Proximity of Parks and Schools to Highways in Alameda County

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ABSTRACT

My research aims to answer the question whether certain characteristics affect a park or schools risk of exposure to vehicle emissions. My research focuses on parks and schools because I am specifically interested in analyzing how children are affected by toxic air pollution. To measure exposure to vehicle emissions I measured the distance (m) between schools and parks and highways or highly trafficked roads. I analyzed ethnicity/race data, education level, and median household income for parks. For schools I analyzed title 1 eligibility, ethnicity/race data, and academic performance. I found that as academic performance decreased the distance between schools and highways decreased. Title-1 eligible schools were 1.79 times more likely to be located within 250m of a highway or highly-trafficked road. The odds of a school that serves predominantly minority students being near a highway are 2.5 times the odds of a predominantly white school. There was no correlation between education level and the distance between parks and schools. Parks in a predominantly white area were less likely to be near a highway or highly-trafficked road. Lastly, there was a low positive correlation between income level and the proximity between parks and highways.

KEYWORDS

environmental justice, toxic air pollution, highly-trafficked roads, particulate matter (PM 2.5), children

INTRODUCTION

Emissions from passenger vehicles are a major contributor to pollution which places residents near highways and highly trafficked roads at risk for adverse health effects. Increased urbanization in California will exacerbate current air quality issues because urban areas experience worse air pollution (Yang 2020). Vehicle emissions pose a serious danger to human health because it is a source of particulate matter smaller than 2.5 micrometers (PM 2.5). Particles smaller than 10 micrometers can penetrate deep into your lungs and may even enter your bloodstream (EPA 2021). Clearly PM2.5 is extremely dangerous, for instance a study estimated that PM2.5 emissions from vehicle-related traffic lead to approximately 3,100 premature deaths per year in California (Hill et. al 2014). Adverse health effects from vehicle emissions have been well documented with symptoms including wheezing, higher incidence of asthma, and flu among other health complications (Houston et. al 2006). Any population exposed to high traffic levels are susceptible to health complications, but certain demographics such as children are especially vulnerable.

According to a report done by the World Health Organization (WHO) children are especially vulnerable to the effects of air pollution because they breathe more rapidly and therefore absorb more pollutants. Children are also vulnerable to health complications because they are still undergoing a fundamental developing stage where their brains and bodies are still developing (Perera 2017). Children are also smaller in stature, so they live closer to the ground, where certain pollutants reach peak concentrations (Houston et. al 2006). As expected, children are the most frequent visitors for K-12 public schools and parks. Therefore, I am researching parks and schools to understand if children are being exposed to toxic air pollutants from vehicle emissions.

To determine if children in specific demographic groups face a higher risk of exposure, I will investigate if certain characteristics affect a park or school's risk of exposure to vehicle emissions. I will study if a park's ethnicity/race data, median household income and education level affect the proximity to highways. I am also researching if a school’s title 1 eligibility, academic performance, and race/ethnicity data affect the proximity to highways. Additionally, I want to know if a school and park’s size affects the risk of exposure to toxic air pollution from vehicle emissions.

BACKGROUND

California air quality and environmental justice

California has seen an increase in wildfires and high ozone days due to climate change (NCA 2018). This is a severe issue since California already suffers from some of the worst air quality in the nation and it will only worsen as climate change progresses (EDF 2021). High ozone days are extremely dangerous because during high ozone days the weather conditions are highly likely to combine with pollution emissions, forming high levels of ground level ozone (Arkansas 2017). This causes harmful health effects such as respiratory complications, airway inflammation, and premature aging of the lungs (Lippmann 1989). Researching vehicle emissions is critical to understanding the state's air pollution issue because light-duty vehicles are responsible for 13% of the nitrogen oxide pollution and 28% of the state's carbon dioxide pollution (EDF 2021). Additionally, highway vehicles are one of the largest sources of disparity for exposure to particulate matter 2.5 (PM 2.5). For example, people of color experience higher-than-average exposure to highway vehicle emissions opposed to white individuals who face lower-than-average exposure levels (Tessum 2021). Racial-ethnic disparities amongst PM 2.5 exposure are still prevalent despite overall PM 2.5 exposure decreasing across the U.S. For instance, a study conducted in the U.S. found that communities of color and low-income communities are disproportionately affected from vehicle-related pollution (Rowangould 2013). Low-income individuals and people of color face a higher burden of exposure because they make up a large percentage of the individuals residing near roads and highways (Rowangould 2013). An issue that has been discussed is whether the roads and highways were placed near vulnerable communities or if these individuals moved into areas with a large number of roads and highways.

