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Understanding Asthma and Environmental Inequities Among Asian Communities in California: The Impact of Structural Racism

By

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A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Public Health

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Committee in charge:

Professor Jason Corburn, Chair
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Professor Denise Herd
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Abstract

Understanding Asthma and Environmental Inequities Among Asian Communities in California: The Impact of Structural Racism

by

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Doctor of Public Health
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People of Asian origin, including Asian Americans, immigrants, and refugees, constitute the fastest-growing racial/ethnic group in the United States. Despite the fact that there are known chronic health disparities among Asian people, comparatively few studies examine the relationships between structural racism and chronic health conditions in Asian communities. The prioritization of successful and healthy narratives of Asian people may cause health researchers to overlook their inclusion in medical research. As a result, studies rarely include Asian people as a distinct racial/ethnic group, and furthermore, peer-reviewed literature rarely reports health outcomes for this group. This underrepresentation and subsequent lack of robust research on health disparities for Asian people means that there are few, or precariously funded, health and social programs for those who are at risk for health inequities.

Asthma is a chronic respiratory illness that has become a severe problem in the United States. Health statistics from the state of California suggest that some Asian people experience asthma inequities. Disaggregated health data shows that Filipino and Japanese people have a lifetime asthma prevalence of more than double their Korean and South Asian counterparts; however, there has been little to no research conducted to understand the drivers of this disparity. Public health research suggests that structural racism is a fundamental cause of racial/ethnic disparities in health. Studies have found that asthma has associations with two forms of structural racism, racial residential segregation and environmental racism, but Asian people have little to no inclusion in this type of research. While evidence suggests that Asian people experience disproportionate exposures to air pollution when they live in Asian segregated areas, there are no studies to my knowledge that explore health outcomes associated with this phenomenon.

To address these gaps in knowledge, this dissertation uses mixed methods to expand understanding of how structural racism impacts the health of Asian people. The first paper is a case study that examines how an Asian community in Richmond, California has responded to decades of experiencing disproportionate exposure to air pollution and poor health outcomes. I use the Asian Pacific Environmental Network's regional campaign for "Regulation 12, Rule 16" and local campaign for "No Coal in Richmond" to describe how an Asian organization employed critical environmental justice strategies as tools to achieve its clean air goals. The second paper is a quantitative analysis that examines the ecologic associations between racial residential segregation for Asian people in California and the age-adjusted rates of emergency department (ED) visits for asthma per 10,000 in the neighborhoods where they live. I also examine community-level contextual factors as modifiers of this relationship. Finally, I use spatial

statistics to identify areas in California that warrant future study on individual and community-level contextual factors that may contribute to asthma morbidity in Asian communities. The third paper is a narrative review that assesses the conceptualization, measurement, and examination of how racial residential segregation has been utilized in asthma research. I investigate the extent to which Asian people have been included in such studies and summarize best practices for future research that includes Asian populations.

Dedication

For my dad, Josenolito, who encouraged me to pursue my dreams and fostered my love of learning and curiosity about the world.

For my mom, Merlita, who redefined work ethic for all of us.

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Note: I researched and wrote this dissertation on xučyun (Huichin) territory, the ancestral and unceded homelands of the Chochenyo-speaking Ohlone people. UC Berkeley was established here in 1868, and I recognize that I have benefitted from the use and occupation of this land as a member of the UC Berkeley community

Table of Contents

Abstract **1**
Table of Contents ..... **iv**
List of Tables ..... **vi**
List of Figures ..... **vii**
Introduction **1**
The Hidden Asthma Burden Among Asian People in California 2
Expanding Structural Racism Research to Include Asian People 2
References 5
Paper 1. The Right to Breathe Clean Air: A Case Study of Asian American, Refugee, and Immigrant Community Organizing Against Air Pollution in Richmond, California **8**
Abstract 8
Introduction 8
Background 10
Methods 12
Vignettes 14
Discussion 26
Conclusion 32
Tables 33
References 36
Paper 2. Estimating the Differential Impact of Racial Residential Segregation on Age-Adjusted Asthma Emergency Department Visit Rates in California: An Exploratory Analysis of Asian Neighborhoods **44**
Abstract 44
Introduction 44
Background 46
Data and Methods 48
Results 52
Discussion 56
Conclusion 61
Tables and Figures 62
References 70
Paper 3. A Narrative Review of Racial Residential Segregation in Asthma Research (2003-2021): Where are the Asian People? **75**
Abstract 75
Introduction 75
Background 76
Methods 80

Results....81
Discussion....86
Conclusion....89
Tables....90
References....104
Conclusion....108

List of Tables

Paper 1

Table 1. Oil Refineries and Support Facilities under BAAQMD Jurisdiction (2017)

Table 2. Vignette #1 - Summarized Timeline of Selected Events with Analytic Framework

Table 3. Vignette #2 - Summarized Timeline of Selected Events with Analytic Framework

Paper 2

Table 1. Descriptive Statistics for Asian Neighborhoods by Segregation Status and Neighborhood Characteristics, California, 2015-2019

Table 2. Selected Counties with Asian Segregated Neighborhoods by High versus Low Age-adjusted Asthma ED Visit Rates, California, 2015-2019

Paper 3

Table 1. Literature Review Search String by Database and Returned Results

Table 2. Summary Table of Studies on Segregation and Asthma

Table 3. Literature Review Findings: Conceptualization, Measurement, and Examination of Segregation

List of Figures

Paper 1

Figure 1. APEN Facebook Event Post for Emissions Limit Rally, September 3, 2014

Figure 2. APEN Facebook Event Post for Joint Rally, December 16, 2015

Figure 3. APEN Website Media Update by Chiravann Uch, June 1, 2017

Figure 4. APEN Facebook Event Post for Community Forum, October 22, 2014

Figure 5. APEN Facebook Event Post for Richmond City Council Meeting, December 3, 2019

Paper 2

Figure 1. Effect Measure Modification by Neighborhood Characteristics on the Association between Asthma ED Visits and Asian Segregation Level in California, 2015-2019

Figure 2. Effect Measure Modification by Neighborhood Environmental Air Pollution on the Association between Asthma ED Visits and Asian Segregation Level in California, 2015-2019

Figure 3. LISA Scatterplot for Age-adjusted Asthma ED Visit Rates

Figure 4. LISA Scatterplot for Asian Segregated Neighborhoods

Figure 5. LISA Analysis Map: Neighborhoods Identified for Future Study, Sacramento County, CA

Figure 6. LISA Analysis Map: Neighborhoods Identified for Future Study, San Diego County, CA

Introduction

People of Asian origin constitute the fastest-growing racial/ethnic group in the United States (US).[1] Despite the fact that there are known chronic health disparities among Asian people,[2] comparatively few studies examine the relationships between structural racism and chronic health conditions in Asian communities.[3,4] The model minority myth drives a commonly held misconception that all Asian people in the US are healthy, hardworking individuals who have successfully overcome social and economic hardships.[5] Although this label may seem beneficial, it has harmed Asian people and the other racial/ethnic minorities that it simultaneously disparages.[5] The model minority myth has structural, public health implications due to its view of Asian people as a monolithic group.[5,6]

First, the prioritization of successful and healthy narratives of Asian people may cause health researchers to overlook Asian populations in medical research,[6] resulting in their infrequent inclusion as a distinct racial/ethnic group in studies.[7] Second, there is a comparative lack of health outcomes reported for Asian populations, with a review finding that only 2.6% of articles in high-impact research journals reported health outcomes for Asian people during a two-year study period.[7] These gaps in health research further erase the experiences of disadvantaged Asian subgroup members who have diverse needs for healthcare, socioeconomic support, and social programming.[4,5,8] Another study found that 0.18% of the National Institutes of Health research budget was dedicated to projects focused on Asian populations across an 18-year study period, indicating general underrepresentation in US health disparities research.[9] These compounding phenomena perpetuate the lack of robust health research on disparities and inequities for Asian people as a group and among subgroups.[7,8] Consequently, there are few, or precariously funded, health and social programs for Asian people who are at risk for health inequities.[6,8]

A small, but growing body of literature examines inequities in chronic health conditions among Asian populations. A study by Gordon et al. found that Asian people as a group had similar diabetes mellitus (DM) prevalence as Black and Latino people.[10] However, Filipino and South Asian people had the highest DM prevalence when compared to all other groups after the health data was disaggregated.[10] In the same study, Asian people as a group had similar hypertension prevalence as Latino people, yet lower prevalence than Black people.[10] Notably, Filipino people had similar hypertension prevalence as Black people after the health data was disaggregated.[10] These findings suggest that health inequities exist among Asian people, but may be obscured due to the overall lack of representation in health research.

California (CA) has the largest Asian population in the US, with at least 23 distinct subgroups.[11] Advocacy from Asian organizations regarding the heterogeneity of the group caused state officials to recognize the need to better understand and address unique health, educational, and socioeconomic challenges experienced by Asian people.[11] As such, CA was the first state in the US to pass legislation, Assembly Bill No. 1726, that mandates the state health department to collect and disseminate disaggregated health data for Asian, Native Hawaiian, and other Pacific Islander subgroups.[12,13] Detailed health information for Asian subgroups has been pivotal to the publication of the few detailed studies that examine health among Asian people.[2,10] The ongoing availability of disaggregated health data and subsequent research tailored to Asian subgroup

populations are necessary for adapting health systems, research funding, health programs, and policies to address previously obscured health inequities.[6] Public health efforts must debunk the model minority myth to accurately capture the diverse health experiences and needs of the rapidly growing Asian population.

Note about language in this dissertation: To be inclusive of people of Asian origin who do not identify as American, yet live in the US, this dissertation will use the terminology "Asian people." I acknowledge the discourse that exists around the best terminology for referring to Asian people, and I feel that this option is more inclusive than public health's default terminology of "Asian American." Furthermore, I use the terminology "Asian communities" to refer to where Asian people live, while "Asian populations" refers to broad, yet different groups of Asian people. To align with the majority of public health research, I use the US Office of Budget and Management's standards on race/ethnicity and define Asian people as "having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent."[14] I acknowledge that Asian people in the US are heterogeneous from one another, come from at least 23 subgroups, and may identify as immigrants or refugees.[11,15] I also acknowledge that Native Hawaiian and Pacific Islander populations, who are often grouped with Asian people in health studies, experience significant health and socioeconomic inequities that are also obscured by aggregate data.[10,11] This topic is beyond the scope of this dissertation because I do not examine Native Hawaiian or Pacific Islander populations in my papers. However, I mention it here because I also avoid the use of common terminology "Asian American and Pacific Islander (AAPI)." Language that describes people of Asian origin is still evolving and requires deeper analysis outside of this dissertation.

The Hidden Asthma Burden Among Asian People in California

Asthma has become a severe health problem in the US over the past 35 years.[16,17] It is a chronic disease of the respiratory system that does not have a cure.[18] Asthma affects nearly 25 million people in the US each year[19] and is responsible for over $81 billion in health care costs.[20] Asthma negatively impacts society because it causes approximately 12.8 million missed school days, 12 million less productive work days, and other social disruptions each year.[18] Research has shown that asthma heavily impacts Black, Native American, and multi-racial people more than other racial/ethnic groups, so it has remained a priority concern for healthcare professionals and public health researchers.[16]

At the national level, the Office of Minority Health (OMH) states that Asian people "generally have lower rates of asthma than the white population."[21] Current statistical reporting may cause this misnomer because health researchers commonly collect, analyze, and present data on Asian people in aggregate form.[4] Evidence suggests that the asthma burden in Asian subgroups has been overlooked. For example, in California, Asian and Latino people appear to have the lowest lifetime asthma prevalence rates of 11.7% and 11.3%, respectively, when compared to Native American (21.8%) and Black (19.8) people.[22] However, disaggregated data for Asian people reveals that Filipino and Japanese people experience asthma disparities with lifetime prevalence rates of 16.9% and 16.8%, respectively.[22] These rates are more than double those of Korean (5.7%) and South Asian (7.5%) people, which demonstrates that aggregated data for Asian people can obscure stark differences in asthma status among subgroups.[22] This can

cause and perpetuate poor health outcomes in the subgroups that are overlooked and underrepresented in health research and programming.

Expanding Structural Racism Research to Include Asian People

As cited by Bailey et al., structural racism is "the totality of ways in which societies foster [racial] discrimination, via mutually reinforcing [inequitable] systems… that in turn reinforce discriminatory beliefs, values, and distribution of resources."[23] Racial residential segregation (segregation) is a form of structural racism that has been used to socially sort and physically separate people by race/ethnicity.[24] Segregation prevents minority groups from accessing resources that could benefit or protect their health.[25] Therefore, segregation is a fundamental cause of racial/ethnic health inequities for several chronic health diseases, including asthma.[24,26] Environmental racism, race-based discrimination in processes that result in "minority and low-income communities facing disproportionate environmental harms and limited environmental benefits,"[27] causes detrimental exposures and further exacerbates these health inequities.[27–29]

A socio-ecological approach to health suggests that inequities in asthma prevalence and morbidity are driven by systemic and structural inequities, including housing, socioeconomic position, and environmental exposures.[30,31] Communities of color also tend to experience social stressors related to racism and segregation, such as poverty and violence, which contribute to negative impacts on health over the life course and across generations.[32] Asthma can also be common amongst family members due to intergenerational trauma and toxic stress.[32,33] Consequently, asthma health inequities have become more severe and concentrated in the same neighborhoods over time.[27] While most studies have examined pediatric asthma outcomes, research suggests that higher incidence,[34–37] prevalence,[38,39] and healthcare utilization [40–42] for asthma is associated with living in census tracts,[35,37–41] ZIP codes,[34] and counties[42] with higher concentrations or proportions of Black and/or other racial/ethnic minority residents. Asthma inequities have been associated with living in predominantly Black communities due to their experience of structural racism and subsequent divestment in housing, health, education, employment, and other resources.[43]

Public health studies have found significant relationships among environmental quality, residential segregation, and health status.[26,28] However, comparatively few studies have examined these relationships for Asian people. Morello-Frosch and Jesdale found that Asian and Pacific Islander people who live in extremely segregated areas have an increased risk of exposure to air pollutants associated with cancer when compared to those who live in less segregated areas.[44] Another analysis by Payne-Sturges and Gee indicated that Asian and Pacific Islander people are more likely to reside in counties that violate air quality standards when compared to people of other races/ethnicities.[45] Grineski et al.'s disaggregated analysis reveals that an increase in the proportion of Asian residents in census tracts is associated with significantly greater cancer risk from hazardous air pollutants.[46] They also found that census tracts with higher proportions of Chinese, Korean, and South Asian residents, as well as those with high concentrations of people who speak a non-English language and people who are US-born, have significantly greater cancer risk compared to white residents. The lack of robust studies examining the relationships between segregation and environmental health outcomes among Asian people may be attributed

to the model minority myth, which asserts the false narrative that Asian people do not experience poor health outcomes.[4]

This dissertation asserts that public health research must counter the model minority myth by using a relational approach to health, which considers both compositional and contextual factors. Beyond including Asian people in this research, the incorporation of context about where they live, such as historical, social, political, and environmental factors, can provide a more holistic understanding of the complex and dynamic relationships between place and people.[47] To examine how structural racism impacts the health of Asian populations in CA, I ask:

1. **How have Asian American, refugee, and immigrant people advocated for their health and the environment in Richmond, California, where there are disproportionate exposures to air pollution?**
2. **Is racial residential segregation related to asthma morbidity in California's Asian communities, and how do community characteristics like air pollution exposure modify the relationship?**
3. **How is racial residential segregation conceptualized, measured, and examined in studies that explore its relationship with asthma status and are Asian people included?**

The first paper examines how a Southeast Asian community in Richmond, California has responded to decades of experiencing disproportionate exposure to air pollution and poor health outcomes. I use a case study on the Asian Pacific Environmental Network (APEN)'s regional campaign for "Regulation 12, Rule 16" and local campaign for "No Coal in Richmond" to describe how an Asian organization helped community members protect their health and the environment. I highlight APEN's critical environmental justice strategies as tools to achieve clean air goals when contemporary environmental solutions allow industries to continue polluting local communities.

The second paper examines the association between racial residential segregation (measured with the location quotient) for Asian people in California and the age-adjusted rates of emergency department (ED) visits for asthma per 10,000 in the neighborhoods where they live. I examine community-level contextual factors such as median household income, educational attainment, nativity status, and air pollution as modifiers of this relationship. I also assess spatial patterns in the location of Asian segregated neighborhoods and their asthma ED visit rates to identify places for future research on this topic.

The third paper is a narrative review that assesses the conceptualization, measurement, and examination of how racial residential segregation has been utilized in asthma research. I also investigate the extent to which Asian people have been included. The key findings are summarized to highlight current theoretical and methodological challenges in research, as well as to provide recommendations for future public health research practices.

Together, these studies provide insight into structural and community-level factors that may drive asthma inequities in Asian populations that have been historically overlooked in public health research.

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Paper 1. The Right to Breathe Clean Air: A Case Study of Asian American, Refugee, and Immigrant Community Organizing Against Air Pollution in Richmond, California

Abstract

The environmental justice (EJ) movement has mobilized low-income communities and communities of color to assert their right to clean air, water, and land since the mid-1980s. Asian American, immigrant, and refugee communities have since made notable contributions to the EJ movement when it comes to climate change, occupational health, urban redevelopment, and food-related issues. This paper utilizes a structural racism framework to examine how an Asian American, refugee, and immigrant community organization, Asian Pacific Environmental Network (APEN), has organized against air pollution in Richmond, California to protect the health of the community and the environment. I use a case study on APEN's regional campaign for "Regulation 12, Rule 16" and local campaign for "No Coal in Richmond" to understand how APEN achieves its clean air goals and objectives when government institutions enact environmental solutions that allow industries to continue polluting. This analysis reveals that APEN's multi-scalar advocacy and coalition-building are necessary for achieving EJ when challenged by private sector interests and institutional failure to protect public health and the environment. This paper contributes to a growing body of research that suggests environmental racism and resultant injustices persist over time due to the mismatch between community EJ interests and those of the private sector and regulating institutions. It also highlights how Asian people have been essential to achieving and working toward EJ and health equity in California. Finally, the findings echo calls for the EJ movement to directly challenge "pollution friendly" environmental solutions proposed and enacted by institutions that are mandated to protect public health and the environment.

