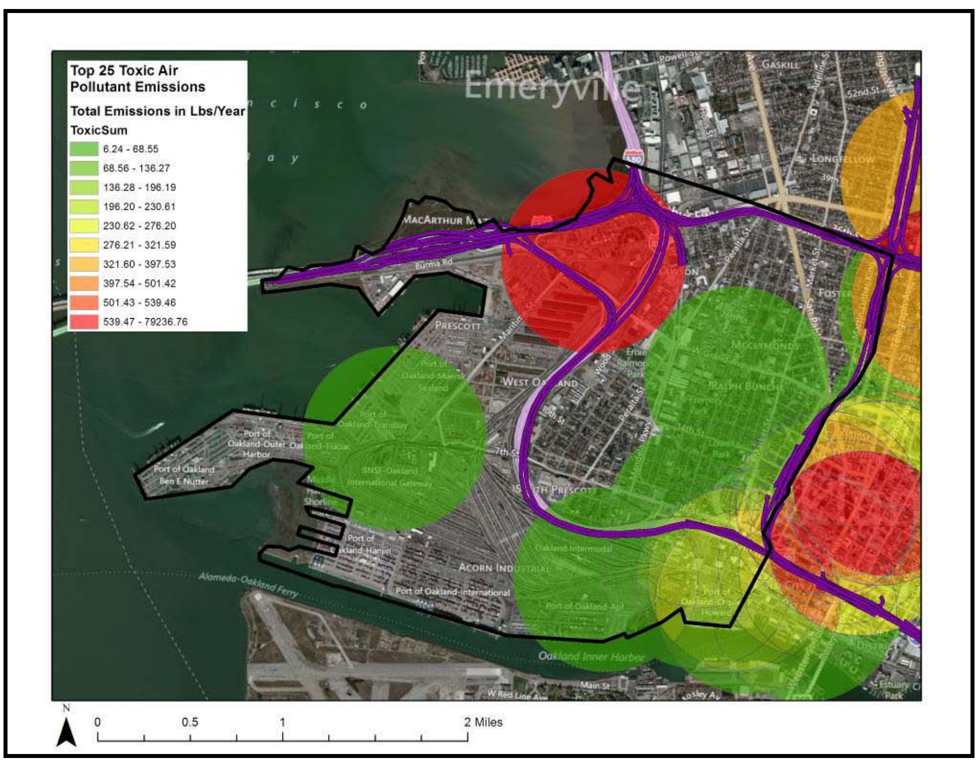

Figure 3. Suitability analysis map for top 25 toxic air pollution emission facilities. The area shaded red indicates high potential cumulative exposure to toxic air pollutants.

DISCUSSION

I found the average number of facilities that emit either criteria air pollutants or toxic air pollutants near each school and childcare center in West Oakland is higher than, or comparable to the average number of facilities in Oakland. The average total emission within a 0.5 mile radius of each sensitive site is greater in Oakland than in West Oakland. This suggests the pollution from point-sources is not disproportionately burdening children in schools and child care centers in West Oakland compared to Oakland. However, it is important to keep in mind that Oakland itself is home to an abundance of industry as a result of the Port of Oakland and while West Oakland's average emission per sensitive site is calculated to be less, this does not mean that their current amounts do not have an adverse health effect to the exposed children. Nevertheless, sensitive sites in West Oakland may experience less air pollution in comparison because there are just so few sensitive sites, and they do not happen to be sited near areas heavily impacted by cumulative emissions. However, the suitability map suggests there are areas in West Oakland that are heavily impacted by air pollution, with a 0.5 radius of criteria air pollutant emissions totaling over 670 tons/year and toxic air pollutants totaling over 79,000 pounds/year. These are areas in which we want to ensure there are no plans to site schools, childcare centers, and other centers of vulnerable populations. Interestingly, my original intention for this study was to assess the impacts of air pollution to more types of centers of vulnerable populations– senior centers, hospitals, and health clinics—but none were to be found in West Oakland, which is an entirely different question of justice.

Mobile sources, which are the major source of pollution for West Oakland, were not accounted for in this study. The primary pollutant of concern from mobile sources is diesel trucks that emit diesel particulate matter (BAAQMD CARE Program). Local diesel trucks bring containers from nearby warehouses, and long-distance trucks carry cargo to and from the Port of Oakland, often times not following specified truck routes that aim to reduce traffic within the community (Mendoza 2011). CARB estimates West Oakland is burdened by 265 tons/year of diesel particulate matter from mobile sources associated with port activities and 873 tons/year from all sources such as docked ships and local industries (Di, P.D. 2008). Diesel particulate matter emissions contributes to 1,200 excess cancer deaths per million (Di, P. D. 2008). If mobile sources were also accounted for, the average emissions near each sensitive site would have been larger for Oakland, particularly for West Oakland. I have found point-sources for diesel particulate matter are also significant potential contributor in exposure for schools and childcares in West Oakland, with an average emissions of 83.63 pounds/year compared to 62.98 pounds/year in Oakland.