Toxic air pollution in the Bay Area

It has been well documented that California has a severe air quality issue overall, however urban areas may be at an even higher risk. Individuals living in urban areas are at a higher risk of exposure because urban areas have more traffic than rural areas (CDC 2017). The same study found that air quality improves as an area becomes more rural. Additionally, urban area vehicle emissions are potentially more harmful than rural emissions because urban areas are more populated, so emissions affect a larger number of people. For instance, "an urban ton of PM2.5 causes $3,300 in damages" versus $1,100 for a rural ton (Muller and Mendelsohn 2007).

Alameda County is in the Bay Area where there have been several studies researching air quality. In the Bay Area more than 2,500 lives have been lost yearly due to traffic-related air pollution exposure (Southerland et. al 2021). Analyzing the Bay Area may be informative because there has been evidence of environmental justice issues. For instance, an analysis by the EDF found that in the Bay Area communities of color experienced double the rate of asthma from NO2 which is typically "used as a marker for transportation-related pollution" (EDF 2021). I will be using Alameda County as a case study for California air pollution concerns because it is an urban area located in the Bay, which increases the likelihood of toxic air emissions. Some potential limitations of my study are that I am only analyzing one Bay Area County, and Alameda County may not be representative of all counties in the Bay. Future studies should analyze other Bay Area counties in addition to Alameda County to obtain more accurate data.

What came first: pollution or people?

If certain Alameda County cities are potentially being targeted and having highways placed in their neighborhoods at a disproportionate rate based on their demographics then there is evidence of Environmental injustice. Environmental injustice is evident when people of color are "impacted by environmental hazards to a greater extent" than white individuals. Environmental justice also occurs when impacted communities have a larger percentage of low-income individuals or minorities present (Downey 1998).

An ongoing debate in the Environmental Justice community is the "chicken or the egg" debate. The chicken or the egg debate attempts to answer the question of how racial and economic disparities have come about by asking if pollution or people came first. One side of the debate argues that people came first and the disproportionate siting of environmental hazards in communities of color happens after people of color move into the area. This side of the argument insinuates that communities of color are targeted and are having environmental hazards placed in their communities purposefully. Environmentally dangerous facilities are potentially located near racial and ethnic minorities because "industries desire to minimize production costs by siting new facilities in places where land values are low" (Mohai 2020). These locations may coincide with where ethnic and racial minorities live. Other than economic limitations another reason it may be difficult for ethnic minorities to move away from environmental hazards is housing discrimination.

The other side of the argument states that pollution came first, and the construction of environmental hazards happened then people of color moved in. Potential explanations for this side of the debate are that the prevalence of environmental hazards decreases property values and the quality of life. This then causes more affluent white residents to move out of the community, and the poor and minorities to move into the area. In my research I am going to determine if communities of color in Alameda County are being targeted and are purposefully experiencing a disproportionate rate of environmental hazards being built in their neighborhoods.

Race versus class debate

In addition to the "chicken or the egg" debate, scholars have argued whether race or income are a better predictor for risk of exposure to toxic air pollution. I will be using both race and income and intersecting factors because "conceptualizing race and income as interdependent factors" can help us understand environmental discrimination (Downey 1998). Using both factors is informative because race and income work together "to produce racially and environmentally inequitable outcomes" (Pulido 2000). When race and income are used as competing factors it "decontextualizes race and income" and causes researchers to separate them from the social, political, and historical processes that have contributed to the disparities in environmental hazard distributions (Mohai 2015).

There has been a long history of economic and racial disparities in the nation. For instance, there is an increasing wealth gap between rich and poor in tandem with significant disparities between white populations and people of color (Mohai 2020). By analyzing race in my research, I will investigate whether certain racial demographics are disproportionately burdened by vehicle emissions. Similarly, by analyzing income levels, I will investigate whether low-income communities are being targeted and having to carry the burden of toxic air pollution.