Introduction

Black, Indigenous, low-income, and other minority communities have suffered the ill effects of disproportionate environmental exposures in the United States (US).[1] The human health hazards and environmental impacts of industrial air pollution and other chemical contaminants have been well-documented in these communities since the 1960s.[1–3] In addition to direct environmental exposures, the impacts of greenhouse gas-related climate change, such as global warming, sea level rise, and severe weather events, continue to affect vulnerable communities today. Consequently, contemporary community groups and environmental organizations have expanded their environmental justice (EJ) objectives beyond the demand for localized health and safety to an overarching goal of eliminating the use of fossil fuels and greenhouse gas emissions from major polluters. These climate change-centered EJ objectives and goals have required innovative place-based approaches to ongoing community efforts and policy change.[4,5]

The San Francisco Bay Area (Bay Area) is often highlighted for issues of environmental (in)justice due to a long history of multi-racial/ethnic community organizing and environmental activism in the presence of oil refineries, shipping ports, and other industrial polluting sources.[6] Notably, the Chevron oil refinery in Richmond, California (CA) is the largest of the Bay Area's

four oil refineries, which account for 27.23% of CA's crude oil capacity.[7] The Chevron refinery's location in a low-income area with communities of color has created historical tension between the area's residents, private sector representatives, environmental regulators, and legislators.[6,8,9] Although CA is known to be at the forefront of progressive environment and climate-related policy, marginalized and vulnerable communities like those in Richmond, CA (Richmond) continue to experience a disproportionate burden of environmental exposures and health inequities.[3,10] Consequently, several EJ groups and organizations established their roots in the Bay Area and have represented the environmental and health concerns of local residents since their inception.

The Asian Pacific Environmental Network (APEN) is an EJ organization formed in Richmond to organize community members against their exposure to air, water, and land pollution from industrial sources. APEN is unique from other EJ groups because its leadership, staff, and members overwhelmingly identify as Asian American, immigrant, and refugee people. The representation of Asian people is sparse in American EJ literature when compared to other racial/ethnic groups due to misconceptions that these issues do not impact Asian people or that Asian people are not advocates for the environment.[8,11–13] APEN's decades of environmental and health advocacy in the Bay Area create a special case that highlights the contributions of Asian people to the EJ movement. Furthermore, the EJ movement's development and context in the Bay Area, as well as CA's legislation and regulations for air pollution, provide a rich history that can be analyzed for drivers and patterns of environmental racism and health inequities in vulnerable communities.

In this paper, I use an instrumental case study to elucidate how Asian American, refugee, and immigrant (Asian) people have been critical to achieving and working towards EJ and health equity in Richmond and the Bay Area. Instrumental case studies are used to highlight a single, bounded case to illustrate a larger theme of interest.[14] As an instrumental case study, I selected two APEN campaigns to create a single, bounded case that illustrates how an Asian organization used critical EJ strategies to achieve their clean air goals.[14] To do this, I analyze two vignettes focused on APEN's air pollution action items, the regional campaign for "Regulation 12, Rule 16" and the local campaign for "No Coal in Richmond." This analysis examines problem-solving strategies, actions, and processes to highlight how APEN achieves its clean air goals and objectives through multi-level advocacy and coalition building. I formulate each vignette with research from multiple, publicly available sources. I then examine each vignette for social, political, and historical context related to environmental racism, as well as motivating factors for APEN's advocacy and strategies to combat air pollution in Richmond. Through this analysis, I argue that structural racism and "pollution-friendly" state-sponsored environmental solutions drive ongoing environmental and health injustices in Richmond. For the purpose of this paper, "state" refers to both regulatory and governing bodies from local, regional, and state-level jurisdictions.[15] I use this collective term because each level of government and regulatory agency is a major stakeholder in the creation and administration of environmental law.

I begin with a brief overview of structural racism and the development of the EJ movement. I also highlight developments in contemporary EJ theory as relevant to this case study. Next, I provide the regulatory and legislative context for air pollution policy in CA to set the historical backdrop for the policies and laws confronted in the case study vignettes. Then, I

describe the methods used, with a case selection that introduces APEN and Richmond, CA and a description of how data was collected and analyzed. I present the two case study vignettes with the following sections in each: EJ problem, APEN's solution, APEN's strategies, vignette outcome, and EJ result. Finally, I discuss how 1) structural racism drives localized air pollution and 2) APEN's community organizing around air pollution has led to local EJ solutions despite a persistent mismatch between community EJ interests and those of the private sector and regulating institutions.

Background

Structural Racism and Environmental Justice: Movement and Theory

Research suggests that structural racism is a fundamental cause of health inequities in the US[16,17] As cited by Bailey et al., structural racism is "the totality of ways in which societies foster [racial] discrimination, via mutually reinforcing [inequitable] systems… that in turn reinforce discriminatory beliefs, values, and distribution of resources."[17] Structural racism includes environmental racism, or race-based discrimination that results in "minority and low-income communities facing disproportionate environmental harms and limited environmental benefits."[1] As early as the 1960s, disenfranchised groups, mostly low-income people of color, garnered national attention as they protested the disposal of toxic industrial waste near their homes.[18] These gatherings gave rise to EJ as a social movement in the US as people became more concerned with the health implications of toxic exposures in their home environments. The movement adopted a multifaceted approach to environmental problem-solving and transitioned into a field of scholarship in the 1980s.[19]

Contemporary EJ praxis requires three key elements to operationalize its goals: social movements, public policy, and scholarship.[19] Thus, contemporary EJ is defined as "a framework for understanding and acting to address the disproportionate, unfair, and unequal environmental burdens that the poor and people of color populations experience due to exposures of toxic harms and receiving less legal and other protections than white and well-off communities."[20] EJ scholarship in the US has largely focused on environmental racism and the EJ movement within and among Black, Native American, and Hispanic/Latino communities.[2,18] Comparatively, few studies have examined environmental exposures for Asian people, and they mainly focus on air pollution exposure and heat risk-related land conditions.[21–25] The air pollution-focused studies suggest that Asian people are disproportionately exposed when they live in high-density co-ethnic areas.[21–24] Despite this, there are even fewer articles detailing the involvement of Asian people in the US-based EJ movement,[6,11,12] several of which were published in an anniversary edition of the journal *AAPI Nexus: Policy, Practice and Community*.[26] This paper adds to the EJ literature by emphasizing the transformative work of Asian people within the EJ movement.

This analysis utilizes the critical EJ perspective, which challenges assumptions and gaps from earlier works of EJ scholarship.[27] The critical EJ perspective examines the intersectionality of EJ communities, the multi-scalar nature of EJ issues, the role of state complacency in EJ issues, and the purported expendability of EJ communities.[27] In addition to highlighting EJ contributions from Asian communities, the case study's two vignettes emphasize the utility of scale in EJ actions. Although scale is a technical term that refers to the "measurement of the ratio

between the size of objects in the world and their size on a map,"[28] scale in this paper refers to different levels of government and regulation: city/local, regional, state, and national. I argue that multi-scalar actions, like those from APEN, are essential to achieving EJ outcomes that align with community goals and objectives as the state continues to enact "pollution-friendly" environmental solutions.

Historical EJ and Air Pollution Policy in California and Richmond, CA

CA is known to be a leader in state-level environment and climate-related legislation, particularly with bills that have targeted vulnerable communities for environmental protection and support. Significant EJ-related legislation includes Senate Bill 535, Assembly Bill 1550, Senate Bill 1000, and Assembly Bill 617. The *California Global Warming Solutions Act of 2006: Greenhouse Gas Reduction Fund*, also known as Senate Bill 535 from 2012, required the state to allot 25% of Greenhouse Gas Reduction Funds for disadvantaged communities and another 10% to go to programs in those communities.[29] CA defines disadvantaged communities as:

> "Areas disproportionately affected by environmental pollution and other hazards that can lead to negative public health effects, exposure, or environmental degradation"
>
> and/or
>
> "Areas with concentrations of people that are of low income, high unemployment, low levels of homeownership, high rent burden, sensitive populations, or low levels of educational attainment."[29]

Assembly Bill 1550 (2016), or *Greenhouse gases: investment plan: disadvantaged communities*, further specified that the 10% of the disadvantaged community funds assigned in Senate Bill 535 could be divided in half, with 5% going to and benefiting disadvantaged communities and the other 5% being flexible for use in neighboring communities within a half mile of designated disadvantaged areas.[29] Senate Bill 1000 (2016), or *Land use: general plans: safety and environmental justice*, required general plans in CA to include EJ elements by January 1, 2022.[30] The EJ elements would require local governments to identify objectives and policies for disadvantaged communities to reduce the unique or compounded health risks, promote civil engagement in the public decision-making process, and address the needs of residents in those communities.[30] These three bills provided initial steps toward EJ because they allocate funds for and establish structural recognition of disadvantaged communities that have suffered the effects of harmful exposures over time.

Assembly Bill 617 (2017), or *Nonvehicular air pollution: criteria air pollutants and toxic air contaminants*, purports to advance EJ in disadvantaged communities with the intention of attaining long-term health equity.[31] It requires the CA State Air Resources Board (CARB) to select disadvantaged communities for air pollution programs, to provide grants to community-based organizations for technical assistance with the programs, and to support community participation in the programs.[31] Assembly Bill 617 is unique from other EJ legislation in CA because it establishes direct pathways for community direction and engagement with local air pollution regulations.[31] Local air districts, who enforce regulations at the regional

level, would be required to uphold emissions reduction plans as identified and described, in part, by community members.[31]

Senate Bill 535, Assembly Bill 1550, Senate Bill 1000, and Assembly Bill 617 are all pieces of legislation that utilize aspects of an EJ framework. However, their ability to create tangible change and enact EJ remains contested by residents who live near industrial sources of air pollution and environmental advocates.[32] Consequently, local governments in CA have adopted city-level resolutions and enacted ordinances to fill gaps left by state-level legislation. This case study will elucidate how local communities continue to experience disproportionate burdens of air pollution exposure despite the existence of these "pollution mitigation" policies. It will also highlight efforts to increase regulation at the regional and local levels when statewide regulations are insufficient for ensuring clean air in the most burdened communities.

Methods

Case Selection: Asian American, Immigrant, and Refugee Advocates for EJ in Richmond, CA

Approximately 30% of all Asian people in the US reside in CA, for a total population of about 6.7 million people.[33] As a result, much of the documented engagement of Asian people on EJ topics has occurred in CA,[8] despite Asian people experiencing disproportionate environmental exposures nationwide.[11,12] The Asian Pacific Environmental Network (APEN) is a notable EJ organization run by Asian people in Richmond and the Bay Area. APEN was established in 1993 after its founders attended the First National People of Color Environmental Summit.[8] Their EJ work began in Richmond, which included organizing the Laotian community in light of the 350 industrial sites and toxic hazards that surrounded their neighborhood.[8] APEN's organizing has mobilized Asian youth, extended influence into Oakland, CA's Chinatown neighborhood, and organized the Asian Pacific American Climate Coalition (APACC).[8] Some of their EJ successes include the establishment of a multi-lingual warning system for emergencies at the Chevron oil refinery in Richmond and the defeat of CA Proposition 23, which would have suspended the state's greenhouse gas emissions reduction program.[8]

I use an instrumental case study for this analysis because I aim to explore how Asian people in the US have contributed to the EJ movement in light of evidence that they experience disproportionate exposure to air pollution. APEN's identity as an Asian community organization makes their work a distinct representation of how Asian people have been essential to achieving and working towards EJ and health equity in Richmond, the Bay Area, and CA. Furthermore, I use two of APEN's recent clean air campaigns to illustrate how critical EJ strategies can help EJ advocates achieve their goals. I highlight how APEN facilitates and challenges state-sponsored solutions for clean air as vulnerable communities continue to experience disproportionate air pollution and related health inequities.

Study Location

CA is an ideally suited location for a case study that highlights the involvement and contributions of Asian people in the US EJ movement. The Richmond area is also known for its

extensive history of multi-racial/ethnic community organizing and environmental activism. There are many communities of color in Richmond with large populations of Black, Latino, and Asian residents who are concerned about their environmental exposures and health.[32] Notably, the West County Toxics Coalition (WCTC) and Communities for a Better Environment (CBE) have worked together with APEN to hold polluting industries accountable in the Richmond area.[6,32] In addition to the Chevron oil refinery, other industrial sources of air pollution include "a chemical plant, a coal and petroleum coke terminal, organic liquid storage and distribution facilities, wastewater treatment plants, a landfill, organic waste metal facilities, and industrial and manufacturing plants of various sizes."[34] To further add to the pollution burden, mobile sources of air pollution include multiple frequently congested highways, seaports, railways, and railyards.[34]

It is no surprise that, on average, residents in Richmond "breathe about three chemicals at a time."[35] This respiratory burden is reflected in statewide tracking for environmental exposures because Richmond and its adjacent neighborhoods are in the 90th to 99th percentile for asthma rates in the state.[36] Residents in this city also tend to experience significant socioeconomic challenges such as high unemployment, a high housing cost burden, and a high poverty rate at 14.7% in Richmond.[34,37] The neighborhoods adjacent to pollution sources rank in the 80th to 85th percentile for poverty compared to the rest of CA.[38] Thus, the area has been identified as a disadvantaged EJ community due to persistent exposure to air pollution, proximity to large sources of air pollution, high rates of health inequities, at-risk socioeconomic conditions, and vulnerable populations.[34]

Data Collection

This case study details APEN's efforts to attain clean air for their community with two campaigns between 2012 and 2021. Data on the "Regulation 12, Rule 16" and "No Coal in Richmond" campaigns was collected from multiple publicly available sources to triangulate and verify events in chronological order. I collected initial information for each campaign from APEN's website and social media accounts. Given that the Bay Area Air Quality Management District (BAAQMD) was the government agency that considered passing Regulation 12, Rule 16, I collected data from BAAQMD's website. Similarly, the City of Richmond considered passing the ordinances at the center of the "No Coal in Richmond" campaign, so I collected city council materials and other archival data sources from Richmond's website. I searched other community organizations' websites if they participated in the campaigns with APEN. Finally, I searched news websites for coverage of both campaigns to verify the outcomes of actions and meetings.

The final data source formats included technical reports, public comments on proposed regulations, public comments at community meetings, news articles, blog posts, social media posts, press releases, and videography from action campaigns and community meetings. For this case study, I use a framework in which environmental racism is considered a form of structural racism. I examined each data source for social, political, and historical context related to environmental racism, as well as motivating factors for APEN's advocacy and strategies APEN employed in either campaign. I built each vignette by focusing on the human health risks associated with the air pollutants targeted by APEN, followed by the "solution" that APEN

advocated for in each campaign. I end each campaign vignette with a description of APEN's organizing strategies and the final outcomes.

Vignettes

Vignette #1 Regional EJ Action (2017): Bay Area Air Quality Management District - Regulation 12, Rule 16

Problem: There are no California laws or regulations that limit oil refinery-wide emissions, which are hazardous to human health and the environment.

Particulate Matter 2.5 (PM2.5) is a human health hazard that consists of ultra-fine suspended particles and aerosols that measure 2.5 microns or less in diameter.[39] Oil refineries are a major source of PM2.5, as well as the PM2.5 precursor pollutants nitrogen oxides (NO_X) and sulfur dioxide (SO_2).[39,40] PM2.5 precursor pollutants are significant because they combine with ammonia in the atmosphere to form ammonium sulfate, which is a PM2.5 aerosol that further contributes to overall PM2.5 concentrations.[39] Exposure to PM2.5 is associated with a myriad of short- and long-term adverse health outcomes, including asthma, lung cancer, cardiovascular disease, and reduced life expectancy.[39,41] In 2015, diesel PM2.5 was responsible for 82% of cancer risk from toxic air contaminants in the Bay Area.[39] Consequently, PM2.5 is one of the most toxic air pollutants in the Bay Area.[39]

In 2012, five oil refineries in the Bay Area contributed 9% of direct PM2.5 emissions, 4% of NO_X emissions, and 41% of SO_2 emissions.[40] Furthermore, these refineries are responsible for 70% of greenhouse gas (GHG) emissions from stationary sources, which contribute to hotter temperatures and increases in PM2.5 exposure.[39] In Richmond, CA, the Chevron oil refinery has released increasing amounts of PM2.5 and GHGs over time. A comparison of five-year averages for emissions at the Chevron oil refinery reveals a 9.8% increase in PM2.5 and a 5.8% increase in GHGs from 2011-2015 to 2016-2020.[42] The increased release of PM2.5 and GHGs (hereby abbreviated as "emissions") over time poses a significant threat to public health in Richmond. A law or regulation that limits emissions from oil refineries would protect both human health and the environment.