Another systematic way in which this study undercounts for exposure to pollution is through edge effects. This can occur when points of interest, in this case, heavy polluters, lie immediately outside of the specified boundaries but can have an impact (Chakaroborty and Maantay 2011). Although this is likely to have occurred for 0.5 mile radius buffers, it is also likely to have occurred for pollution sites outside of the city's boundaries. Because I did not collect information on criteria and toxic air pollutants for cities that bordered Oakland, which likely have polluting sites close enough to the Oakland border to affect Oakland residents, this can contribute to undercounting. Future studies should eliminate the possibility of edge effects by including cities surrounding the targeted community.

Beyond the potential undercounting by not including non-point-source pollution and edge effects, it is once again critical to keep in mind that not only the exposure levels for the population in West Oakland be higher, but there are still potential cumulative effects and synergistic effects between chemicals. Studies that have found health effects with low-level air pollution still did not account for potential cumulative exposure effects, which is a critical problem for West Oakland since it is home to many types of industry emitting multiple chemicals (Xia and Tong 2005). The children of West Oakland are faced with an exceptionally dangerous health situation in which they are biologically vulnerable as children, socially and economically vulnerable coming from a low-income community of color, and residing in the high air pollution community with multiple chemical exposures of West Oakland. Looking forward, public officials must be careful in the siting of future schools and childcare centers, and take steps in reducing current levels of air pollution from multiple sources—both point-sources and non-point sources.