Distance-based exposure modeling

Unit-hazard coincidence and distance-based modeling are commonly used in environmental justice research to determine exposure from environmental hazards. In a unit-hazard coincidence method researchers select a geographic unit, such as census tracts or zip code area. They then determine which geographic units contain the environmental hazards and identify them as a "host" unit. Researchers will then compare the demographic characteristics of host and nonhost units to determine if there are any statistically significant differences between them. A pitfall of this method is that "the unit- hazard coincidence method failed to control adequately for proximity" (Mohai 2020). For instance, if all residents in a unit live far from the hazards, then there is no reason to suspect an association between the facility and the racial and socioeconomic characteristics of that unit because all residents are far away.

A "distance-based" method is argued to be more robust than other methods such as the "unit-hazard coincidence" method. Distance-based methods are more robust because they control for the exact location of hazardous sites and the distance between individuals and the sites (Mohai and Saha 2015). In order to determine the risk of exposure that individuals face to toxic vehicle emissions, I will be using a distance-based method. I will analyze the distance from highways to parks and schools in Alameda County cities. I will then combine the distances with race, income, education, and size in order to determine disparities between exposure to toxic air pollution.

METHODS

Study site

I researched parks and schools in Alameda Counties 14 incorporated cities. Alameda Counties incorporated cities include: Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City. According to the Alameda County Office of Education website there are 18 school districts within Alameda County. I excluded school districts for unincorporated cities, since they are not part of my study site. Additionally, I excluded private schools because they do not rely on funding from the city which may lead to inaccurate representation of the city's demographics. Online schools were also excluded because they do not have a campus so the students are not exposed to physical environmental hazards while attending class. Adult schools were also excluded, because my research is focusing on childrens' exposure to vehicle emissions.

School data collection

Income, academic performance, size and racial data

I analyzed the percentage of minority students enrolled, title I eligibility, and academic performance. To collect data on Alameda County school's academic performance, I accessed the California School Dashboard Data which measures a school's academic performance. The California School Dashboard divides academic performance into five color categories from red being the lowest performance level, to blue being the highest performance level (https://tinyurl.com/e2hpj4jv). After downloading the NCES Common Core of data for Alameda County public schools I collected data on each school's race and income levels. I used the percentage of minority students enrolled and title I eligibility. I classified schools as predominantly serving minorities if more than 50% of students enrolled are a ethnic/racial minority. Title I eligibility was used as a socioeconomic indicator of the student body because eligible schools are considered as high poverty by state and federal regulations, requiring at least 40 percent of enrolled students come from low-income families (NCES 2022). I used the total students enrolled to represent the size of each school, since larger schools will most likely have more students enrolled.

Proximity data collection

In order to locate public schools in Alameda County geographically I downloaded the ArcGIS Alameda County Schools map layer. The ArcGIS U.S. Public Schools map displays a geographic marker and school name for all schools in Alameda County. After locating the school I used the point to line proximity tool to generate a table of the distances between schools to highways and highly-trafficked roads (Figure 1). The blue points are the geographic markers used for schools in the ArcGIS U.S. Public Schools map layer. The red line is the highways and highly-trafficked roads data in the National Highway System dataset. The pink line is the distance, in meters, calculated between parks and schools.

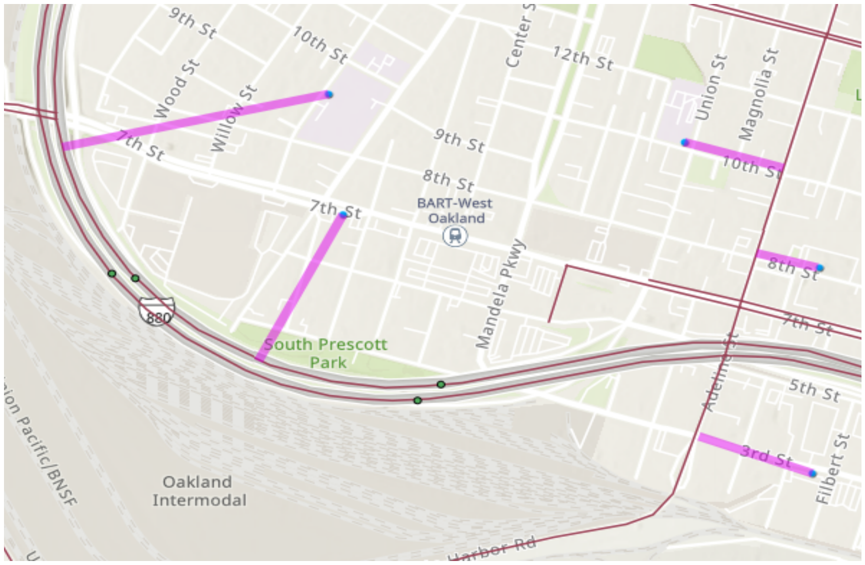

Figure 1. ArcGis U.S. public school map. I overlayed the ArcGis U.S. Public School map with the CalTrans National Highway System dataset to calculate the distances between schools and highways.