Solution: Pollution Regulation at the Regional Level

Air pollution and industrial emissions can be regulated at multiple levels of government, including at the city, state, and national levels. CA is an exceptionally large and geographically diverse state, so the state administers air pollution regulation in 35 regional districts.[43] The Bay Area's regional district, the BAAQMD, has regulated air pollution and industrial emissions from the region's oil refineries since 1960.[44] Data from air pollution monitoring and modeling show that oil refineries, like Chevron in Richmond, are a significant source of localized air pollution.[45] APEN has members and constituents who are immediately impacted by this historic source of PM2.5 and GHGs.[9,46] Thus, APEN and other community organizations targeted BAAQMD's regional-level regulatory standards as a point of action to improve local air quality in Richmond.[9,46]

APEN, CBE, and other community organizations developed suggestions and revisions for regulatory language on refinery-wide emissions from 2016 to 2017. The formal BAAQMD regulation was known as "Regulation 12, Rule 16: Petroleum Refining Facility-Wide Emissions Limits."[45] While CBE was the primary community organization that submitted initial comments on the conceptual rule in early 2016,[47] APEN and other organizations contributed to and supported the revision stages of the regulation with collectively submitted public comments to BAAQMD after September 2016.[9,46] Rule 16 intended to establish emissions limits for the following criteria pollutants: GHGs, NO_X, SO_2, particulate matter 10 microns and smaller (PM10), and PM2.5.[9,46] Each oil refinery and refinery support factory under BAAQMD's jurisdiction would have its own limits for each criteria pollutant (Table 1).[45] The annual limits for each pollutant would be calculated by averaging that pollutant's baseline values over the previous five years for each facility.[45,46] Furthermore, an additional 7% would be added to the five-year average to account for normal variations in emissions and to provide refinery operation flexibility.[45,46]

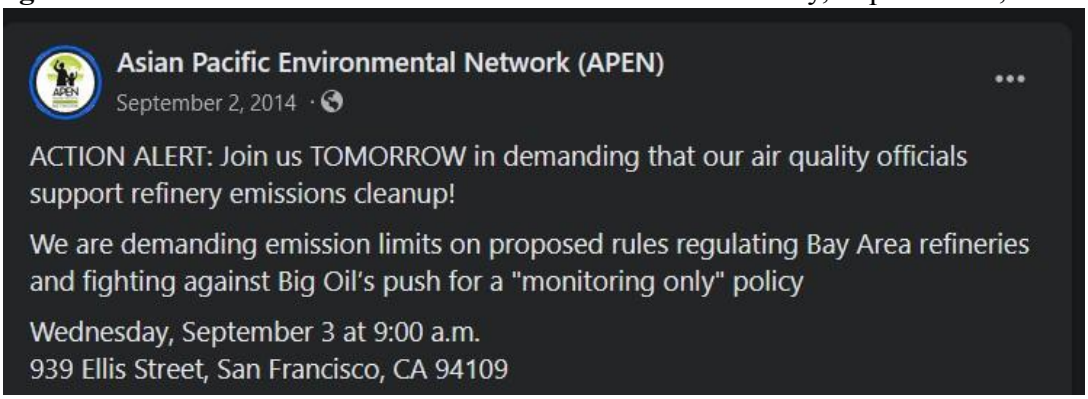
Strategies: Persistence Over Time and Coalition Building

APEN has a long history of advocating for more regulations on the Chevron refinery in Richmond;[6] however, they amplified their efforts in 2012 when a significant fire occurred at the Chevron oil refinery in Richmond. The event on August 6, 2012 triggered a level 3 community warning system (CWS) notification,[48] which was the same CWS that APEN's Laotian Organizing Project fought to have available in multiple languages for future emergencies back in 2005.[49] Sirens warned community residents to shelter-in-place (SIP) indoors for about 4.5 hours; and although SIP was lifted on the same day as the fire, the hazardous smoke impacted the health of residents for about two weeks after the fire.[48] In total, approximately 15,000 people sought medical care for respiratory distress and other chest-related concerns at nearby health facilities.[48] This event galvanized APEN and other EJ organizations like CBE to demand more stringent regulation on air pollution and emissions from oil refineries. They increased pressure on BAAQMD to establish regulatory limits on air pollution.[50] At this time, BAAQMD stated that there were no laws or regulations that limited oil refinery-wide emissions and announced the intention to limit impending emissions increases in 2013.[46]

Although BAAQMD announced its intention to limit emissions, no laws or regulations were passed in 2013. APEN organized to demand limits on oil refinery-wide emissions in 2014, and it coincided with their campaign for a Just Transition, a movement to divest from oil and transition toward renewable energy in Richmond.[4,51] For example, APEN released a video that featured Richmond resident and APEN member Mey Saechao on August 4, 2014 to garner community support and attention for the campaign. In the video, Mey Saechao appeals to community members and officials with her story of experiencing negative health effects from the 2012 Chevron fire and how Chevron should be held accountable for its role in air pollution.[52] Additionally, APEN held a rally with its members and constituents at the BAAQMD office in San Francisco on September 3, 2014.[53] APEN demanded that emissions limits be included in new oil refinery rules that were in development at the time (Figure 1).[53] BAAQMD attempted to reverse their previous stance on limiting increases in oil refinery emissions by suggesting that formal monitoring rules would be sufficient. However, public pressure from APEN and other

community organizations influenced BAAQMD's board to vote in favor of developing rules and regulations to explicitly limit refinery emissions on October 15, 2014.[54]

Figure 1. APEN Facebook Event Post for Emissions Limit Rally, September 3, 2014[53]



APEN sustained the campaign to demand that BAAQMD establish limits on refinery emissions over the next three years. Efforts to establish regional air pollution regulations for oil refineries required expanding and extending their network beyond organizations in the East Bay. They joined together with local community and environmental organizations to collectively demand limits on refinery emissions from BAAQMD. BAAQMD had previously voted to develop rules and regulations on refinery emissions; however, they modified the initial proposal to allow greater emissions with new oil projects, which was in direct contrast with the original plan.[54] APEN, CBE, the Sierra Club's Bay Area chapter, and the Sunflower Alliance held a joint rally at the BAAQMD office on December 16, 2015 to reiterate their demands for the original refinery emissions cap (Figure 2).[55]

Figure 2. APEN Facebook Event Post for Joint Rally, December 16, 2015[55]



From 2015 to 2017, APEN collaborated with a large coalition of local and regional "public interest" groups committed to clean air in the greater Bay Area. In addition to community and environmental organizations, several health-oriented organizations joined the coalition. Members of this coalition included, but were not limited to:

> Communities for a Better Environment (CBE), the Sierra Club, 350 Bay Area, the Richmond Progressive Alliance (RPA), the Sunflower Alliance, Crockett-Rodeo United to Defend the Environment (C.R.U.D.E.), Benicians for a Safe and Healthy Community, the Rodeo Citizens Association (RCA), the Interfaith Climate Action Network of Contra Costa County, the Community Science Institute—CSI for Health and Justice!, Greenaction for Health and Environmental Justice, the California Nurses Association (CNA), Center for Biological Diversity, Mill Valley Community Action Network, Amazon Watch, Idle No More SF Bay & Refinery Healing Walks, and the Good Neighbor Steering Committee[46]

This coalition of approximately 20 public interest groups placed significant pressure on BAAQMD to approve and adopt Regulation 12, Rule 16.[46] The coalition also brought substantial media attention to the potential adoption of new regulations. In April 2017, multiple people from APEN appealed to the public ahead of BAAQMD's vote in an interview with the Bay Area's historic KALW Public Media.[50] Inn Villayngeun discussed his five-year, lingering cough, which he developed after the 2012 Chevron explosion, while Torm Nompraseurt described the pervasiveness of air pollution from the oil refinery:

> "We cannot run; we cannot hide… Here, the chemical is everywhere."[50]

Beyond appealing to local stakeholders, the coalition also emphasized that the adoption of limits on oil refinery emissions would make BAAQMD a pioneer in regional air pollution regulation.[56]

Outcome: Regional Rule Approved, but Subsequently Overruled at State Level

The BAAQMD Board voted in favor of adopting Regulation 12, Rule 16 in May 2017.[57] APEN heralded their efforts and celebrated this vote as a historic win for their community and the EJ movement (Figure 3).[51] In her media update, APEN's Operations Director Chiravann Uch emphasized APEN's dedication to health and self-determination:

> "We will all breathe easier with healthier and cleaner air. We will protect our bodies and our planet."[51]

Although APEN and its coalition members achieved their goal in the Bay Area, their adversaries in the oil industry were working to undermine these efforts, albeit at the state level.

Figure 3. APEN Website Media Update by Chiravann Uch[51]



Simultaneously, in 2017, CA's Cap-and-Trade legislation was set to expire and required additional legislative action to extend the program to 2030.[58] The first renewed Cap-and-Trade legislation, known as Assembly Bill 378, meant to integrate aspects of EJ into state legislation by

allowing CARB to limit air pollution emissions from refineries and other industry sources regulated by Cap-and-Trade.[58] The new state-level regulatory limits would have ideally aligned with BAAQMD's newly approved regional-level emissions limits, which would have undergone formal implementation in 2017 due to the gradual adjustment process. However, the oil industry and its partners thwarted this multi-level alignment of emission regulations from oil refineries in CA. In the first half of 2017, Chevron and its trade group, the Western States Petroleum Association (WSPA), spent $7.1 million and $3.9 million, respectively, on lobbying during the first half of 2017.[59] Their goal was to counter efforts to impose regulations or restrictions on oil refineries and their supportive industries.[58,59] First, Chevron and WSPA successfully lobbied "moderate" Democrats and Republicans by encouraging them to either vote against or abstain from passing AB 378.[59] For example, WSPA alone paid 17 "moderate" Democrats a total of $1.2 million while AB 378 was active.[58,60]

After AB 378 failed to pass on June 1, 2017,[58] the oil and gas (hereafter collectively called "fossil fuel") industry and its partners ensured that the replacement Cap-and-Trade legislation, Assembly Bill 398, removed the power to limit oil refinery emissions from both regional air districts and CARB.[32,58] As a result, APEN and over 50 public interest groups dedicated to climate justice and EJ across CA issued statements opposing AB 398.[61] Kaswan described the aftermath of AB 398 passage as "effectively halt[ing] GHG control efforts underway in the Bay Area" and "gutt[ing] CARB's then-proposed direct refinery limits."[58] Thus, although APEN, CBE, and the coalition had a successful campaign for regional oil refinery emission limits, the oil industry succeeded in nullifying regional and state control over emissions limits two months later in July 2017.[58,59] Miya Yoshitani, APEN's executive director at the time, stated:

> "It's kind of Jerry Brown acting like Santa Claus, the Tooth Fairy, and the Easter Bunny, all in one for big oil."[62]

Vignette #1 Final Result: The campaign on a Bay Area regulatory cap for oil refinery emissions was a success, but state-level legislation overruled the regional regulations shortly thereafter. Functionally, it was a "failure."

Vignette #2 Local EJ Action (2020): Richmond City Council - "No Coal in Richmond" Campaign

Problem: The Levin-Rich Terminal's storage and transportation of coal and petroleum coke contributes to localized air pollution in Richmond.

Coal is a fossil fuel used to generate approximately 40% of the world's electricity.[63,64] Coal breaks into fine particulate pieces whenever it is handled, and the subsequent coal dust is a component of PM2.5 (previously discussed in Vignette #1).[63] While there are significant health impacts from using coal in and of itself as a power source,[64] this case study emphasizes the health impacts from the physical transportation and open storage of coal. It is often transported in uncovered railway cars and stored in open stockpiles, both of which contribute to ambient PM2.5

in adjacent areas.[64] Petroleum coke (pet coke) is a coal-like byproduct of crude oil refinement that is used for fuel or in metal production.[65] Pet coke also has associated "fugitive" PM2.5 dust, which is characterized by high silt content and high vanadium-nickel ratios.[65] Notably, pet coke has five times the silt content than coal, and therefore, the open storage of pet coke has an even higher risk of contributing to PM2.5 pollution in surrounding areas.[65]

The human health hazards of PM2.5 were previously discussed in Vignette #1 of this paper. Strikingly, a recent study on Bay Area's railway communities, including Richmond, identified that the open transportation of coal has negative effects "on mortality, hospitalization for cardiovascular and respiratory disease, asthma exacerbation, work loss, and days of restricted activity."[64] Richmond's residents are at particularly high risk of morbidity and mortality from coal and pet coke-associated PM2.5 exposure due to localized high rates of chronic diseases such as asthma and cardiovascular disease, as well as a lower life expectancy.[64,66] A Richmond city ordinance to phase out, and subsequently ban, the transportation and open storage of coal and pet coke would improve and protect the community's health.[66]

Solution: Modify Richmond's Municipal Code

The CA state constitution provides cities with the authority to create and enforce ordinances and regulations regarding municipal affairs.[67] Additionally, the state constitution provides cities the authority to "protect and promote the health, safety, and/or welfare of its citizens."[67] City councils in CA exercise their authority to modify municipal code through resolutions and ordinances.[68] In general, resolutions are administrative actions that express the opinion of a city council, which can indicate the intention to adopt formal legislation in the future.[68] Ordinances are formal legislative actions that change municipal code.[68] The city of Richmond could use its authority to regulate coal and pet coke as materials stored and transported within its jurisdiction.

Richmond's City Council announced their official opposition to coal and pet coke operations in two resolutions passed on May 19, 2015.[69,70] Richmond's Resolution No. 47-15 provided three opinions necessary to operationalize a future ban on the open transportation and storage of coal and pet coke in Richmond.[69] First, Resolution No. 47-15 detailed the city's support for the oversight and regulation of the storage and handling of coal and pet coke at the local, state, and federal levels.[69] Next, the resolution requested BAAQMD to amend Regulation 6, Rule 1 to ameliorate the PM2.5 pollution associated with the open transportation and storage of coal and pet coke.[69] Thirdly, the resolution directed Richmond's city staff to research the city's options for self-regulating the "storage, handling and transportation" of coal and pet coke if BAAQMD did not act on the city's request to amend Regulation 6, Rule 1.[69] Resolution No. 48-15 provided two opinions that further supported a future ban. In this resolution, Richmond joined 27 cities in Washington and Oregon that passed resolutions to oppose the mining, export, and burning of coal.[70] The resolution also stated the city's opposition to the transportation of coal and pet coke along waterways and densely populated areas in California.[70] Finally, Richmond's City Council passed a third resolution on April 19, 2016, in solidarity with the City of Oakland, CA, to oppose the shipment of coal at the Port of Oakland.[71] This resolution reiterated Resolution No. 48-15 as it applied to the Port of Oakland, and it announced public support for state-level legislation (Senate Bills 1277 and 1279) to prohibit coal terminals in the state.[71]

Richmond's City Council's history of passing resolutions to regulate the open transportation and storage of coal and pet coke provided the basis for which it could adopt formal ordinances in the future. It was not a coincidence that Richmond's City Council announced its opposition to coal and pet coke as this was due, in part, to grassroots organizing by APEN.

EJ Strategies: City Council Election Campaigns, Multi-generational Organizing, and Coalition Building

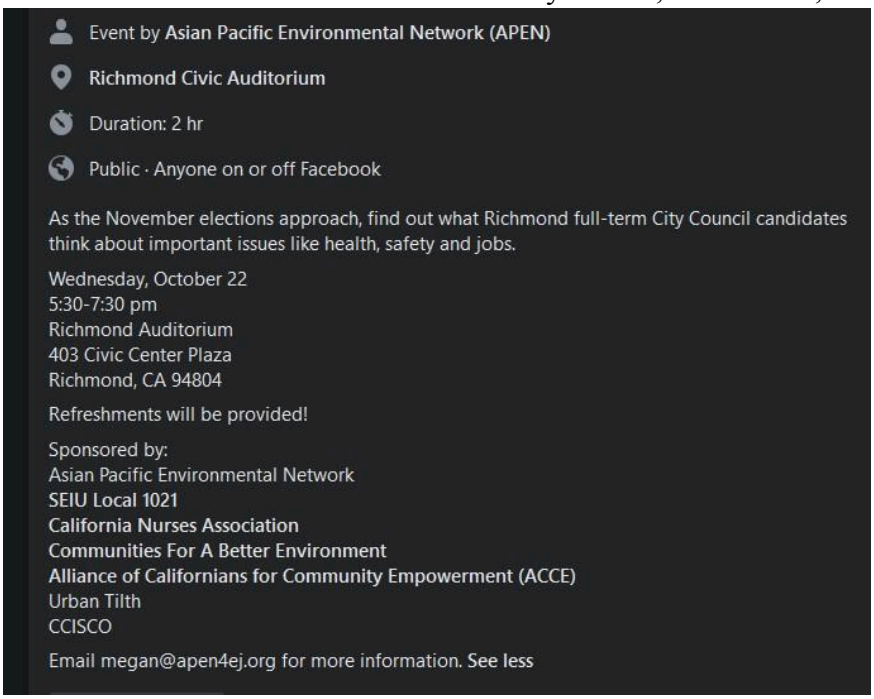
Over time, APEN has built power against large multinational corporations by endorsing city council members and other politicians committed to passing legislation that prioritizes human health, justice, communities, and the environment over corporate profits. For example, APEN holds community forums with their constituents and other Richmond residents to inform and unite them regarding political candidates' views on health, the environment, and safety. In this case, APEN prepared for Richmond's City Council election in November 2014 by holding a joint voter's forum on October 22, 2014 with other EJ organizations and local unions.[72] They collaborated with SEIU Local 1021, CA Nurses Association, CBE, Urban Tilth, and others to unite their constituents in electing city council candidates who prioritized health equity and EJ (Figure 4).[72]

The 2014 campaign to elect progressive candidates for Richmond City Council was a success because the three resolutions to oppose the coal and pet coke industry were passed by those same candidates in 2015 and 2016. APEN continued to build power by engaging their members, other community residents, organizational allies, and city council members over the years. For example, to further galvanize their constituents ahead of the November 2018 election, APEN posted a Facebook video with members Lipo and Saeng Chanthanasak on September 3, 2018.[73] In the video, the Chanthanasaks describe living in Richmond as Laotian refugees, and they detail their health experiences with Chevron's fires and their 14-year membership with APEN.[73] Mr. Chanthanasak notes that city council members did not previously engage with their constituents when they first joined APEN in 2004; however, after working with APEN for over a decade, "now, five of the current city council members have pledged that they would not to accept money from corporations."[73] Aside from reassuring other Asian American, immigrant, and refugee constituents that APEN's work on election campaigns can generate change and provide hope, Mr. Chanthanasak appeals to potential supporters' health concerns:

> "We are the poor people affected by the pollution and smoke from the refinery. This causes many deaths in our community. We want industries to reduce the amount of toxic chemicals and pollution. We need clean air."[73]

APEN continued to host election campaigns centered on candidates' commitment to community concerns, health, and clean air through the next major election cycle in 2020. At the time, APEN's executive director Miya Yoshitani and electoral organizer Seng So posted a blog to celebrate APEN's successful campaign to elect progressive candidates to Richmond City Council. They emphasized APEN's celebratory theme with the slogan, "When we organize, we win."[74]

Figure 4. APEN Facebook Event Post for Community Forum, October 22, 2014[72]



The "No Coal in Richmond" campaign coincided with a significant transition among APEN staff and leadership. The Laotian elders who organized with APEN following the First National People of Color Environmental Summit in the 1990s had reached retirement age and needed to pass on their work.[75] The impending departure of APEN's senior community organizers had the potential to disrupt the campaign's traction; however, APEN used the transition of leadership to their advantage by engaging multiple generations of Asian American, immigrant, and refugee people in the campaign. For example, Denny Khamphanthong attended the People's March for Climate, Jobs, and Justice in San Francisco in 2018 even though he was not involved in EJ work at the time.[75] He describes the inspiration he felt upon seeing APEN's senior organizers speak at the event:

> ".. I heard someone from APEN on a microphone talking about Richmond, the Khmu and Laotian refugee experience, and the battle for Environmental Justice. I immediately made my way to the speakers, where I saw APEN organizer [Torm] Nompraseurt and APEN leader Saeng Chantanasak speaking to a large audience about their struggle. These were people from my community, people who looked like my aunts and uncles who I might see at family parties or gatherings in my neighborhood."[75]

Mr. Khamphanthong kept in touch with the elders at APEN who voiced their intentions to retire and pass on their work after having been organizers for over 20 years.[75] In early 2019, Laotian

elder and APEN's senior community organizer Torm Nompraseurt invited Mr. Khamphanthong to APEN Academy, where Mr. Khamphanthong would learn about APEN's mission, values, organizing, and its commitment to a Just Transition.[75] Of equal importance, Mr. Khamphanthong simultaneously created community bonds with other young adults interested in carrying APEN's EJ mission and visions forward. By late 2019, Mr. Khamphanthong was one of the lead organizers for the "No Coal in Richmond" campaign, and he would not have been there without ongoing guidance and encouragement from APEN's senior leadership and staff.

