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Minimizing air pollution exposure: A practical policy to protect vulnerable older adults from death and disability

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ABSTRACT

Air pollution causes an estimated 200,000 deaths per year in the United States alone. Older adults are at greater risk of mortality caused by air pollution. Here we quantify the number of older adult facilities in Los Angeles County who are exposed to high levels of traffic derived air pollution, and propose policy solutions to reduce pollution exposure to this vulnerable subgroup. Distances between 20,362 intersections and 858 elder care facilities were estimated, and roads or highways within 500 of facilities were used to estimate traffic volume exposure. Of the 858 facilities, 54 were located near at least one major roadway, defined as a traffic volume over 100,000 cars per day. These 54 facilities house approximately 6000 older adults. Following standards established for schools, we recommend legislation mandating the placement of new elder care facilities a minimum of 500 ft from major roadways in order to reduce unnecessary mortality risk from pollution exposure.

1. Introduction

Today it is estimated that 200,000 people die per year in the United States alone due to inhalation of air pollution (Caiazzo et al., 2013). The relative risk for mortality due to living in a heavily polluted area is roughly equivalent to the relative risk of being overweight (a BMI between 25 and 39.9 kg/m^2) (Pope et al., 2002). Study of the ACS Cancer Prevention II population showed that for every 10 $\mu g/m^3$ increase in fine particulate matter ($PM_{2.5}$) concentration, an important component of air pollution, there was a concurrent increase of 6% in mortality due to cardiopulmonary conditions, an 8% increase in mortality from lung cancer, and a 4% increase in total all-cause mortality (Pope et al., 2002). National guidelines are 35 $\mu g/m^3$ daily maximum and 12.0 $\mu g/m^3$ annual maximum for $PM_{2.5}$.

While air pollution negatively affects everyone, children and older adults are especially vulnerable to adverse health effects. Air pollution exposure at a young age can cause cognitive impairments and asthma (Perera et al., 2006; Morgenstern et al., 2008), while pollution exposure at older ages causes a disproportionate increase in mortality, when compared to middle aged individuals (Hoek et al., 2002; Katsouyanni et al., 2001). Mortality from air pollution exposure is mainly due to cardiovascular and cardiopulmonary effects (Brook et al., 2004; Chen et al., 2013; Pope et al., 2002).

Typical age related declines in the cardiovascular system, such as decreased reserve capacity, decreased elasticity of the arterial wall, and decreased ability to respond to norepinephrine signals to adjust blood pressure, make the older adult population extremely vulnerable to cardiovascular and cardiopulmonary disease, and exposure to air pollution amplifies these risks. Although individuals aged 65 and over only represent 13.3% of the population, they account for 42.8% of all cases of heart disease, and 52.1% of coronary disease (Center for Disease Control, 2010). Exposure to high levels of $PM_{2.5}$ is associated with an increased intima-medial thickness, a common measure of the progression of atherosclerosis (Adar et al., 2013). Individuals exposed to $PM_{2.5}$ also showed a decrease in heart rate variability resulting in less adaptability to changes in cardiovascular demands, increasing susceptibility to myocardial infarction (Adar et al., 2007). Particulate matter also causes inflammation of the alveolar cells in the lung, which then releases signaling molecules that increase blood coagubility, raising the chances of clot formation (Ruckerl et al., 2006).

Older adults, especially those in poor health with diminished cardiovascular function, are not as adept at handling these added stressors, therefore they have a higher risk of mortality as a result of the exposure. Individuals with preexisting conditions, especially

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cardiovascular or cardiopulmonary conditions, are more vulnerable to air pollution (Goldberg et al., 2001). Also, individuals who sustained a myocardial infarction during heavy pollutant exposure show an increased 10-year future mortality risk, and survivors of a previous myocardial infarction show greater all around mortality later in life if exposed to air pollution (Rosenbloom et al., 2012; Berglind et al., 2009). Exposure to $PM_{2.5}$ has also been associated with increased mortality to individuals with type-2 diabetes (Peters, 2012; Katsouyanni et al., 2001), where older adults are again overrepresented, comprising 39.4% of the diabetic population.

Increasing awareness of the harmful effects of air pollution has led to the development of guidelines to prevent excess exposure to these toxicants. The EPA has been successful in monitoring and reducing air pollution across cities in the United States, however, its measurement methods are coarse and very poorly measure the variability within the city. Two locations within the same city often have greater differences in pollution concentration than the difference between two cities, and the difference in risk can also be larger within a city than between two cities (Jerrett et al., 2005; Miller et al., 2007). In one study, the range of exposure to particulate matter within Los Angeles was 20 $\mu g/m^3$, versus a range of 16 $\mu g/m^3$ between 116 other cities studied (Jerrett et al., 2005). Colloquially know as hot spots, these are areas within a city with much higher pollution concentration than background, often due to higher traffic volume. Identifying these areas of greater pollution concentration, and minimizing exposure to sensitive populations in these areas is a critical step to minimize adverse health effects from pollution exposure.