Parks data collection

Income, race, size and education level data

I collected race, median household income, and percentage of individuals 25 and older with a bachelor's degree or higher for each census tract that an Alameda County park was located in. I used the percent of individuals with a bachelor's degree to represent educational level, because the amount of individuals with a high school diploma has increased dramatically over the years. In 2017 around 90% of the U.S. population aged 25 and older had a high school diploma, in comparison to 1940 when less than half of people 25 and older had a high school diploma (CENSUS 2017). Therefore, I believe that attainment of a bachelor's degree more accurately reflects educational level. I calculated the size of each park by converting the area (square miles) provided by the USA Parks map layer for parks to meters squared. An issue was the original dataset collected area in square miles. Most local parks were too small to have an area in square miles, so the area was calculated as zero.

Census tract data

Using ArcGIS I created a map layer for census tract boundaries and park boundaries. I downloaded the USA Parks map layers which display boundaries for all parks in Alameda County as polygons. First I located the location of a park, focusing on one Alameda County city at a time. After locating the park I determined which census tract it belonged to and collected data for the census tract, by using the Alameda County Census Tract layer in ArcGis (Figure 2). Using Excel I created a datasheet with all parks and their respective census tracts. I accessed CENSUS data (https://data.census.gov/) selecting all census tracts that were part of my study group (Figure 2). After selecting all desired census tracts, I used the table tool which creates a table of all tracts and the statistics I analyzed.

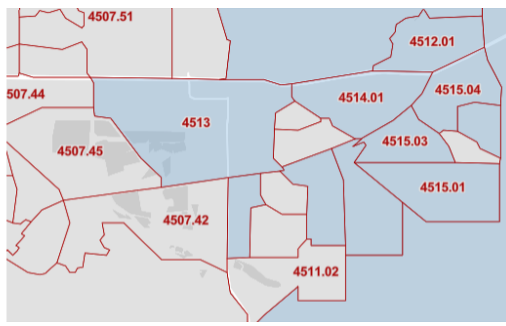

Figure 2. Census tract data map. Census tract boundaries are respresnted by the red lines with the census tract number. I selected the census tracts that are a part of my study group by selecting them which highlights them in light blue.

Proximity data analysis

To calculate the distance between parks and highways and highly-trafficked roads I used the proximity tool in ArcGIS. Parks were input as polygons and highways and roads were represented as lines. Using the generate near tool USA parks were designated as the starting location. The proximity tool generated a table which I exported as a csv file which contained the distances between parks and highways in meters.

Highways and highly-trafficked roads data

I accessed the CalTrans GIS highway datasets and downloaded the CalTrans National Highway System dataset and opened it in ArcGIS. The National Highway system dataset includes all principal arterials (i.e. Functional Classifications 1, 2 and 3). I used the proximity tool to measure the distance between highways and highly-trafficked roads to parks or schools in meters. I categorized the distances into 4 categories: ≤100 m, >100–250 m, >250–500 m, >500–1,000 m, and >1,000 m. Only schools and parks with distances of 250m and smaller were considered near vehicle emissions, because literature I referenced when creating my methods determined (based on previous scientific literature) 250m is an ideal cutoff distance. This is mostly due to the fact that vehicle pollutants drop to near-background levels at 200m when upwind, and around 300m when downwind (WHO 2013).

Statistical analysis

School statistical analysis

After calculating the minority statistics for parks and schools I created an excel sheet that contained all my data. I calculated the percentage of students enrolled for each race/ethnicity by dividing the number of students enrolled in each race by the total number of students enrolled at each school. I calculated odds ratios using R (RStudio 2022) to analyze the association between race/ethnicity and the distance between schools and highways. I compared each race/ethnicity's odds ratio to the odds ratio computed for white students to determine if minority students are at greater risk of exposure. I repeated the same steps to analyze the association between title I eligibility and the proximity of schools to highways and highly trafficked roads.