The strengths of multi-generational collaboration and mentorship further influenced Mr. Khamphanthong's approach to organizing. He visited Richmond High School as part of the "No Coal in Richmond" campaign during which he met with Earth Team's youth interns. He wrote:

> "This is what gives me hope: we are building a new generation of leaders, carrying our elders' vision forward and fighting for real justice for our communities."[75]

Aside from teaching the interns about APEN's history, mission, and vision, he discussed how the "No Coal in Richmond" campaign would be a critical EJ milestone for their community.[76] Mr. Khamphanthong detailed how the Levin Richmond Terminal's activities facilitated hazardous exposures to coal and pet coke and contributed to air pollution in nearby neighborhoods and schools.[76] APEN's work and Mr. Khamphanthong's story inspired two Richmond High School student interns to join in advocacy for a city-level ban on coal and pet coke.[75]

Richmond City Council held the first public hearing for an ordinance to phase out and subsequently ban coal and pet coke on December 3, 2019.[77] A large coalition of community, health, and environmental advocates joined the meeting to express their support for the ban.[78] APEN's strategy included an appeal to city council members with personal testimony from three generations of EJ advocates. Mr. Khamphanthong was the first person from APEN to provide public comment during the meeting. He first described Nystrom Elementary School's close proximity to the Levin Richmond Terminal's open coal piles, and he later detailed his family's experience with cancer and the negative health effects of air pollution.[77] As part of his final support for the ban, he stated:

> "Richmond has lost people to disease caused by pollution and had to put their lives on hold to take care of their loved ones. This is why our members support the ordinance to phase out coal and petroleum coke. We need to put an end to the toxins… that our members, family, and community are exposed to. Our families' and communities' health is more important than corporate greed."[77]

Next, APEN elder Lipo Chanthanasak took the stand alongside Torm Nomprasuert, who assisted him with interpretation and translation to English. Mr. Chanthanasak described his 16-year legacy with APEN and living in Richmond with air pollution. He appealed to the City Council by describing how Richmond's residents suffer from the cumulative burden of toxic air pollutants:

> "... we all suffer from pollution, especially [from] Chevron. And now we have to deal with coal – the coal is… dangerous for our health. [W]e breathe [it] in every second."[77]

Finally, two Earth Team interns from the Richmond High School "No Coal in Richmond" event provided their own statements regarding coal and pet coke. Miguel Moya described his experience growing up in Richmond and his outlook on the prospective ban:

> "Growing up I've witnessed a lot of people having asthma, a lot of my classmates and my teammates have had to quit the baseball team because of their asthma… By getting rid of coal, we will see health and economic benefits that will improve quality of life for all of us. And me personally, as a youth in my community, I see a better future."[77]

Brenda Medina similarly emphasized the negative health effects of air pollution in her appeal:

> "Coal trains can lose a pound of coal dust per car for every mile they travel… Lots of people live near the tracks including people like children, newborns, older people who are more prone to lung diseases... Coal dust contains heavy metals that are toxic including mercury, lead, nickel, tin, and radioisotopes. It causes lung diseases that can bring about impairment, disability, premature death."[77]

Mr. Khamphanthong, Mr. Chanthanasak, Mr. Moya, and Ms. Medina were all recruited and supported by APEN in their public comments; however, notably, they also attended the meeting as part of a larger coalition (Figure 5).

APEN's history of collaborating with other health and environmental organizations remained consistent for this campaign. The wider coalition comprised many groups APEN previously partnered with the United Teachers of Richmond CTA/NEA, Sunflower Alliance, CBE, Sierra Club SF Bay Chapter, Baykeeper, Richmond Progressive Alliance, No Coal in Oakland, and the Interfaith Climate Action Network of Contra Costa County.[79] The coalition was also supported by the California Nurses Association when it came to the ordinance hearings.[79] Each member group of the coalition brought representatives to the city council meeting to advocate for voting "yes" on the coal and pet coke ban in Richmond. As such, nearly 70 members of the public provided comments at this critical ordinance hearing.[80]

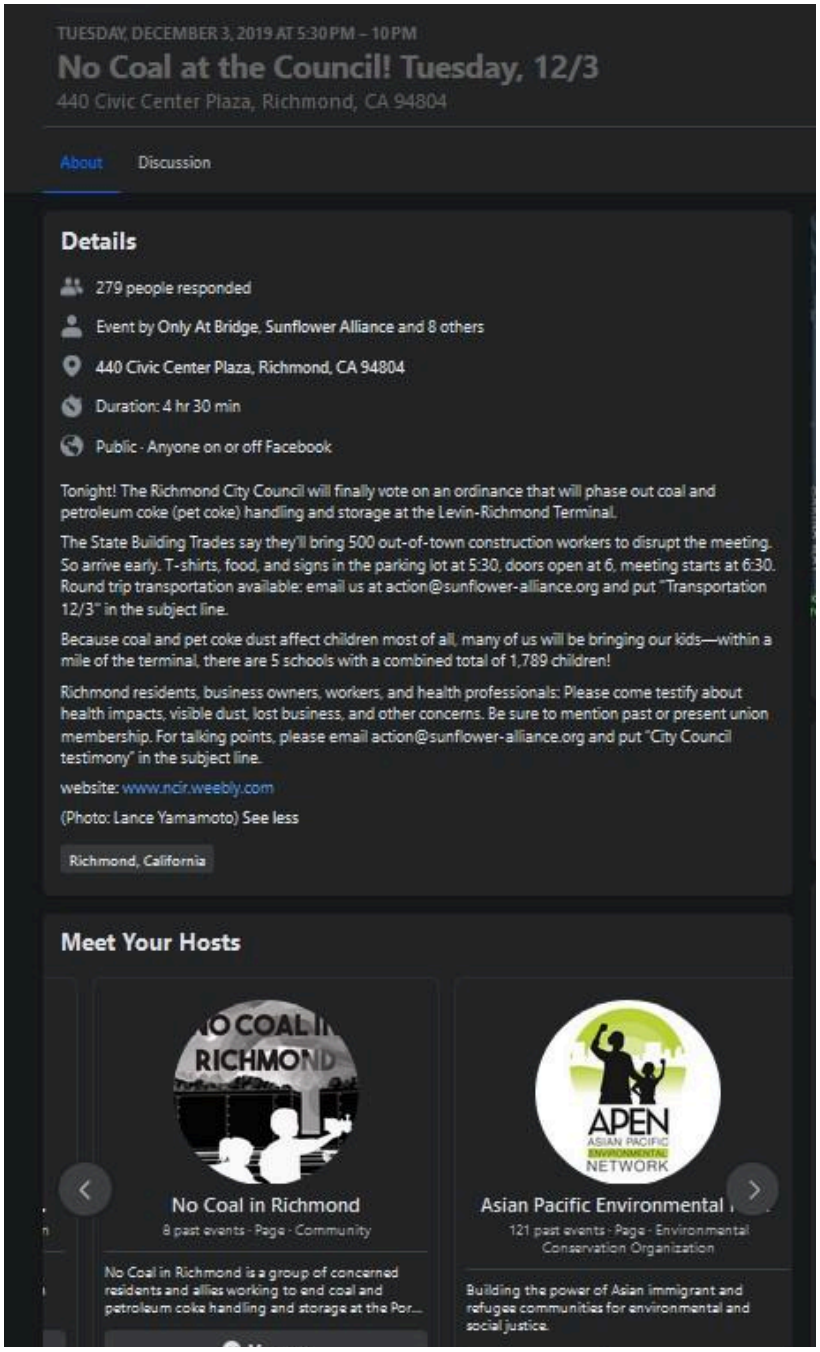
Notably, several members of local trade unions spoke against the proposed ban on behalf of their union jobs and employers. Many were people of color who also resided in Richmond. Arnie Morgan from Operating Engineers Local 3 stated:

> "I'm for labor and I'm sure you guys are, too… I don't think we can afford to lose good paying jobs like this, especially in the Bay Area. Good paying union jobs with health care..."[77]

Antwon Cloird, a retired member of Laborers Local 324, further suggested that the ordinance would remove job opportunities for people who were formerly incarcerated:

> "I live in Richmond. I was raised here. I worked here. But I got my start through the brotherhood. After coming out [of] 35 years of crack, they gave me opportunity and look at what I'm doing now. Don't tell me this stuff don't work. If you're talking about a second chance in a first chance life, that's what the brotherhood gives. So, when you cancel these jobs, you have a lot of people in here with records."[77]

Figure 5. APEN Facebook Event Post for Richmond City Council Meeting, December 3, 2019[78]



Brenda Medina, an APEN-supported high school student, acknowledged the community divide between EJ advocates and trade union workers during her statement in favor of the ordinance:

> "...[W]e're talking about union members. Yeah, you know, they have a job, but coal is running out regardless. It's not renewable. Once it's gone, it's gone forever. So, what happens then? At least now they have a Just Transition. We're not ripping away their jobs in one day."

Outcome: Richmond's Ordinance Passed and Upheld in Court with a Settlement

On December 3, 2019, Richmond's Mayor Tom Butt deferred the council's deliberation on the coal and pet coke ordinance to the next general meeting on January 14, 2020, where it passed despite a single "no" vote from Councilmember Bates.[80,81] The ordinance's second hearing began on January 21, 2020 and continued on February 4, 2020, where the ordinance was formally adopted into city law despite a single "no" vote from Vice Mayor Bates.[82,83] Richmond's Ordinance No. 05-20 aligned with the sentiment and trajectory set by City Resolutions 47-15, 48-15, and 32-16 (previously discussed) because it discontinued and banned the open storage and transportation of coal and pet coke in the city.[67] In order to address corporate and union worker concerns about job availability and stability,[77] Ordinance No. 05-20 provided a three-year transition period for all coal and pet coke operations to adjust their businesses to other lawful means.[67]

Both the City of Richmond and its City Council received immediate legal backlash from the corporations involved in the transportation and storage of coal and pet coke. Levin-Richmond Terminal Corporation, Wolverine Fuel Sales, the state of Utah, and Phillips 66 filed a total of five lawsuits to contest the ordinance at the state and federal levels within six weeks of adoption.[84,85] For the state lawsuits, CA Superior Court Judge Steven K. Austin dismissed claims from Phillips 66, Levin Richmond Terminal Corporation, Richmond Pacific Railroad Corporation, and Levin Enterprises, Inc. and ruled in favor of Richmond and its City Council on December 24, 2020, nearly 10 months after the coal and pet coke ordinance was passed.[86] For the federal lawsuits, APEN's coalition partners, the Sierra Club and SF Baykeeper, supported Richmond and its City Council in federal court by enlisting legal services from Earthjustice. The litigation lasted until November 12, 2021, when all parties announced a formal settlement that upheld the original ordinance, albeit with an extended transition period until 2027.[84,87]

Vignette #2 Final Result: The ban on transporting and storing coal and petroleum coke in Richmond, CA will take effect on December 31, 2026.

Discussion

Through this case study, I find that the inequitable systems of Richmond's low-income and minority neighborhoods, fossil fuel industry siting/operation, and environmental degradation are mutually reinforced by 1) the prioritization of corporate and private sector interests and 2) insufficient institutional and state regulation of both industrial operations and air pollution. This case study identified two drivers of the persistent environmental racism present in Richmond: 1)

racial capitalism and 2) "pollution-friendly" environmental solutions. Finally, despite the myriad of challenges with environmental racism, APEN achieved localized success through multi-scalar advocacy and organizing, paired with coalition and community building. Summarized timelines with the analytic framework for Vignette #1 and Vignette #2 can be found in Table 2 and Table 3, respectively.

Racial Capitalism Drives the Mismatch Between Community, Corporate, and State Priorities

Health data from Richmond reveals disproportionate health inequities in terms of asthma, cardiovascular disease, and premature death.[64,66] Environmental data and research also suggest disproportionate environmental exposures to toxic air pollutants in Richmond's low-income, non-white neighborhoods.[45] However, time and again, APEN and their allies have experienced a plethora of decades-long battles against corporations involved in the fossil fuel industry. Historically, many battles ended in state "solutions" that allowed for industries to continue polluting the environment (e.g. Vignette #1), while some achieved EJ successes (e.g. Vignette #2).

In terms of community priorities, APEN's mission focuses on obtaining a clean and healthy environment in which communities can live, work, learn, play, and thrive.[88] As such, the two campaigns in this case study emphasized the sanctity of human health and breathing clean air in a community overburdened by pollution. The public appeals from APEN's members and constituents had consistent themes: widespread morbidity, premature mortality, and the right to breathe clean air.[50,52,73,77] These pleas echoed decades of EJ advocacy to reduce cumulative pollution burdens in Richmond, and they came from three generations of EJ advocates, including Richmond's youth, working-age adults, and elders.[77]

The corporate priorities seen in Vignette #1 are a stark contrast. Chevron emphasized maintaining fuel production at their Richmond oil refinery with no emissions limits so as to accommodate both hypothetical fluctuations in consumer demand and the potential addition of new oil refinery technologies.[89] Purportedly, restrictions on emissions would limit the ability to temporarily increase production during times of high demand, and it would also prevent the potential installation of new oil refining technologies due to localized construction-associated emissions.[89] Chevron's appeal used threats of further environmental degradation and increased GHG emissions throughout CA due to fuel imports from abroad and the transportation of fuel from other areas of the country.[89] WSPA, which describes itself as "a non-profit trade association representing [26] companies that explore for, produce, refine, transport and market petroleum, petroleum products, natural gas and other energy supplies in California, Arizona, Nevada, Oregon, and Washington," represented private sector interests as it supported Chevron's claims.[90] WSPA prioritized the delegitimization of Regulation 12, Rule 16 with the arguments that local emissions limits are illegal, do not reduce emissions, and do not benefit climate change.[90]

The corporate priorities seen in Vignette #2 echo those from Vignette #1. The Levin Richmond Terminal group emphasized maintaining current operations with the transportation and storage of coal and pet coke so as to keep trade jobs and local businesses in operation.[80,86] Purportedly, the phase-out and ban of coal and pet coke in Richmond would have the potential to close the Levin Richmond Terminal,[86] thereby potentially eliminating 60 jobs from the local

economy.[84] Similar to Chevron, Wolverine Fuel Sales and Phillips 66 threatened that the ban would cause an increase in environmental degradation and increase GHGs because they would need to transport coal and pet coke, respectively, to other areas of CA to continue their export operations.[86] In terms of private sector priorities, several trade unions voiced opposition to the ordinance to "protect" middle-class, union jobs.[77]

In both vignettes, the facilities responsible for air pollution primarily prioritize maintaining business operations at full capacity, with the option to expand capacity. This would both maximize and potentially increase their capital gains as businesses. The neighborhoods where they operate are primarily low-income communities of color that experience environmental racism with disproportionate exposure to air pollution.[64,91] Evidence suggests that some of these neighborhoods experienced further increases in air pollution even after CA instituted a state-wide GHG regulation system.[91] This demonstrates that there is an interrelationship where the facilities rely on disadvantaged communities for operation, and as long as the facilities operate at their current capacity, the communities will continue to bear the largest burden of polluted air. This is indicative of racial capitalism, where, according to Melamed, the "procedures of racialization and capitalism are ultimately never separable from each other."[92]

The mismatch of community and corporate/private interests in both vignettes reflects the process by which racial capitalism assigns lesser value to low-income and non-white lives in Richmond. More specifically, this phenomenon has been referred to as the devaluation,[3] insignificance,[10] and dispensability[5] of communities where the maintenance of polluting industrial operations and the economy supersedes the localized protection of human health and the rectification of environmental contamination. The arguments in favor of polluting industries are then bolstered with hypothetical threats of worse environmental degradation outside of the focus communities,[5,86,89] which disregards the persistent health, social, and environmental problems in communities like Richmond's. Despite having some of the most "progressive" state-level environmental policies, the historical pattern of devaluation, insignificance, and dispensability of EJ communities has been described throughout CA, including in the San Joaquin Valley[10] and Los Angeles.[93] The same phenomenon is noted in a myriad of EJ cases across the US, with some recent examples seen in Louisiana[5] and Texas.[94]

EJ scholars further suggest that racial capitalism can uphold environmental racism through racialized labor forces.[3,10] Polluting industries employ people of color in trade jobs that cause environmental exposures at work and at their homes in nearby communities.[10] Richter refers to this as "the state-sanctioned positioning of bodies of color in poorly regulated jobs and spaces of extreme environmental 'non-compliance.'"[10] While this was not a theme central to this case study, it became apparent during the research process. Corporate entities threatened the loss of jobs in both campaigns; thus, it is equally notable that multiple trade unions provided statements in support of their industry employers. In Vignette #1, the United Steel Workers provided public comments that sought to delay and potentially discredit Rule 12, Regulation 16.[95] Their primary arguments echoed Chevron's (previously discussed), and they also suggested that the regulation would not adequately address pollutants that harm workers and communities.[95] In Vignette #2, trade unions, such as United Steel Workers Local 326, Operating Engineers Local 3, and Laborers Local 324, took a more direct approach with their appeals.[77]

The unions had current and retired members provide public testimony against the ordinance to ban coal and pet coke, many of whom were people of color and Richmond residents. Their primary arguments were that the city did not care about accessible middle-class jobs and that the ordinance was being driven by outside "special interest" groups like the Sierra Club.[77] In this scenario, a racialized workforce advocated to sustain Richmond's source of health and environmental harm under the auspices that the fossil fuel industry is the only meaningful employment for those who rely on trade jobs, particularly if they have been incarcerated.