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APPENDIX A: Map of Oakland

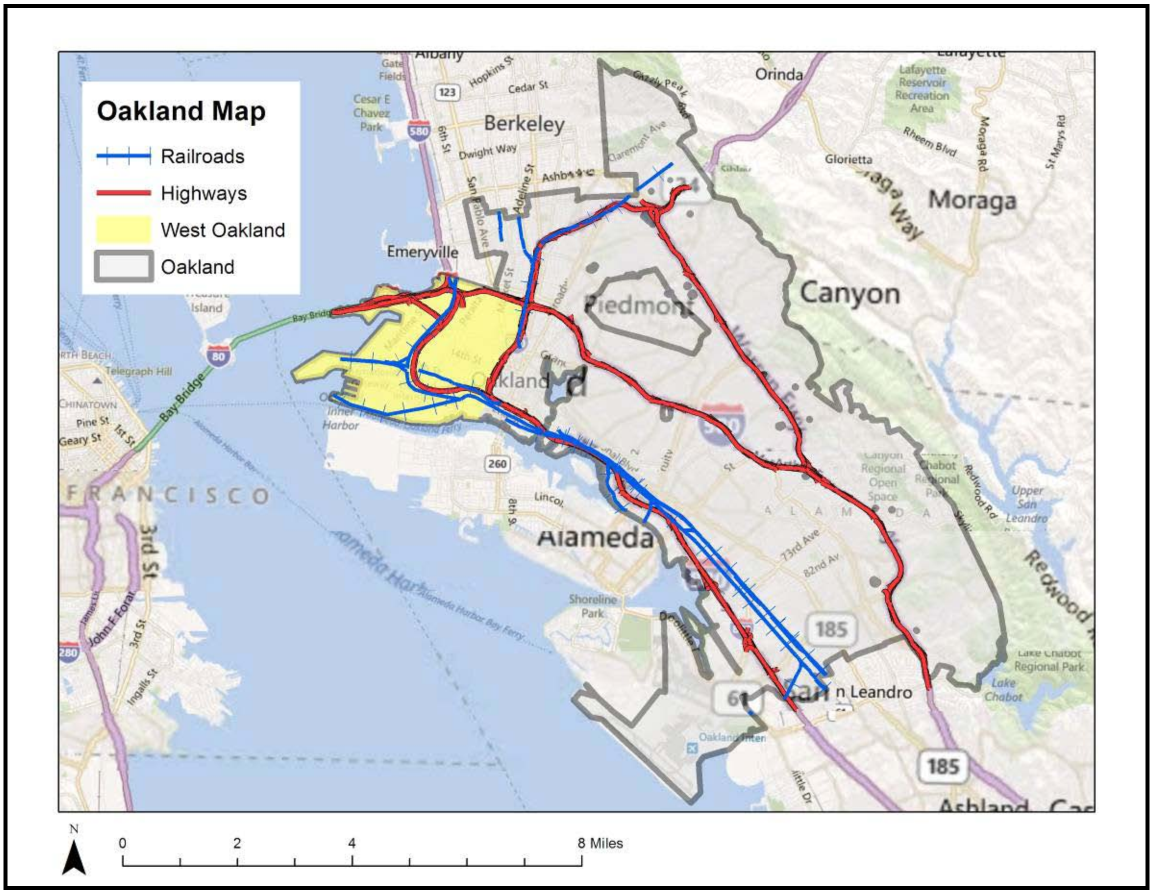

Figure A. Map indicating the location of West Oakland. Also shown are railroad and highway systems.

APPENDIX B: Buffer Analysis

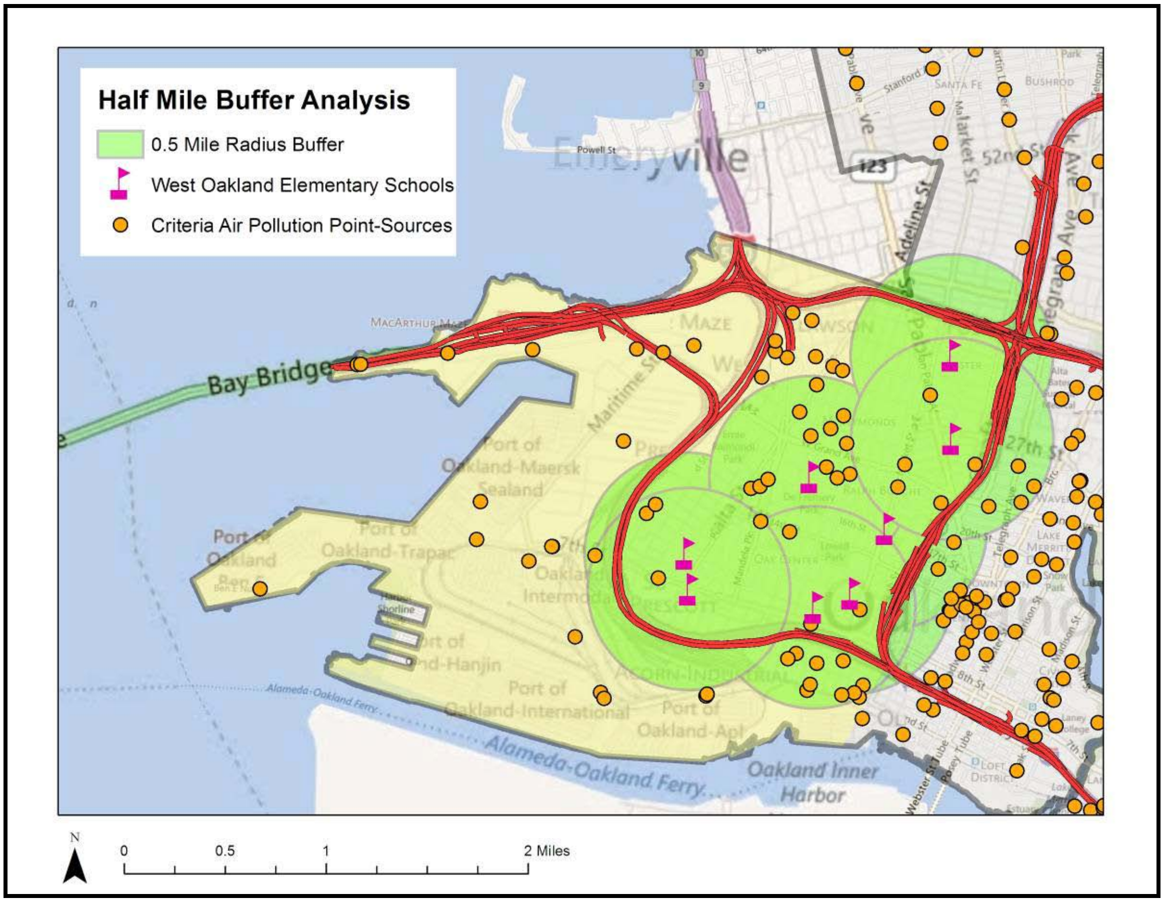

Figure B. Example of a half mile buffer analysis. Half mile radius buffer is drawn around a school, criteria air pollution sources are identified if they fall within this buffer.