In order to analyze whether academic performance had an effect on the distance between schools and highways or highly-trafficked roads I calculated the average distance for each academic level. Using Excel I calculated the regression coefficient by performing a linear regression of the medians for each academic level.

Parks statistical analysis

To determine if minorities were more likely to live near parks that are near highways or highly trafficked roads I used odds ratios. I compared the odds ratio for each non-white race/ethnicity and comapred it to the odds ratio for white individuals.

In order to determine the association between education and income level and the proximity of parks to highways I calculated the pearson's correlation coefficient. First, I recorded data on the percentage of individuals aged 25 and older that have a bachelor's degree or higher on an excel sheet containing the distances calculated. After importing the data into Rstudio, I ran the pearson's correlation test to determine if there was a correlation between the two variables. The same steps were repeated to analyze the correlation between median household income and the distance between parks and highways. Due to issues with data collection, I was unable to obtain results on the correlation between the size of parks and proximity to vehicle emissions.

RESULTS

Schools' results

I found that as academic performance decreased so did the distance between schools and highways or highly-trafficked roads (Figure 3). Title-1 eligible schools were at a higher risk of being exposed to vehicle emissions. The odds of a title-1 eligible school being within 250m of a highway were 1.79 times the odds of a non-eligible school (Table 1). Predominantly white schools were less likely to be located within 250m of a highway or highly-trafficked roads. The odds of a school serving predominantly minority students being near a highway are 2.5 times the odds of a white school. The odds of a predominantly hispanic school being near a highway were 1.15 times greater than a predominantly white school (Table 1). Additionally, predominantly black schools were 1.04 times more likely to be near a highway or highly trafficked road (Table 1).

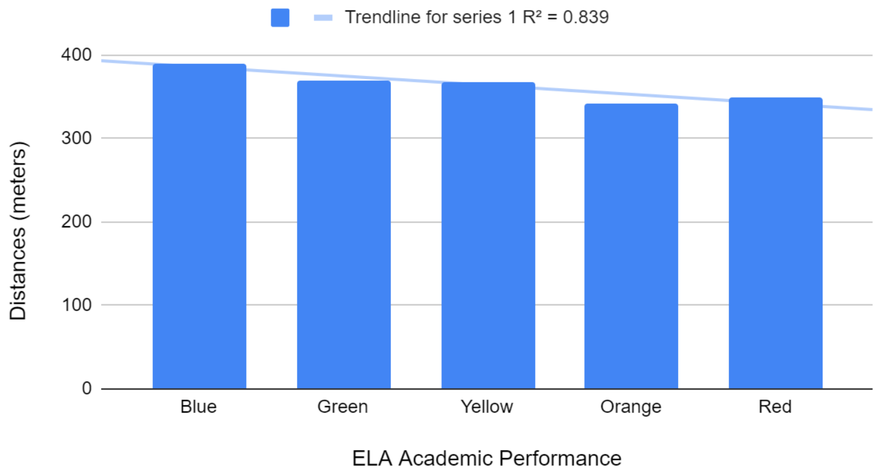

Figure 3. Graph for Academic Performance correlation to the Distance between Schools and Highways. The graph demonstrates that the distance between schools and highways decreases as Academic Performance worsens. The correlation coefficient $R^2 = .839$.

Table 1. Odds ratio for schools' data

Variable	Odds Ratio	95% Confidence Interval
Title-1 Eligibility	1.79	1.05-3.07
Hispanic	1.15	.66-1.98
Black	1.04	.31-3.56
White	.40	.42-1.18

Parks' results

Parks with a higher percentage of minorities were more likely to be located within 250m of a highway or highly trafficked road. Non-white ethnic/racial groups had a larger odds ratio than white individuals to live near a park located within 250m of a highway or highly-trafficked road. Hispanic individuals were .89 times more likely to live near highways than White individuals. Parks that had a majority minority population were 1.4 times higher than predominantly white parks.

There was no correlation between the percentage of individuals with a bachelor's degree and the distance between parks and highly-trafficked roads (Table 2). There was a low positive correlation between median household income and the distance between parks and highways. As the median household income increased the larger the distance between parks and highways (Table 2).