This aspect of racial capitalism positions people of color who live in the same communities against each other in the struggle to survive. One group of community members (trade union workers) prioritizes perceived economic security and represents the fossil fuel industry's interests, while the other group (EJ advocates) prioritizes human health and a safe environment. Meanwhile, the fossil fuel industry relies on both groups as part of racial capitalism's economic process. On one hand, trade union workers must sustain extractive industry through 1) their work in exposure-prone positions [10] and 2) representation of their employers' interests within the community. On the other hand, EJ advocates, other community members, and the localized air serve as "sinks" where pollution can be deposited as part of the industrial process.[3] This divide between trade union job workers and EJ activists has been documented since at least the 1990s.[96] Notably, the two sides were unified under the Just Transition movement from the mid-1990s to the mid-2000s due to APEN's collaboration with the Oil, Chemical Atomic Workers Union.[96] The Just Transition movement of this time tapered off due to changes in union leadership, a stronger focus on green jobs (rather than EJ), and a lack of funding.[96] APEN's ongoing dedication to the Just Transition campaign provides promise for future collaboration and unification. Finally, while it is beyond the scope of this current case, the interrelationships between the prison industrial complex, the fossil fuel industry, and issues of environmental racism can be further examined in future research. Some aspects of these relationships have been explored around prison development;[97] however, EJ scholarship could expand by focusing on how the fossil fuel industry may impact people's reentry into society after incarceration.

In an effort to address industry and local economic concerns during this case, APEN and other Richmond residents vocally support a Just Transition away from extractive industries whereby industrial trade jobs would convert to sustainable, generative jobs for the same workers.[4,75] Some might argue that Phillips 66 is an example of a corporation that began a Just Transition after the lawsuit settlement in 2021. Pet coke exports were no longer an economic option, so Phillips 66 began to convert its oil refinery to a biofuel facility[84] and announced that the conversion would create 500 construction jobs and preserve over 650 jobs at the facility.[98] The full conversion to a renewable energy complex was completed in 2024.[99] In the case of Levin Richmond Terminal, the corporate operators were ultimately given seven years to pivot their business for the storage and export of any other lawful substances within the city.[67,100] Therefore, if Levin Richmond Terminal's operators used the seven years for a Just Transition like Phillips 66, jobs at the terminal would not cease to exist at the onset of the ban on coal and pet coke. These are important outcomes related to the case, yet it is beyond the scope of this case to cover in depth. Future EJ research can focus on the implementation, impact, and effects of the Just Transition after successful EJ campaigns.

In terms of state priorities, democratically elected officials are typically beholden to the resident constituents who elected them. However, elected officials also act on behalf of the state and are compelled to make decisions that will maintain and/or improve economic conditions in the communities they serve. EJ solutions that are "pollution-friendly" (discussed further in the next section) result from these two priorities working against each other under racial capitalism, with elected officials more often prioritizing the economy over the health concerns of resident constituents.

Although it is not the primary focus of this case study, Vignette #1 raised questions about the impartiality of elected officials who receive substantial campaign donations from the fossil fuel industry. Elected state officials received multi-million dollar campaign donations from the fossil fuel industry and narrowly prevented the passage of environmental legislation that prioritized prevention and protection from air pollution.[59,60] This ensured that the replacement legislation would allow the fossil fuel industry to continue to pollute without true GHG restrictions, which directly undermined decades of grassroots organizing at the local- and regional levels.[58] Vignette #2 also had similar interference with political campaign donations. Richmond Levin Terminal made substantial donations to Richmond City Council candidates who sought to overturn the ordinance to ban coal and pet coke.[101] Nevertheless, the attempt to shift City Council members failed due to APEN's work in garnering community support for progressive candidates who would prioritize health and the environment.[74] The impact of the fossil fuel industry's political purchasing power on EJ outcomes is a growing area of research. For example, a recent study found that politically connected fossil fuel firms are less likely to receive penalties for non-compliance and incur lower fines when compared to firms that do not make substantial donations to elected officials.[102] Additional search on similar impacts at the local level and state levels can provide further insight into the processes that foster continued health and environmental "failures" in EJ communities.

"Pollution-friendly" Environmental Solutions: Insufficient Regulation of Industrial Operations and Air Pollution

Research has established that state entities do not consistently reprimand, regulate, and prevent further environmental inequity in low-income communities of color.[103] When the state does intervene, additional studies have shown that state-level (generalized) regulation can fail to address EJ concerns for the most at-risk and burdened communities.[58,91,104] For example, many consider CA's Cap-and-Trade program to be at the forefront of state-level climate and greenhouse gas solutions. The Cap-and-Trade program purports to reduce overall air pollution through a system of generalized caps on industrial emissions with set credits based on previous emissions.[58] The program yields to corporations by allowing them to "trade" or sell/purchase credits, if one corporation has excess credits and another corporation needs more due to increased emissions.[58] However, fossil fuel companies, in particular, have continued to emit comparable, if not more, toxic air pollutants into local communities due to the trading system.[91] Hence, APEN and other local EJ groups have targeted regional and local regulations in an attempt to mitigate the localized effects of the Cap-and-Trade system (discussed further in the next section), as well as the gaps left by state EJ legislation.

In Vignette #1, one can observe how CA's hallmark EJ legislation and comparatively stringent air pollution regulations did not address or assist APEN's EJ case in Richmond. Opponents of Regulation 12, Rule 16 claimed that the regional regulations were unnecessary because Cap-and-Trade was sufficient to reduce air pollution statewide.[46] This assertion did not address the disproportionate burden of air pollution exposure in Richmond's local communities. APEN, CBE, and other EJ organizations further rejected these claims because Regulation 12, Rule 16 would have provided multi-pollutant combustion emissions control,[46] which has been found to be more effective and efficient than Cap-and-Trade's pollutant-by-pollutant approach.[58] Additionally, BAAQMD itself has found that a multi-pollutant approach would be best for improving air quality in the region.[39] Ultimately, state-level legislators renewed Cap-and-Trade with AB 398, which included provisions to negate and undermine years of grassroots advocacy for stringent regional air pollution standards.[58] EJ advocates and residents who suffer from the harmful effects of localized air pollution continue to purport that the Cap-and-Trade program allows polluters to release toxic emissions.[62] Hence, APEN has taken a multi-scalar approach to advocating for clean air in their communities.

Multi-Scalar Advocacy and Intersectional Organizing: Strategies to Confront Environmental Injustice as a Multi-Scalar Problem

Critical EJ theory suggests that EJ research and practice should be multi-scalar in terms of spatiality and temporality.[27] This pillar of critical EJ is meant to expand the EJ movement to accommodate the expansive global and historical nature of environmental degradation.[27] As such, multiple levels of intervention are necessary to combat environmental racism, which is embedded into geopolitical structures, such as environmental regulation, conservation, and extraction of natural resources.[3,103,104] This case study illustrates how APEN used advocacy at multiple levels of government to achieve its goal of securing policy to reduce localized air pollution for its communities in Richmond. Vignette #1 revealed that successful advocacy for regional regulations on air pollution reduction could be thwarted with state-level legislation. Despite EJ losses at larger geographic scales, Vignette #2 provided an example of how APEN leveraged city-level ordinances in the following years to secure a path toward cleaner air in Richmond's communities. The strategy of organizing two campaigns with the same goal of clean air yet different policy objectives (e.g. regional emission regulations versus local substance bans) aided APEN's success when one campaign was stymied. In terms of the case study's temporality, the success of APEN's clean air actions will have come to fruition at least 15 years from the start of Vignette #1 in 2012 to the end of Vignette #2 in 2027. Future critical EJ research in CA can emphasize temporality as new environmental policies are enacted over time.

APEN's multi-scalar organizing was supported and enhanced by their community building and coalition work. This reflects another pillar of critical EJ that emphasizes an intersectional approach.[27] For both campaigns, APEN fostered a sense of community among Asian people in Richmond through the use of social media and in-person outreach events. This facilitated the involvement of at least three generations of Richmond residents in Vignette #2. These constituents strengthened appeals to air pollution regulators and lawmakers with narratives of experiencing environmental health inequities due to air pollution exposures in their communities. APEN continued its long history of multi-racial, multi-class organizing and coalition-building in both campaigns. In Vignette #1, APEN's membership in the broad coalition

Moving forward, APEN's recent expansion to Southern California provides future opportunities for additional vast multi-scalar EJ actions. The Los Angeles region has an extensive history of intersectional EJ organizing between multi-racial, women-led groups,[93] which will complement APEN's historical strategy of coalition-building in future campaigns.

This case emphasized an EJ campaign's success with a city-level ordinance to ban the storage and transportation of coal and pet coke in Richmond. This can be a promising strategy for future campaigns; however, there may be low transferability to other local jurisdictions because previous campaigns with this strategy have not always been successful. For example, a local ordinance in Union, Louisiana banned toxic substances within its jurisdiction, but the ordinance itself was overturned when a corporation challenged the ordinance's legality in court.[1] Another case in Emelle, Alabama demonstrated that city-level ordinances that call for toxic substance fees, rather than outright bans, can also be challenged and overturned in court.[1] Furthermore, the precedent for local bans on toxic substances may not apply elsewhere within the state of CA. The No Coal in Richmond campaign was a success, but the future of a similar No Coal in Oakland campaign is undecided.[105] Both cities are in the SF Bay Area and they both sought to ban coal and pet coke, yet a court decision upheld Richmond's ordinance, and a different court decision rendered Oakland's ordinance useless. These implications further emphasize the importance of multi-scalar advocacy to address EJ concerns when current methods of interfacing with the state achieve inconsistent results.

Conclusion

This case study described two campaigns in which APEN sought government-based EJ solutions to ameliorate Richmond's experience of environmental health inequities related to cumulative air pollution. The vignettes illustrate the persistent mismatch between the concerns of Richmond's community residents, those of the fossil fuel industry, and those of the state. Despite being at the forefront of EJ laws and regulations, CA and its local governments did not have air pollution or environmental policies to sufficiently protect low-income communities of color in Richmond from exposure to excessive PM2.5. Racial capitalism is a driver of environmental racism that perpetuates insufficient environmental policies and differing priorities of Richmond's stakeholders. APEN faced these challenges by employing critical EJ strategies of multi-scalar advocacy and intersectional coalition-building. These efforts ultimately yielded success in securing a city-level ordinance to reduce exposure to coal and pet coke PM2.5 in Richmond. The case study revealed opportunities for future EJ research focused on the relationship between the prison industrial complex and the fossil fuel industry, the Just Transition process after EJ successes, the impacts of political contributions to EJ failures, and further critical EJ studies.

Tables

Table 1. Oil Refineries and Support Facilities under BAAQMD Jurisdiction (2017)[45]

Name	Location
Chevron Products Company (BAAQMD Plant #10)*	Richmond, CA
Phillips 66 Company—San Francisco Refinery (BAAQMD Plant #21359)*	Rodeo, CA
Shell Martinez Refinery (BAAQMD Plant #11)*	Martinez, CA
Tesoro Refining and Marketing Company (BAAQMD Plant #14628)*	Martinez, CA
Valero Refining Company—California (BAAQMD Plant #12626)* - associated asphalt plant (BAAQMD Plant #13193)	Benicia, CA
Air Products and Chemicals Hydrogen Plant (BAAQMD Plant #10295)**	Martinez, CA
Air Liquide Hydrogen Plant (BAAQMD Plant #17419)**	Rodeo, CA
Martinez Cogen, L.P. (BAAQMD Plant #1820)**	Martinez, CA

*Oil Refinery **Oil Refinery Support Facility BAAQMD = Bay Area Air Quality Management District

Table 2. Vignette #1 - Summarized Timeline of Selected Events with Analytic Framework

Vignette #1 Regional EJ Action: Bay Area Air Quality Management District - Regulation 12, Rule 16						
Year	**APEN action**	**Critical EJ Perspective**	**Pollution-friendly Environmental Solutions**		**Mechanism under Racial Capitalism**	
2012	Intensified advocacy for refinery emissions limits after Chevron fire	—	—	SB 535 (2012), AB 1550 (2016), SB 1000 (2016) state-wide EJ legislation does not improve localized air pollution in Richmond	State prioritizes community: BAAQMD announced intention to limit refinery emissions	Persistent Mismatch Between Community, Corporate, and State Priorities
2013	Rally at BAAQMD in response to BAAQMD's reversal on refinery emission limits	—	—		State prioritizes corporations: BAAQMD reversed stance on refinery emission limits due to pressure from fossil fuel industry	
2015	Joint Rally at BAAQMD	Intersectional & Multi-scalar (same time as Vignette #2) Organizing	—		—	
2015 - 2017	Joint actions and statements, with coalition expansion to over 20 groups and organizations	Intersectional & Multi-scalar (same time as Vignette #2) Organizing	—		—	
2017	BAAQMD passed Reg 12, Rule 16; however, it was superseded and nullified at the state level	Multi-scalar (same time as Vignette #2) Organizing	AB 378 - did not pass (extended Cap-and Trade with complimentary language for regional refinery emissions limits) AB 398 - passed (extended Cap-and-Trade and prohibited regional refinery emissions limits)		State prioritizes corporations: Fossil fuel industry thwarted AB 378, and subsequently influenced the passage and content of AB 398	

Table 3. Vignette #2 - Summarized Timeline of Selected Events with Analytic Framework

Vignette #2 Local EJ Action: Richmond City Council - "No Coal in Richmond"						
Year	**APEN action**	**Critical EJ Perspective**	**Pollution-friendly Environmental Solutions**		**Mechanism under Racial Capitalism**	
2014 - 2016	Joint campaign to elect city council members	Intersectional & Multi-scalar (same time as Vignette #1) Organizing	—	SB 535 (2012), AB 1550 (2016), SB 1000 (2016, AB 617 (2017) state-wide EJ legislation does not improve localized air pollution in Richmond	State prioritizes community: Elected city council members pass resolutions to ban coal and pet coke in 2015	Persistent Mismatch Between Community, Corporate, and State Priorities
2016 - 2018	Continued elections campaigns	Multi-scalar (same time as Vignette #1) Organizing	—		State prioritizes communities: Five city council members pledge to not accept corporate donations	
2018 - 2019	Elders recruit new generation of APEN organizers, who then recruit youth organizers	Intersectional, Multi-generational Organizing	—		—	
Dec 2019	Joint coalition attendance at city council public hearing for the ordinance to ban coal and pet coke	Intersectional, Multi-generational Organizing	—		Community divide between people of color: EJ advocates support the ban, while trade union workers oppose the ban on behalf of their jobs and companies	
2020	Joint coalition attendance at city council meeting	Intersectional Organizing	—		State prioritizes communities: City council passes ordinance to ban coal and pet coke	

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Paper 2. Estimating the Differential Impact of Racial Residential Segregation on Age-Adjusted Asthma Emergency Department Visit Rates in California: An Exploratory Analysis of Asian Neighborhoods

Abstract

Asian people constitute the fastest-growing racial/ethnic group in the United States, and despite the fact that there are known chronic health disparities among Asian people, few studies examine the relationships between structural racism and chronic health conditions in Asian communities. This study broadly examines the asthma burden in Asian neighborhoods in California between 2015 and 2017. I assess the association between racial residential segregation (measured with the location quotient) for Asian people and the age-adjusted rates of emergency department visits for asthma per 10,000 in the neighborhoods where they live. I examine the role of community-level impacts and contextual factors such as median household income, educational attainment, nativity status, and air pollution as modifiers of this relationship. Finally, I conduct an exploratory spatial analysis to identify potential spatial patterns in the relationship. I find that neighborhoods with an underrepresented Asian population have the highest rates of asthma emergency department visits, while segregated Asian neighborhoods have the lowest rates. These findings suggest an unspecified protective aspect of segregation for Asian segregated neighborhoods that requires further investigation.

Introduction

Asthma is a chronic disease of the respiratory system that does not have a cure.[1] Medication adherence can assuage symptoms such as wheezing, chest tightness, and difficulty breathing, but asthma can still cause life-altering and life-threatening health outcomes.[1] Nearly 25 million people in the United States (US) are impacted by asthma every year,[2] with overall prevalence rates being 7.7%.[3] Asthma's chronicity, paired with acute exacerbations of symptoms, leads to cumulative costs of over $81 billion in health care expenditures.[4] Heavy disease morbidity can result in missed days of school, missed work, and unemployment.[1]

Populations that suffer disproportionately from asthma differ in terms of age, race/ethnicity, socioeconomic position (SEP), and geographic location.[5] When it comes to age, children require hospital-based treatment for asthma at more than twice the rate for adults, with rates of 85.3 per 10,000 for emergency department (ED) visits (compared to 38.3 in adults) and 10.3 per 10,000 for hospital inpatient stays (compared to 4.2 in adults).[6] Black, Native American, and multi-racial people have the highest prevalence rates of current asthma (over 10%).[3] Furthermore, people who live below the poverty threshold have the highest prevalence rates of nearly 11%.[6] The cumulative effect of these characteristics and risk factors can be observed in Black children who live in high-poverty urban neighborhoods because they experience the worst morbidity through frequent hospital-based care.[7] National trends in asthma are also consistent with state-level data, which are strongly patterned by race/ethnicity and age. In California (CA), Black, Native American, and Puerto Rican people have the highest lifetime asthma prevalence rates, and asthma prevalence among children is 20-40% higher when compared to adults.[8]

The Office of Minority Health (OMH) reports that Asian people in the US "generally have lower rates of asthma" when compared to their white counterparts.[9] Current statistical

reporting may cause this misnomer because health researchers collect, analyze, and present data on Asian people in aggregate form, which obscures health status among subgroups.[10] Evidence suggests that the asthma burden in Asian subgroups has been overlooked. Asian and Latino people in CA are reported to have lower lifetime asthma prevalence rates of 11.7% and 11.3%, respectively, when compared to Native American (21.8%) and Black (19.8%) people.[8] However, asthma disparities among Asian people become apparent when health data is disaggregated by Asian subgroup. Filipino and Japanese people have lifetime asthma prevalence rates of 16.9% and 16.8%, respectively, which are more than two times those of Korean (5.7%) and South Asian people (7.5%).[8] Statistics derived from aggregate data can obscure stark differences in asthma status among subgroups, which can be problematic when health research and programming are based on state-released disease reporting.