In this study we quantify the number of older adult facilities, specifically nursing homes, assisted living facilities, and adult day healthcare centers, in Los Angeles County that are currently being exposed to unnecessarily high levels of traffic derived air pollution. Methods for the reduction in pollution exposure through the strategic placement of facilities are proposed.

2. Materials and methods

2.1. Data acquisition

Data were compiled from publicly available databases, which provided information for line coordinates of roads and highways in Los Angeles, traffic counts at one mile intersections or freeway exits, and addresses and occupancies for facilities throughout Los Angeles which cater to the older adult population. These sources were the 2010 TIGER road file for road and highway coordinates, while the Los Angeles Department of Transit traffic survey 10-year summary and the State of California 2012 Annual Average Daily Traffic Report provided traffic data. The nursing home data was provided by the CA.gov site, with the Department of Social Services providing data on adult day health care and assisted living facilities, and skilled nursing facilities data provided by the health facilities section.

Data on road and highway coordinates came from a 2010 TIGER road file (Topologically Integrate Geographic Encoding and Referencing) of the county of Los Angeles. The TIGER file contained geographical coordinates in GCS_NORTH_AMERICAN_1983 for 2,366,677 nodes on the centerline networks of roads used by the US Census Bureau. Additionally, the TIGER road file also contained MAF/TIGER feature classification codes (MTCC), depicting the type of road on which each node was located. Node coordinates were converted to latitude and longitudes using Global Mapper 15 software so that they could be more easily incorporated with traffic and facility location data. Traffic data is a combination of the Los Angeles Department of Transit traffic survey section 10 year 2001–2010 summary, and the State of California 2012 Annual Average Daily Traffic Report. The first file had eastbound, westbound, southbound, and northbound traffic counts for 20,362 intersections in Los Angeles. The second file contained traffic count data for one mile increments on major highways throughout the Los Angeles area. Information on freeway name, exit names, and average monthly and daily traffic counts were available for 763 points.

Data on assisted-living facilities (ALF), adult day health care (ADHC), and skilled nursing facilities (SNF) were available for download from the CA.gov website. Information on ADHC and ALF was provided through the department of social services link (https://secure.dss.cahwnet.gov/ccld/securenet/ccld_search/ccld_search.aspx), while information for SNF was provided through the health facilities section (https://hfcis.cdph.ca.gov/search.aspx). These files contained facility addresses and capacity. Very small facilities—those with less than 6 beds—and those without current licenses were excluded from our analysis. Overall, our analytical sample consisted of 858 facilities (192 ADHC, 400 SNF, and 266 ALF), see Fig. 2.

2.2. Analysis

The high performance computing cluster from the University of Southern California was used for analyses. From available information on city addresses, latitude and longitude were estimated for the facilities and intersections using the STATA module, Geocode3 (Bernhard, 2013). Next, the Haversine distances—a measure of the distance between two points on a sphere—was estimated between the 858 facilities and 2,366,677 geographical points in the TIGER road file using the STATA module Vincentry (Nichols, 2003). Given that node coordinates for roads were calculated for the midpoint of the road, distances to facilities were adjusted based on road type to reflect a more accurate measure of the distance between the facility and the nearest side of a road. We subtracted 66 ft from distances between facilities and major freeways, based on the assumption that most major freeways in Los Angeles have eight lanes and two shoulders, leading to an overall diameter of 132 ft. Similarly, 52 ft was subtracted from distances between facilities and major freeways, given that the average diameter for a Secondary Highway Class II is 104 ft. Finally, for residential roads, whose diameters are estimated to be approximately 60 ft, we subtracted 30 ft from their distances to nearby facilities.

Once the distance was estimated for every facility by road point combination, only road points that were less than or equal to 500 ft away from any given facility were kept ($n = 33{,}064$). The 500 ft cutoff was chosen in light of the proposed policy of restricting construction of new building to a minimum of 500 ft from a major roadway, a distance based on established school regulations, and founded on numerous studies modeling spatial dispersion characteristics of $PM_{0.1}$, including studies done in Los Angeles (CARB, 2005; CA SB 352; Hagler et al., 2009; SCAQMD, 2005; Zhu et al., 2002, 2009). The goal in the current analysis is to quantify the number of facilities within this 500-ft radius and exposed to high $PM_{0.1}$ concentrations. We choose to calculate distance between facilities and road points rather than between facilities and intersections or highway exits given that the later may not actually represent the closest road point to a facility. However, given that traffic counts are only provided for intersections and freeway exits, traffic counts for road points within 500 ft of a facility were estimated by matching them with the nearest intersection or freeway exit on the same street and then assigning that traffic count to them. This was done by calculating the Haversine distance between each road point and each intersection or freeway exit which shared either a primary or cross street. Based on these distances, the closest location with measured traffic count was