Table 2. Correlation analysis for parks and schools

Variable	**Correlation Coefficient**	**95% Confidence Interval**	**P-value**
Median Household Income	0.2007691	0.08405537 0.31204858	0.0008497
% of Individuals with a Bachelor's degree or higher	0.02000585	-0.09620082 0.13567449	0.7362
Size of Schools	0.001276512	-0.1261743 0.1286859	.98

DISCUSSION

It is evident that children are being exposed to toxic vehicle emissions while visiting parks or public schools. Based on my results we can state that children in certain socioeconomic and racial groups face a higher risk of exposure to vehicle emissions. As stated in my introduction, environmental justice occurs when minority or low-income individuals face an unequal burden to environmental hazards. Therefore, we can state that there is environmental justice in Alameda County.

Summarizing results

My original central research question asked whether certain characteristics affected a park or schools' risk of exposure to toxic air pollution. I found that there were differing results for parks and schools. To analyze public schools in Alameda County I asked if title-1 eligibility, race/ethnicity, and academic performance affected a schools proximity to highways. All characteristics had an impact on the distance between schools and highways. For parks I studied if median household income level, % of individuals with a bachelor's or higher, and race/ethnicity impacted the proximity to highways. All characteristics except median household income level impacted the distance between parks and highways. This result did not align with my expected hypothesis, because I expected that lower-income individuals would be closer to highways. This disparity may be due to the fact that I did not include unincorporated cities in my study. Lasty, I wanted to know if a park's or school's size affected its proximity to highways or highly trafficked roads. Due to time constraints I was only able to obtain results for schools. I found that there was no correlation between the size of schools and the distance to highways. Overall, it is evident that lower-income and minority communities in Alameda County experience a greater risk of exposure to vehicle emissions.

Lack of resources in impacted communities

Lower-income and minority individuals are at greater risk to experience health complications from air pollution, because they are more likely to reside near highways as stated above. This is a significant issue, because exposure to toxic air pollution from vehicle emissions has been linked to several health problems including a higher prevalence of respiratory diseases, cardiovascular disease, and cancers (Deguen et al. 2012). Individuals residing in areas with toxic air pollution likely do not have access to proper healthcare to treat health complications from exposure vehicle emissions. Low-income families face many barriers such as lack of insurance coverage, lack of access, and unaffordable costs when seeking medical coverage (Angier et al. 2007). The same study found that children from lower socioeconomic backgrounds experience a lack of access to health care services and poorer health. This health inequality is partly due to Black and Hispanic individuals living in the poorest, and most polluted areas that do not provide access to quality housing (Graeml 2019). Providing quality housing is important because according to the Berkeley Public Health Division 80% of our health is impacted by our environments.

Limitations and future directions

A large limitation in my data is that I am only focusing on Alameda County which may not be an accurate representation of the entire Bay Area. Future studies should widen the study group to include more counties and cities in Northern California. It would also be beneficial if future studies included unincorporated cities. Another limitation in my study group is that I excluded private schools. It may be interesting to include private schools and compare data between public and private schools. Future research should also focus on neighborhood level analysis because similar to my research most studies focus on individual cities. City-scale studies may not accurately capture the spatial distribution of air pollution because they potentially dilute hot spots with high concentrations of air pollution (Apte et al. 2021). Another limitation in my study is that I was unable to obtain results on the area of a parks' impact on proximity to highways or highly-trafficked roads. In the future I would also use the area of a schools' campus rather than the total students enrolled to represent the size of a school. Lastly, future studies should consider including Annual Average Traffic Volume (AADT) Data in addition to distance to approximate the risk of exposure. Including AADT data is beneficial because it informs us on the amount of pollution individuals are being exposed to.

Broader implications

Understanding which communities are most vulnerable to exposure to toxic vehicle emissions is valuable information for policymakers. Knowing where to allocate resources and funds helps officials serve the individuals that have greatest disadvantage. By allocating funds to communities in need, officials can minimize the health inequality minorities and low-income individuals are facing. Additionally, urban city planners should aim to reduce the amount of schools and parks built near highways or highly trafficked roads. In addition to removing environmental health hazards outside of people's homes, improving indoor environmental quality is important. Increased prevalence of asthma may be due to disproportionate exposure to indoor environmental hazards such as lack of storage space, hazardous cooking facilities, and lack of circulation in addition to many other factors (Kreiger and Higgins 2002). Overall, it is crucial that we make steps to minimize the disparities in environmental and physical health that minorities and low-income individuals face.

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