Racial/ethnic disparities in asthma are not fully explained by individual-level factors rather, they are attributable to the social determinants of health.[11] For example, health statistics may indicate that race/ethnicity is an individual risk factor for asthma in and of itself; however, race/ethnicity is not biological and cannot be the source of differences in health.[12] It is racial discrimination, or racism, that informs differential access to health-benefiting and protective resources.[13] The concept of race is socially created because perception delineates race, not true shared ancestry or history.[12] Furthermore, race/ethnicity functions as a system of social ordering for racial discrimination in social relations.[11,12]

Racial residential segregation (segregation) is a prominent example of how racism has been used to socially and physically separate people by race/ethnicity.[11] Defined as "the physical separation of the races in residential contexts,"[14] segregation prevents minority groups from accessing resources that could benefit or protect their health.[13] Consequently, segregation is a fundamental cause of racial/ethnic health inequities in several chronic diseases, including asthma.[14,15]

In this study, I assess associations between local segregation and asthma outcomes in Asian American, refugee, and immigrant (Asian) neighborhoods in CA from 2015 to 2017. CA has the nation's largest Asian population,[16] and is therefore ideally suited for a study exploring the contextual and structural factors that may contribute to adverse asthma outcomes among this fast-growing population. I ask: "How are racial residential segregation and community characteristics related to asthma outcomes in Asian communities in California?" To answer this question, I examine the association between racial residential segregation and age-adjusted asthma emergency department visit rates in communities according to their level of Asian segregation. I also examine the effects of neighborhood characteristics such as socioeconomic position, nativity, and air pollution exposure on the association between racial residential segregation and asthma outcomes in the same communities. I hypothesize that nativity will modify the relationship between segregation and asthma, where Asian segregated neighborhoods with a high density of non-US born residents will have lower rates of asthma ED visits compared to non-segregated neighborhoods. I also hypothesize that air pollution will modify the relationship between segregation and asthma, where, regardless of segregation status, neighborhoods with increasing levels of air pollution will have higher rates of asthma ED visits.

Background

Theory: The Relationships Between Segregation and Health Inequities

Link and Phelan developed fundamental cause theory to describe how social conditions are formative and centrally important drivers of racial/ethnic health inequities.[17] Williams and Collins extend this research and identify segregation as one of the most notable sources of racial/health inequities in the US[14] In their influential paper, they identify and describe the mechanisms by which segregation functions as a fundamental cause of health inequities.

First, segregation is associated with numerous health outcomes such as heart disease, tuberculosis, low birthweight, lead poisoning, and asthma.[14,15] Second, segregation is linked to health outcomes through multiple pathways and upstream risk factors such as educational opportunities, employment opportunities, housing quality, neighborhood violence, and access to health care.[14] Third, the effects of segregation are reproduced and persist in the same neighborhoods over time. Williams and Collins state that the "divestment of economic resources in these neighborhoods has led to a decline in the urban infrastructure, physical environment, and quality of life in these communities."[14] Finally, segregation prevents access to flexible resources such as quality public school education, economic purchasing power, and political power.[14] Williams and Collins conclude that efforts to reduce racial/ethnic inequities in health must move beyond individual interventions to the inclusion and consideration of socioeconomic conditions and geographic contexts.[14]

Social epidemiology research has also examined how segregation "gets under the skin" to cause health inequities. Massey's biosocial model of stratification suggests that environmental stress, from exposure to violence and low-resource neighborhoods, contributes to and perpetuates allostatic load in the bodies of Black people who live in segregated areas.[18] Allostatic load refers to a condition of multi-system dysregulation due to adaptation to chronic stressors, which leads to generalized susceptibility to disease and poor health outcomes.[18] Thus, Massey's model also connects allostatic load to chronic health conditions associated with "wear and tear" such as heart disease, inflammatory disorders like asthma, and cognitive impairment.[18] Similarly, Gee et al. use segregation to exemplify their conceptual model of how racism can contribute to racial/ethnic inequities in life expectancy and other health outcomes across the life course and over generations.[19] While Massey's model aligns with fundamental cause theory's criteria of multiple health outcomes and multiple pathways, Gee et al.'s model aligns with the other two criteria of persistence over time and alteration of access to flexible resources. While this research primarily examined the experiences and health of Black people in the US, these theories all support the notion that segregation is a fundamental cause of racial/ethnic health inequities.

Research: Segregation and Asthma

Segregation entails both the social stratification and spatial distribution of people based on perceived (or assigned) race/ethnicity. While theory informs the understanding of how segregation creates persistent and multi-generational social stratification, measurement in research reveals patterns in the racial/ethnic spatial distribution of where people live. Massey and Denton assess 20 segregation indices and determine that segregation has five dimensions by which it can be measured: (1) evenness, (2) exposure, (3) concentration, (4) centralization, and

(5) clustering.[20] Evenness is the difference in distribution between two groups among areal units within a specified region.[20] Exposure is the likelihood of contact between minority and majority group members within areal units in a specified region.[20] Concentration is the relative density of a minority group in an area unit.[20] Centralization is the relative degree to which a specified group lives near the center of a city, and it entails the assumption that racial/ethnic minority people in the US tend to live in city centers.[20] Lastly, clustering is the degree to which a group lives in areas that are consolidated next to each other.[20]

Literature that examines the relationship(s) between segregation and asthma in the US generally suggests that higher degrees of segregation for racial/ethnic minority groups entail poor asthma outcomes. While most studies have examined pediatric asthma outcomes, evidence across myriad studies reveals that higher incidence,[21–24] prevalence,[25,26] and healthcare utilization [27–29] for asthma are associated with living in census tracts,[22,24–28] ZIP codes,[21] and counties[29] with higher concentrations or proportions of Black and/or other racial/ethnic minority residents. Two studies indicate that Black children have a higher odds of asthma diagnosis when compared to other children,[21,23] and a study by Brewer et al. also suggests that Asian children have an elevated odds of asthma diagnosis when living in Asian-segregated areas.[23] Notably, several studies suggest that living in historically segregated Black areas may negatively impact a person's asthma status regardless of a person's race/ethnicity.[21,25,27] A combined life course and ecological perspective supports the idea that historically segregated Black communities and their residents experience persistent adverse living conditions due to discriminatory development of their physical, social, economic, and service environments.[30,31]

Context: Segregation vs. Ethnic Enclave in Asian American and Immigrant Neighborhoods

Human migration and integration patterns have changed the nature of US segregation over time, and it has caused the field to grapple with theoretical approaches to research.[30,32] Massey et al. describe a late twentieth century shift from macro- to micro-level segregation in the US by which Black-white segregation changed from a state- and county-level distribution to a city- and neighborhood-level distribution.[32] They also assert that the immigration of Asian and Hispanic/Latino people increased diversity such that it moderated Black-white segregation.[32] Hwang's research on gentrification supports this notion by describing how Asian and Hispanic/Latino immigrants settled in low-cost areas, including predominantly Black neighborhoods.[33] Hwang notably finds that the influx of Asian and Hispanic/Latino residents in predominantly Black neighborhoods did not lead to substantial financial investment or cultural changes associated with gentrification.[33] Massey et al. ultimately argue that contemporary segregation occurs through the interaction of both race/ethnicity and social class, and it manifests in the form of covert, institutionalized discrimination.[32]

Cummins et al. caution that health research on neighborhoods with high ethnic density may be prone to the pitfall of examining composition (the people) versus context (the place), rather than focusing on how the interplay between both can result in differential health outcomes.[34] These neighborhoods have also been referred to as ethnic enclaves or "geographical area[s] where a particular ethnic group is spatially clustered and socially and economically distinct from the majority group."[35] While the definition is similar to that of segregation, this research perspective and terminology suggest that ethnic enclaves are qualitatively different

beyond compositional attributes, such as having large populations of foreign-born residents.[36] Ethnic enclaves may also entail some degree of voluntary move-in, and they may have a positive effect on health outcomes due to the proximity of social and cultural resources.[35–37] A study by Walton suggests that living in ethnic enclaves may only apply to certain Asian subgroups.[38] She found that Chinese and Vietnamese people are overrepresented in ethnic enclaves, while Filipino people are distributed across all neighborhood types, and all other Asian subgroups are underrepresented in ethnic enclaves.[38] Heterogeneity in historical immigration and settlement patterns among Asian subgroups poses a significant challenge for neighborhood research in Asian communities. This study focuses on segregation exclusive to Asian people and considers the impact of nativity. Therefore, for the purposes of this study, Asian segregation and ethnic enclaves will be used interchangeably.

Context: Evidence of Environmental Exposures in Asian Communities

Previous public health studies have found significant relationships between residential segregation, environmental quality, and health status.[15,39] There has been limited research exploring the relationship between environmental exposures and segregation in Asian communities. However, several studies have found that segregation in Asian communities correlates with a higher risk of air pollution exposure.[40–42] One national study suggests that Asian and Pacific Islander people who live in extremely segregated areas have an increased risk of exposure to air pollutants associated with cancer.[43] Another national analysis indicates that Asian and Pacific Islander people are more likely to reside in counties that violate air quality standards when compared to people of other races/ethnicities.[44] Grineski et al.'s disaggregated analysis reveals that an increase in the proportion of Asian residents in census tracts is associated with significantly greater cancer risk from hazardous air pollutants.[41] They also found that census tracts with higher proportions of Chinese, Korean, and South Asian residents, as well as those with high concentrations of people who speak a non-English language and people who are US-born, have significantly greater cancer risk burdens relative to white residents.

The notable lack of robust studies examining the impacts of segregation on health for Asian people has been cited several times, including the need to understand patterns in California where large populations of Asian people live in diverse communities.[10,45] The current study extends this work by examining air pollution as a potential moderator in the relationship between segregation and asthma outcomes for Asian neighborhoods.

Data and Methods

This study utilizes secondary and tertiary data from CA to examine asthma ED visits at the census tract (CT) level. All data used in the analysis was derived from CalEnviroScreen 4.0 and the American Community Survey (ACS), 2015-2019. Data processing, spatial analysis, regressions, and mapmaking were conducted with R (version 4.2.3) Software.

CalEnviroScreen 4.0 is a screening tool that estimates environmental health impacts for communities in CA. It helps to identify communities that are most burdened by excessive environmental pollution while also experiencing socioeconomic and health challenges.[46] It is used by government agencies to ensure equitable treatment and consideration of all CA residents

in decision-making.[46] The tool creates a composite score for communities by combining pollution burden scores with population characteristics. Pollution burden is a summation of different exposures and environmental effects, and population characteristics are a summation of sensitive populations and socioeconomic factors that impact vulnerability.[46] CalEnviroScreen 4.0 uses CTs as proxies for neighborhoods. This analysis utilizes the following data: age-adjusted rate of ED visits for asthma (per 10,000), the annual mean concentration of PM2.5 (micrograms per meters-squared ($\mu g/m^3$)), and the spatial distribution of gridded diesel PM (DPM2.5) emissions (tons/year).[47]

The ACS is a continuous national survey that is sent to a sample of addresses in 50 states, Washington D.C., and Puerto Rico.[48] The ACS gathers demographic information as well as information about education, employment, housing, and other social characteristics. Survey data is released annually, so it is used by government agencies at the state and federal levels to assist with the allocation of more than $675 billion in funds.[48] This analysis utilizes racial/ethnic demographics, nativity status, median household income, and educational attainment from the 2015 to 2019 ACS five-year estimates.

Exposure: Segregation

Estimates from the 2015 to 2019 ACS for the non-Hispanic Asian population were utilized to calculate segregation. This study utilizes the location quotient (LQ) to quantify segregation, which has been increasingly used in health research.[49–52] The LQ quantifies relative segregation of a focus racial/ethnic group at the local level (e.g. CT or community), and it does not require comparison to another racial/ethnic group to render a measurement. The LQ moves beyond concentration, or neighborhood composition, because it considers the spatial distribution of the focus group at a larger geography. The LQ is represented by the following formula:

$$LQ_{im} = (x_{im}/X_i) / (X_m/X)$$

where LQ_{im} is the value for the ith unit (CT) in a region (Metropolitan Statistical Area (MSA)) for minority population group m (Asian). Therefore, x_{im} is the number of Asian individuals living in the ith CT, X_i is the total number of residents in the ith CT of the specified MSA, X_m is the total number of Asian individuals in the MSA, and X is the total number of residents living in the MSA. An LQ of one indicates that a CT's proportion of Asian individuals is exactly equal when compared to the Asian individuals living in the entire surrounding MSA. An LQ score lower than one indicates under-representation in the CT relative to the MSA, while an LQ score higher than one indicates segregation.[49,50] Segregation is more severe as the LQ score moves beyond and higher than one.

To capture hyper-localized variations in racial/ethnic concentration and the evenness at which these areas occur within a regional scale,[53] I focus on MSAs in CA and I use CTs within MSAs as proxies for neighborhoods. There are 8057 CTs in CA; however, I excluded 557 CTs due to missing data in CalEnviroScreen 4.0 and 200 CTs which were located outside of an MSA. The final analytic sample is 7,300 CTs.

Outcome: Asthma Emergency Department Visit Rates

This analysis utilized secondary data estimates from CalEnviroScreen 4.0's indicator for spatially modeled, age-adjusted rate of ED visits for asthma per 10,000 people (averaged over 2015-2017), hereafter referred to as "asthma ED visit rate."[47] The primary data source for the estimates was the Emergency Department and Patient Discharge Dataset from the State of California, Office of Statewide Health Planning and Development (OSHPD).[47] The International Classification of Disease (ICD) codes used to identify asthma ED visits were ICD-9 code 493 (2015) and ICD-10 code J45 (2015-2017).[47] Tracking California processed and spatially modeled the OSHPD data to geographical representation at the CT level for CalEnviroScreen 4.0.[47]

Effect Modifiers: Neighborhood-level Characteristics

Socioeconomic Position (SEP): Median Household Income and Educational Attainment

SEP is a latent construct that cannot be captured with just one measure, and different components of SEP cannot be used as proxies for one another.[54] Median household income (MHI) and educational attainment served as proxies for SEP because both measures have been found to be predictors of both residential segregation[14] and environmental health outcomes.[47] We created the following quartile categories for MHI based on the data: < $53,000; $53,000 - $74,500; $74,500 - $102,500; > $102,500. Nationally, 33% of adults held a bachelor's degree or higher in 2015, so we set the college educational attainment threshold at 33%.[55] As such, a high SEP neighborhood in this study would have an MHI of $102,500 or more and a bachelor's degree attainment of 33% or more.

Nativity

Research on the relationship between nativity and health in the US has found that an "immigrant health paradox" may occur for some foreign-born populations. The paradox suggests that immigrants with low SEP have similar or better health than their US-born counterparts with high SEP.[56] However, studies that focus on Asian people have found heterogeneity in health outcomes, health-seeking behaviors, and health-promoting behaviors among non-US born and US-born Asian people.[56–59] The 2015 to 2019 ACS estimate for CA's foreign born population was 27%.[60] This analysis conceptualizes nativity in terms of residents who were born in the US and its territories compared to those who were born in other countries, regardless of citizenship. As such, a "non-native" neighborhood in this study would have a non-US born population of 27% or more. Neighborhoods with high non-US born populations serve as a reference to observe the potential effects of the immigrant health paradox.

Particulate Matter 2.5 (PM2.5)

Particulate Matter 2.5 (PM2.5) is a mixture of ultra-fine suspended particles and aerosols that measure 2.5 microns or less in diameter.[61] Exposure to PM2.5 is associated with a myriad of short- and long-term adverse health outcomes, including asthma, lung cancer, cardiovascular disease, and reduced life expectancy.[61,62] As cited by Guarnierei and Balmes, PM2.5 exposure is associated with asthma symptoms, poorly controlled asthma, poor lung function, and increased healthcare utilization.[63] This analysis utilized secondary data estimates from CalEnviroScreen

4.0's indicator for the annual mean concentration of PM2.5 (weighted average of measured monitor concentrations and satellite observations, $\mu g/m^3$ across 2015 to 2017).[47] The primary data source for the estimates was the Air Monitoring Network and Satellite Remote Sensing Data from the State of California Air Resources Board (CARB).[47]

I created a second variable for diesel sources of PM2.5 because previous research with the CalEnviroScreen 1.1 data set found that higher concentrations of diesel PM2.5 (DPM2.5) in CA tend to be found in communities of color.[64] Furthermore, the CA Transportation Commission states, "[n]ew highways were frequently constructed through predominately Black, Latino, Asian, and low-income neighborhoods" which contributed to residential segregation and disproportionate roadway-related pollution burden.[65] I used the secondary data estimates from CalEnviroScreen 4.0's indicator for the spatial distribution of gridded DPM2.5 emissions from on-road and non-road sources in 2016 (tons/year).[47] The primary data source for the estimates came from models derived by the California Air Resources Board (CARB).[47] For this analysis, I converted the continuous air pollution data into quartiles for a categorical analysis.

Statistical Analysis

In the descriptive analysis, I tabulated neighborhood-level characteristics by LQ score or the degree of segregation for Asian neighborhoods. In the regression analysis, I used Poisson regression models with a log offset for the total population in each CT to calculate the incident rate ratios (IRRs) and 95% confidence intervals by non-segregated and segregated neighborhoods. I conducted an initial bivariate analysis to assess the primary relationship between asthma ED visit rates and segregation in Asian communities. I operationalized SEP, nativity status, and air pollution as moderators for the primary relationship analyzed. Prior research and social epidemiology theory support the notion that the primary relationship can change depending on the values of these neighborhood characteristics. Furthermore, the unique context and formation of Asian neighborhoods in the US and Walton's typology informed my decision to analyze effect measure modification for each neighborhood characteristic.[37] I assessed effect measure modification for all five neighborhood-level characteristics and found each to have statistically significant relationships ($p < 0.05$). I conducted a subsequent stratified analysis for the neighborhood characteristics: MHI, college educational attainment, nativity, PM2.5, and DPM2.5. All models were adjusted for age (percent of CT population younger than 10 years old and percent of CT population older than 64 years old) and CT density.

Spatial Analysis

Previous research suggests that static measures of segregation, such as the LQ, do not consider spatial relationships within the data and may not fully capture patterns of segregation.[66] Segregated neighborhoods have been known to cluster in the same areas,[66] so I conducted an exploratory spatial analysis for asthma ED visit rates and LQ scores at the CT level to assess for spatial characteristics in the data. I used the spdep package in R for all spatial statistics and plots, and I used the default parameters set by Bivand et al. in the creation of the package.[67] I utilized a queen's contiguity matrix to define CTs with shared borders as neighbors. I calculated two separate univariate Global Moran I statistics to assess for spatial autocorrelation, or overall spatial clustering among neighborhoods, with one statistic for asthma ED visit rates and another for LQ scores. Global Moran I statistics range from -1 to 1, with 1 indicating the strongest

clustering, 0 indicating spatial randomness, and -1 indicating total dispersion of data. Next, I conducted a Local Indicators of Spatial Association (LISA) analysis, or Local Moran I, for asthma ED visit rates and LQ scores. The LISA analysis decomposes the Global Moran I to identify specific neighborhoods that experience spatial clustering of high asthma ED visit rates and/or Asian segregation, as well as those that experience low asthma ED visit rates and/or Asian segregation.[68] Scatterplots and choropleth maps were generated with the R packages ggplot, basemapR, ggspatial, and ggpattern to visualize the LISA analysis results and to observe qualitative associations between segregation and asthma ED visit rates among Asian segregated neighborhoods.

Results

Descriptive Analyses

There were 7,300 neighborhoods included in the study. Approximately 19.8% (n = 1444) of the neighborhoods were identified as segregated for Asian residents, with LQ scores higher than one. Approximately 41.2% (n = 3010) of the neighborhoods had Asian residents proportionate to the MSA Asian population, with LQ scores of one. Approximately 39% (n = 2846) of the neighborhoods had an underrepresented Asian population relative to the greater MSA Asian population, with LQ scores lower than one. Among the Asian segregated neighborhoods, approximately 27% (*n* = 393) had asthma ED visit rates that exceeded the US's average annual asthma ED visit rate of 51.9 per 10,000 people, compared with 41% of the overall study population.[69] For SEP, approximately 17% (*n* = 237) of segregated Asian neighborhoods had an MHI less than $53,000 compared to 25% of the overall population, and approximately 64% (*n* = 923) had a population where less than 33% had a bachelor's degree compared to 71% of the overall population. Approximately 76% (*n* = 1097) of segregated Asian neighborhoods had a population where more than 27% of the residents were born outside of the US, compared to 52% of the overall population. Finally, approximately 28% (*n* = 401) of segregated Asian neighborhoods were exposed to the highest levels of PM2.5 compared to 25% of the overall population, while 25% (*n* = 367) of segregated Asian neighborhoods were exposed to the highest levels of DPM2.5 compared to 25% of the overall population.

Overall, the characteristics of segregated Asian neighborhoods were similar to those of neighborhoods with Asian populations proportionate to the MSA Asian population (Table 1). Residents in segregated Asian neighborhoods and neighborhoods with Asian residents proportionate to the MSA Asian population tended to have lower Asthma ED visit rates, higher MHIs, and slightly higher rates of attaining at least a bachelor's degree. A notable difference was that segregated Asian neighborhoods had a larger proportion of non-US born residents (76%, *n* = 1097) compared to neighborhoods where the Asian resident populations were either equivalent to the MSA Asian population (48%, *n* = 1446) or underrepresented (43%, *n* =1233). Neighborhoods with underrepresented Asian populations tended to have lower SEP in terms of MHI and college educational attainment. Finally, the distributions of PM2.5 and DPM2.5 were similar across all types of neighborhoods.

Regression Analyses

Initial Analysis

There was an association between census-tract level segregation and age-adjusted asthma ED visits per 10,000. Segregated Asian neighborhoods had a 25% lower asthma ED visit rate than neighborhoods with an underrepresented Asian population (*IRR 0.75; 95% CI 0.74, 0.75)*) in fully adjusted models. Residents of neighborhoods with Asian populations proportionate to their MSAs had a 12% lower asthma ED visit rate compared to neighborhoods with an underrepresented Asian population (*IRR 0.88; 95% CI 0.87, 0.88)*).

Stratified Analyses

Median Household Income

The association between segregation and asthma ED visit rates was modified by MHI (Figure 1). For Asian segregated neighborhoods, there was a 9 to 17% lower rate of asthma ED visits across all levels of MHI compared to neighborhoods with underrepresented Asian populations. The association was strongest in magnitude among neighborhoods with an MHI of $53,000 to $74,500 (*IRR 0.83; 95% CI 0.82, 0.85)* and weakest in magnitude among neighborhoods with an MHI level of $74,500 to $102,500 *(IRR 0.91; 95% CI 0.90, 0.93)*.

There were mixed associations comparing asthma ED visit rates between neighborhoods with Asian populations proportional to their MSAs and neighborhoods with an underrepresented Asian population, with a lower rate among neighborhoods with an MHI of $53,000 to $74,500 (*IRR 0.90; 95% CI 0.88, 0.91*) and MHI greater than $102,000 (*IRR 0.97; 95% CI 0.95, 0.99*) and a higher rate among neighborhoods with an MHI of $74,500 to $102,000 (*IRR 1.04; 95% CI 1.02, 1.06*). There was no association between asthma ED visit rates and neighborhoods with Asian populations proportional to their MSAs among neighborhoods with an MHI less than $53,000.

Educational Attainment

The association between segregation and asthma ED visits was modified by college educational attainment (Figure 1). For Asian segregated neighborhoods, there was a 14 to 20% lower rate of asthma ED visits regardless of educational attainment compared to neighborhoods with underrepresented Asian populations. The association was strongest in magnitude among neighborhoods with less than 33% of residents with a bachelor's degree (*IRR 0.80; 95% CI 0.79, 0.81*). The association was still protective among neighborhoods with 33% or more of residents with a bachelor's degree or higher (*IRR 0.86; 95% CI 0.84, 0.88*).

There were mixed associations comparing asthma ED visit rates between neighborhoods with Asian populations proportional to their MSAs and neighborhoods with an underrepresented Asian population, with a lower rate among neighborhoods with less than 33% of residents with a bachelor's degree (*IRR 0.90; 95% CI 0.90, 0.91*). There was no association between asthma ED visit rates and neighborhoods with Asian populations proportional to their MSAs among neighborhoods with 33% or more of residents with a bachelor's degree.

Nativity

The association between segregation and asthma ED visits was modified by nativity (Figure 1). For Asian segregated neighborhoods, there was a 23 to 32% lower rate of asthma ED visits across levels of neighborhood immigration compared to neighborhoods with underrepresented Asian populations. The association was strongest in magnitude among neighborhoods, with 27% or more of residents born outside of the US (*IRR 0.68; 95% CI 0.67, 0.69*). The association was still protective among neighborhoods with less than 27% of residents born outside of the US (*IRR 0.77; 95% CI 0.75, 0.78*).

For neighborhoods with Asian populations proportional to their MSAs, the associations are similar in magnitude and direction across levels of neighborhood immigration compared to neighborhoods with underrepresented Asian populations. Neighborhoods with 27% or more of residents born outside of the US had a 15% lower asthma ED visit rate (*IRR 0.85; 95% CI 0.85, 0.87*). Similarly, neighborhoods with less than 27% of residents born outside of the US had a 14% lower asthma ED visit rate (*IRR 0.86; 95% CI 0.85, 0.87*).

PM2.5

The association between segregation and asthma ED visit rates was modified by PM2.5 (Figure 2). For Asian segregated neighborhoods, there was an 11 to 31% lower rate of asthma ED visits across all levels of PM2.5 compared to neighborhoods with underrepresented Asian populations. The association was strongest and similar in magnitude among neighborhoods with 3.94 to 8.63 $\mu g/m^3$ (Q1) of PM2.5 (*IRR 0.69; 95% CI 0.68, 0.71*), neighborhoods with 10.43 to 11.96 $\mu g/m^3$ (Q3) of PM2.5 (*IRR 0.70; 95% CI 0.68, 0.71*), and neighborhoods with 11.96 to 16.39 $\mu g/m^3$ (Q4) of PM2.5 (IRR 0.69; 95% CI 0.67, 0.70). The association was also protective for neighborhoods with 8.63 to 10.43 $\mu g/m^3$ (Q2) of PM2.5 (*IRR 0.89; 95% CI 0.88, 0.91*).

For neighborhoods with Asian populations proportional to their MSAs, the associations are protective, yet highly variable and range from a 5% to 25% lower rate of asthma ED visits compared to neighborhoods with underrepresented Asian populations. The association was strongest in magnitude among neighborhoods with 3.94 to 8.63 $\mu g/m^3$ (Q1) of PM2.5 (*IRR 0.75; 95% CI 0.75, 0.77*). The association was moderate in magnitude among neighborhoods with 11.96 to 16.39 $\mu g/m^3$ (Q4) of PM2.5 (*IRR 0.85; 95% CI 0.84, 0.86*). The association was minimal, yet similar in magnitude among neighborhoods with 8.63 to 10.43 $\mu g/m^3$ (Q2) of PM2.5 (*IRR 0.95; 95% CI 0.94, 0.97*) and neighborhoods with 10.43 to 11.96 $\mu g/m^3$ (Q3) of PM2.5 (*IRR 0.92; 95% CI 0.91, 0.93*).

DPM2.5

The association between segregation and asthma ED visit rates was modified by DPM2.5 (Figure 2). For Asian segregated neighborhoods, there was a 19 to 30% lower rate of asthma ED visits across all levels of DPM2.5 compared to neighborhoods with underrepresented Asian populations. The associations are stronger in magnitude with increasing levels of DPM2.5 with the strongest association found among neighborhoods with 0.30 to 14.61 tons/year (Q4) of DPM2.5. Neighborhoods with 0.15 to 0.30 tons/year (Q3) of DPM2.5 and 0.07 to 0.15 (Q2) tons/year of DPM2.5 had associations of similar magnitude (*IRR 0.73; 95% CI 0.71, 0.74* and

IRR 0.74; 95% CI 0.73, 0.75, respectively). The association was still protective among neighborhoods with 0.00 to 0.07 tons/year (Q1) of DPM25 (*IRR 0.81; 95% CI 0.79, 0.835*).

For neighborhoods with Asian populations proportional to their MSAs, the associations are protective, weaker in magnitude with increasing levels of DPM2.5 ranging from a 10% to 15% lower rate of asthma ED visits compared to neighborhoods with underrepresented Asian populations. The associations were similar in magnitude among neighborhoods with 0.00 to 0.07 tons/year (Q1) of DPM2.5 (*IRR 0.86; 95% CI 0.85, 0.87*); neighborhoods with 0.07 to 0.15 (Q2) tons/year of DPM2.5 (*IRR 0.85; 95% CI 0.83, 0.86*); and neighborhoods with 0.15 to 0.30 tons/year (Q3) of DPM2.5 (*IRR 0.87; 95% CI 0.86, 0.88*). The associations are weakest in magnitude among neighborhoods with 0.30 to 14.61 tons/year (Q4) of DPM2.5 (*IRR 0.90; 95% CI 0.89, 0.91*).

Spatial Analysis

The exploratory spatial analysis on asthma ED visit rates revealed statistically significant, strong clustering of neighborhoods with high asthma ED visit rates with a Global Moran I statistic of 0.83 ($p < 0.05$). The analysis for LQ scores showed statistically significant, moderate clustering of segregated Asian neighborhoods with a Global Moran I statistic of 0.68 ($p < 0.05$).

The LISA analysis for asthma ED visit rates identified 1,031 neighborhoods with statistically significant relationships between location and high asthma ED visit rates. The LISA scatterplot for asthma ED visit rates (Figure 3) depicts neighborhoods from “high-high” spatial clusters in the top-right quadrant. These neighborhoods, represented in dark red, have high asthma ED visit rates and have surrounding neighborhoods with high asthma ED visit rates. The bottom-left quadrant represents “low-low” spatial clusters. These neighborhoods, represented in dark blue, have low asthma ED visit rates and have surrounding neighborhoods with low asthma ED visit rates. The top-left and bottom-right quadrants contain spatial outliers, where asthma ED visit rates are dissimilar from their neighbors. Statistically significant neighborhood clusters are displayed in colors ($p \leq 0.05$), while non-significant values are white.

The LISA analysis for LQ scores identified 881 neighborhoods with statistically significant relationships between neighborhood location and Asian segregated neighborhoods. The LISA scatterplot for LQ scores (Figure 4) depicts neighborhoods from “high-high” spatial clusters in the top-right quadrant. These neighborhoods, represented in dark red, have high LQ scores, or Asian segregation, and have surrounding neighborhoods with high LQ scores. The bottom-left quadrant represents “low-low” spatial clusters. These neighborhoods, represented in dark blue, have low LQ scores, or underrepresented neighborhoods, and have surrounding neighborhoods with low LQ scores. The top-left and bottom-right quadrants contain spatial outliers, where LQ scores are dissimilar from their neighbors. Statistically significant neighborhood clusters are displayed in colors ($p \leq 0.05$), while non-significant values are white.

The LISA analysis results revealed 58 neighborhoods in CA that have a spatial relationship between location, high asthma ED visit rates, and high Asian segregation, which warrant future investigation beyond this ecologic study (Table 2). The map of Sacramento County (Figure 5) depicts clusters of neighborhoods with similar asthma ED visit rates. Neighborhoods with high asthma ED visit rates are dark red, while neighborhoods with low

asthma ED visit rates are dark blue. Sacramento County has the highest number of Asian segregated neighborhoods that also have high asthma ED visit rates. These neighborhoods are green with a red outline. The maps of San Diego County (Figure 6) depict clusters of neighborhoods with similar levels of Asian segregation. Asian segregated neighborhoods are dark red, while neighborhoods with underrepresented Asian populations are dark blue. San Diego County notably has the highest number of Asian segregated neighborhoods with low asthma ED visit rates, and yet, there are Asian segregated neighborhoods with high asthma ED visit rates within the same county for a future comparison study. The Asian segregated neighborhoods with low asthma ED visit rates are yellow with red outlines. The Asian segregated neighborhoods with high asthma ED visit rates are green with red outlines.

Discussion

General

The results of this analysis show that Asian segregated neighborhoods have the lowest rates of asthma ED visits, while neighborhoods with an underrepresented Asian population have the highest rates of asthma ED visits. However, it is notable for future research that the magnitude of the protective effects for Asian segregated neighborhoods varied depending on neighborhood characteristics. I found that neighborhood SEP and neighborhood composition of non-US born residents modified the relationship where Asian segregated neighborhoods were more protective against asthma ED visits. In terms of neighborhood exposure to air pollution, the protective association with segregated Asian neighborhoods was generally present across all levels of PM2.5 and, notably, increased in magnitude with increasing levels of DPM2.5. These results highlight potential health-protective aspects of living in high-density co-ethnic neighborhoods that may have health-promoting features that protect against asthma ED visits.

This study contributes to the comparatively small but growing public health literature that focuses on segregation and its impacts on the health of Asian people. As previously discussed, there are inconsistencies on whether living in Asian segregated neighborhoods can positively impact health; however, research indicates that segregation may be protective against asthma and other health outcomes. For example, a study by Lee et al. examined asthma prevalence among predominantly Asian children at an elementary school in Boston, Massachusetts' Chinatown.[70] They found that children who lived in Boston's Chinatown were less likely to be diagnosed with asthma when compared to children who lived in all other neighborhoods (*Relative Risk 0.59; 95% CI 0.39, 0.90; $\chi 2$ 6.22, $p = 0.012$*).[70] For other health outcomes, Walton utilized a typology of Asian neighborhoods to assess the relationship between Asian segregation and self-reported health in CA, and she found that Asian people were most likely to report their health as "good" in a segregated neighborhood if the neighborhood had an MHI greater than or equal to $60,000.[37] Yang et al. found that living in a segregated neighborhood had protective effects because Asian women were less likely to smoke during pregnancy when they lived in neighborhoods with Asian people (*probability of smoking decreased from 0.452 to 0.218*).[36] Similarly, Lim et al. found that living in an Asian segregated neighborhood had a small positive effect on reporting good health (*Prevalence Ratio 1.06, 95% CI 0.98, 1.15*), but concluded that the protective effect did not apply to hypertension and diabetes.[35]

While there is evidence that Asian segregated neighborhoods can be protective for the health outcomes of Asian people, studies have still found conflicting or heterogeneous results. For example, the findings of this study and Lee et al.'s contrast those in a study by Brewer et al., which found that Asian children in Houston, Texas have a higher odds of receiving an asthma diagnosis when they live in Asian segregated neighborhoods.[23,70] In terms of other health outcomes, Walton's findings on the protective effect of segregation on self-reported health only apply to Chinese and Korean people when compared to Filipino and Vietnamese people.[37] Inconsistencies in segregation and health research may drive these heterogeneous findings for Asian populations. Acevedo-Garcia et al.'s review on segregation and health described a lack of cross-comparable, robust methods for segregation measurement, as well as too few studies that include Asian people in their study samples.[45] For example, this study utilized the location quotient to measure segregation, Lee et al. did not measure segregation,[70] and Brewer et al. used percentages of each racial/ethnic category.[23] Additionally, Lee et al. and Brewer et al. only used children in their study samples, [23,70] so the findings cannot be directly compared to this study. Acevedo-Garcia et al. suggest that future research on the impacts of segregation on health outcomes should utilize theory-driven and empirically-tested methods to better understand the protective effects from and drivers of health inequities among Asian people.[45]

Although individual health data was not used in this analysis, the overall results also align with public health literature that cites the Ethnic Density Effect (EDE) as a health protective aspect of segregation for minority and immigrant groups. The EDE theorizes that segregation buffers the detrimental health impacts of racism because 1) people are less likely to internalize interpersonal racism when they live among people from the same racial/ethnic group and 2) people create community when they share experiences of racial discrimination with others from the same racial/ethnic group.[71] As such, the social support and networks facilitated by segregation may provide both tangible and intangible health protective resources for people who live in Asian segregated neighborhoods.[71] Research on the drivers of asthma inequities suggests that racial discrimination contributes to chronic and toxic stress, which can trigger asthma morbidity.[72] Thus, with the EDE, segregation may reduce chronic and toxic stress that would otherwise increase asthma morbidity or asthma ED visits.

Socioeconomic Position: Median Household Income and Educational Attainment

I also found that MHI modified the relationship between segregation and asthma ER visits and had a protective effect, with segregation being slightly more protective for neighborhoods with MHIs of $74,500 or less compared to underrepresented neighborhoods. Educational attainment also modified the relationship, with segregation being more protective for neighborhoods where less than 33% of the residents had a Bachelor's degree compared to underrepresented neighborhoods. Both neighborhood characteristics were proxies for SEP, which provides flexible resources that can help residents attain better health.

These findings suggest that segregated Asian neighborhoods have health-protective qualities that standard measures of SEP may not capture. For instance, this study revealed that Asian segregated neighborhoods with the lowest MHIs and less college educational attainment were slightly more protective against asthma ED visits compared to underrepresented Asian neighborhoods. One potential explanation could be due to differences in access to health care

services. A recent study by Guan et al. found that people who live in Asian segregated neighborhoods had overall greater access to primary care health services (*adjusted Prevalence Ratio 1.23; 95% CI 1.17, 1.29*) when compared to non-segregated neighborhoods, although segregated neighborhoods in their study tended to have less poverty.[73] Greater access to health care could improve asthma morbidity, thereby reducing asthma ED visits. Notably, Carreon and Baumeister found heterogeneous results among Asian subgroups when they examined the effect of segregation on health care access among Chinese, Filipino, Korean, Vietnamese, and other Asian people. In comparison to Chinese, Filipino, and Vietnamese people, Korean (*Log Odds Ratio 0.05; 95% CI 0.01, 0.09*) and other Asian people (*Log Odds Ratio 0.05; 95% CI 0.02, 0.09*) had a higher probability of obtaining an annual medical exam when they resided in segregated neighborhoods.[57] The authors suggest that linguistically and culturally appropriate health care services may be more readily available in Asian neighborhoods with a specific ethnic density.[57] Future research may benefit from considering community resources that help Asian people with lower SEP to attain better health outcomes, such as the availability of linguistically and culturally appropriate health care services.

Nativity

Nativity modified the relationship between segregation and asthma ER visits, with segregation being most protective in neighborhoods where 27% or more of the population was non-US born. This finding is consistent with public health literature that reports an immigrant health paradox for asthma outcomes among Asian people. Huh et al. examined the impact of nativity on chronic diseases.[59] They found that non-US born Asian people were 41.8% less likely to have asthma (*Relative Risk Ratio 0.582, $p < 0.005$*) and co-morbid asthma (*Relative Risk Ratio 0.522, $p < 0.01$*) when compared to US born white people, while US born Asian people had asthma prevalence rates that did not significantly differ.[59] Furthermore, non-US born Asian people were less likely to have asthma (*$p < 0.005$*) and co-morbid asthma (*$p < 0.01$*) when compared to their US born counterparts.[59]

Carlisle also reported that non-US born Asians people were -0.65 times less likely to report having respiratory diseases, including asthma, when compared to their US born counterparts (*b -0.65, $p \leq 0.000$*).[74] Iqbal et al. found similar results in their study where non-US born Chinese adults had significantly lower prevalence of current asthma (*3.0%, $p<0.05$*) when compared to their US born counterparts (*8.1%, $p <0.05$*).[75] Notably, this significant pattern was not observed for Asian children or Asian Indian, Filipino, or other Asian adults in their study.[75] This difference in findings among people from different subgroups suggests that future asthma research should use data disaggregated by ethnicity to better understand heterogeneity in asthma outcomes among non-US born Asian people.

Air Pollution: PM2.5 and DPM2.5

Both air pollution measures modified the association between segregation and asthma ED visits. Segregation was generally protective across all quartiles of PM2.5 and DPM2.5, with a notable slight protective gradient for DPM2.5, where asthma ED visit rates were lower as levels of DPM2.5 increased. Literature on the impact of particulate matter on asthma and other health

outcomes in segregated Asian neighborhoods is extremely limited despite evidence that Asian people experience disproportionate exposure to air pollution (previously discussed).

Brewer et al. examined the effects of neighborhood social and environmental characteristics on racial/ethnic disparities in childhood asthma diagnoses.[23] They measured segregation at the census tract level with co-ethnic density.[23] Their findings suggest that living in increasingly co-ethnic neighborhoods was associated with an increased probability of asthma diagnosis for Black and Asian children (*Odds Ratio 2.01; 95% CI 1.46, 2.76* and *Odds Ratio 3.26; 95% CI 1.32, 8.04*, respectively).[23] They also found that living in increasingly co-ethnic neighborhoods was associated with increasing levels of PM2.5 exposure for Black and Hispanic children.[23] However, there were no significant associations between exposure to PM2.5 and asthma risk.[23] This study's general findings regarding the relationship between asthma and PM2.5 exposure are inconsistent with those of Brewer et al.'s study. There are notable differences between the studies that may have contributed to differing results, including different measures for segregation (location quotient versus percent) and different asthma outcomes (ED visit rates versus risk). The heterogeneity in the generalized results suggests the need for future studies to consider utilizing consistent or multiple measures of segregation and asthma for comparable findings.

In a study unrelated to asthma, Williams et al. examined the joint effects of segregation and air pollution exposure on the risk of gestational diabetes mellitus (GDM) among Asian and Pacific Islander (API) women.[76] They measured segregation at the ZIP code level by identifying areas in the upper third of the distribution for API density, the dissimilarity index for API-white people, and the isolation index for API people.[76] Their study cannot be directly compared to this one because their health outcome was GDM and their measures for air pollution were 14 volatile organic compounds (VOCs).[76] While they did not include PM2.5 or DPM2.5 in their study, the results of the study are noteworthy.[76] Their findings suggest that living in an Asian segregated neighborhood is associated with a lower risk of GDM, regardless of air pollution levels.[76] For example, Asian women who had preconception exposure to high benzene levels in Asian segregated neighborhoods had their risk for GDM mitigated by segregation (*Odds Ratio 2.07; 95% CI 1.09, 3.94*) when compared to women who lived in non-segregated neighborhoods with low benzene levels (*Odds Ratio 2.85; 95% CI 1.57, 5.17*) and high benzene levels (*Odds Ratio 3.45; 95% CI 1.77, 6.72*).[76] As such, the overall protective effect of segregation in Williams et al.'s study indicates the need to further explore the mechanisms that facilitate the potential health-protective aspects of segregation for Asian people. Future studies can also benefit from comparing the impacts of different air pollutants on the relationship between Asian segregation and asthma.

Spatial Analysis

This study's spatial analysis of asthma ED visit rates had results that were consistent with previous studies on the spatial patterns of asthma morbidity.[24–28] The Global Moran I revealed a strong clustering of neighborhoods with high asthma ED visit rates in CA. Previous research has highlighted that neighborhoods with high asthma morbidity tend to cluster next to each other and share common characteristics of structural racism and disadvantage, such as neighborhood histories of segregation for Black residents,[25–27] high exposure to air pollution,[24,25] and SEP.[24,28]

The exploratory spatial analysis findings for Asian segregation levels also align with previous research on where Asian people live in CA.[37] The Global Moran I revealed moderate clustering of Asian segregated neighborhoods. Previous studies have shown that Asian people in the US tend to live among other Asian people, and Walton's study utilized Moran's I to create a typology of Asian segregated neighborhoods in CA.[37]

The results of the LISA analysis are beneficial for future, more detailed studies on the relationship between Asian segregation and asthma ED visits. I identified Asian segregated neighborhoods in CA that experience high asthma ED visit rates, as well as those that are segregated but experience low asthma ED visit rates. For example, Sacramento has the largest number of Asian segregated neighborhoods with high asthma ED visit rates (*n = 25*) (Figure 5), while San Diego is the only county that has substantial contrasting clusters of Asian segregated neighborhoods, some with high asthma ED visit rates (*n = 6*) and others with low asthma ED visit rates (*n = 49*) (Figure 6)(Table 2). Subsequent research on the structural drivers of asthma inequities among Asian people can examine these areas for historical and social context that may not be captured in quantitative analyses, particularly those that are done at the ecological level. Finally, studies with individual-level data that is disaggregated by Asian subgroups can ascertain where Filipino and Japanese people tend to live and how their neighborhood characteristics may contribute to their disproportionate asthma burden.

Study Strengths and Limitations

The primary strength of this study is that it is an ecological examination of the relationship between asthma ED visit rates and segregation for Asian people. It is the first study that I am aware of that assesses the relationship between Asian segregation and asthma ER visit rates. I also contribute to the growing literature on segregation and health that moves beyond using CT composition (percent race/ethnicity) to measure segregation. Here, I utilize the location quotient as a more robust measurement of segregation at the CT level.

This analysis has several limitations. First, it is an ecological study that does not utilize individual-level data on who experienced asthma ED visits within each neighborhood. It is possible that those who are experiencing asthma morbidity, as proxied by asthma ED visits, may not be Asian. Known as the "ecological fallacy," this methodological issue occurs when inferences are drawn about individual-level associations based on a group-level analysis.[77] There is a mismatch between the unit of analysis (CTs for this study) and the level of inference drawn (inaccurate associations for asthma among Asian people). One can only draw inferences about the level of Asian segregation in neighborhoods as they relate to neighborhood-level asthma ED visit rates. Therefore, it is possible that the Asian people who experience high rates of asthma ED visits live in neighborhoods where Asian people are underrepresented, which may be segregated for another racial/ethnic group (previously discussed in the background). In order to draw direct inferences regarding Asian people who experience asthma and the segregation level of their neighborhoods, a future study would need to include individual-level health data and confounders.[77]

In addition to ED visits, asthma morbidity manifests in a variety of ways, including primary care provider visits, missed days of work/school, and high medication usage.[1] It is

possible that these other indicators of uncontrolled asthma may better reflect morbidity in some populations but not others. As previously discussed, Asian segregated neighborhoods have been found to have cultural resources that may proffer health-protective benefits to their residents. This study did not incorporate any variables that might have captured this effect, such as proximity to community health centers. Finally, this study also explored the generalized influence of neighborhood characteristics on the relationship between asthma ED Visit Rates and Asian segregated neighborhoods. More precise analyses with disaggregated, individual-level data are needed to understand the drivers of asthma inequities among Asian subgroups, particularly Filipino and Japanese people.

Conclusion

In this study, I found associations between Asian segregation and asthma ED visit rates in CA. The results suggest that living in Asian segregated neighborhoods is protective against asthma ED visits compared to living in neighborhoods where the Asian population is underrepresented or equivalent to the greater MSA. The magnitude of protection varies by neighborhood characteristics such as median household income, college educational attainment, the composition of non-US born residents, and diesel PM2.5, with the composition of non-US born residents having the strongest protective effect. Although racial/ethnic segregation has been associated with health inequities for minority racial/ethnic groups, this ecological-level study found contradicting results for Asian segregated neighborhoods, which had overall lower asthma ED visit rates compared to neighborhoods with underrepresented Asian populations. Future research on the relationship between Asian segregation and asthma outcomes should include individual-level asthma data that is disaggregated by Asian subgroups to disentangle associations that group-level data may obscure. Furthermore, researchers should consider future analyses that utilize robust methods for measuring segregation beyond composition, study populations with multiple age groups, more detailed proxy measures for SEP, and different types of air pollutants.

Tables and Figures

Table 1. Descriptive Statistics for Asian Neighborhoods by Segregation Status and Neighborhood Characteristics, California, 2015-2019

Characteristics			Degree of Segregation as Measured by Location Quotient[1]		
		% Overall Population *n* = 7300	% Underrepresented *n* = 2846	% Equivalent to MSA *n* = 3010	% Segregated *n* = 1444
Asthma ER Visit Rate[2]	≤ 52 visits	59	49	62	73
	> 52 visits	41	51	38	27
Median Household Income	≤ $53,000	25	37	18	17
	$53,000 - $74,500	25	27	25	21
	$74,500 - $102,500	25	20	28	28
	> $102,500	25	16	29	34
Education Attainment	< 33% Bachelor's Degree	71	79	67	64
	≥ 33% Bachelor's Degree	29	21	33	36
Nativity[3]	< 27% Non-US Born	48	57	52	24
	≥27% Non-US Born	52	43	48	76
PM2.5 ($\mu g/m^3$)	3.94 - 8.63	25	27	25	21
	8.63 - 10.43	25	24	27	24
	10.43 - 11.96	25	22	26	27
	11.96 - 16.39	25	27	22	28
Diesel PM2.5 (Tons, Year)	0.00 - 0.07	25	24	19	20
	0.07 - 0.15	25	26	26	28
	0.15 - 0.30	25	25	29	27
	0.30 - 14.61	25	25	26	25

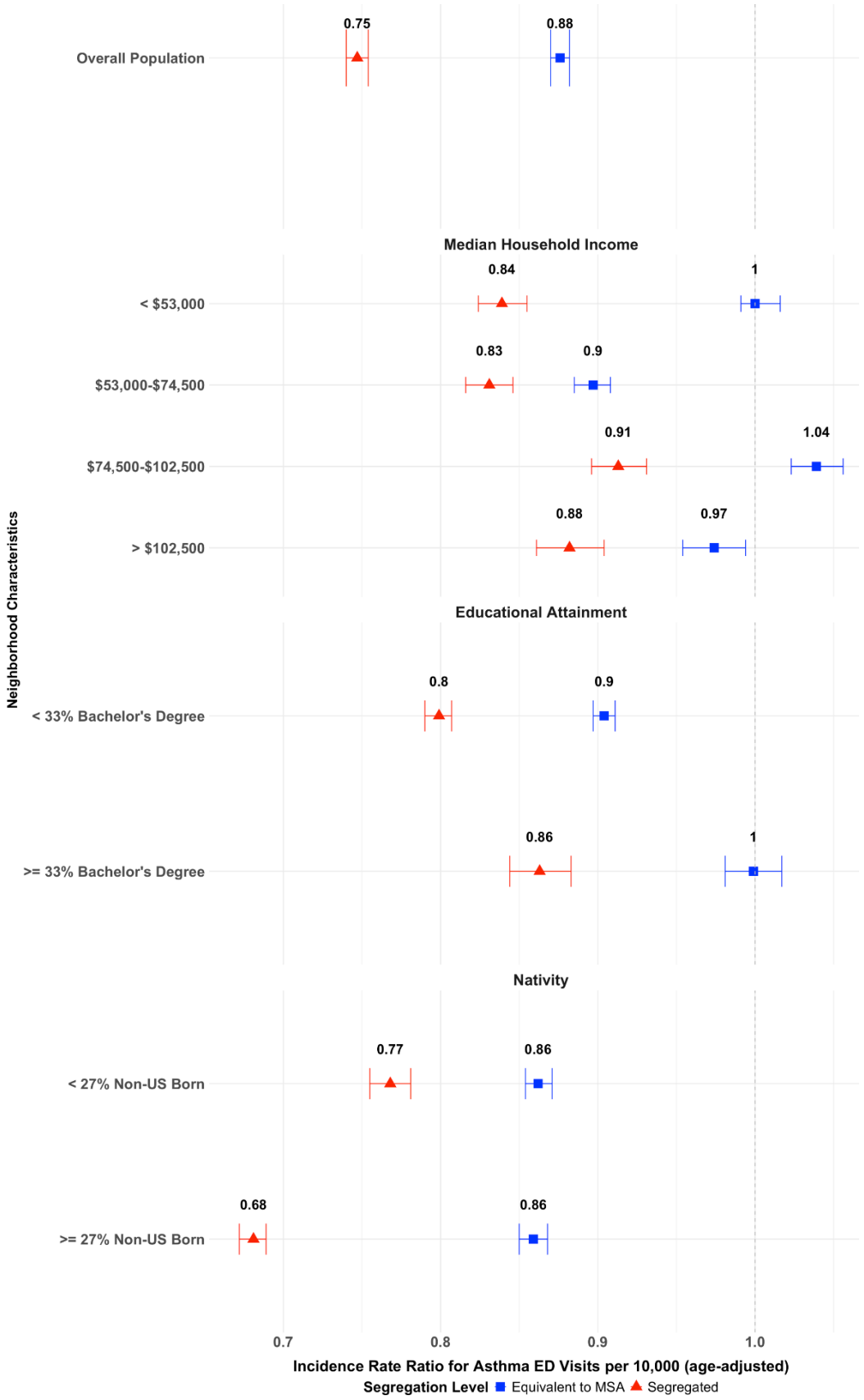
Distribution by segregation level is displayed by column percentage.
Data: 5-year ACS, US Census Bureau (2015-2019); CalEnviroScreen4.0 (2015-2017)
1 Location Quotient: $LQ_{im} = (x_{im}/X_i) / (X_m/X)$; An LQ score < 1 indicates under-representation in the neighborhood relative to the metropolitan statistical area (MSA), while an LQ score = 1 indicates a representative neighborhood and > 1 indicates segregation.
2 Asthma emergency room (ER) visit rate: age-adjusted per 10,000 people, 2019; The average annual asthma ER visit rate in the US was 51.9 (2016-2018).[1]
3 The 2015 to 2019 ACS estimate for CA's foreign-born population was 27%.

Table 2. Selected Counties with Asian Segregated Neighborhoods by High versus Low Age-adjusted Asthma ED Visit Rates,[1] California, 2015-2019

County	**Neighborhoods with High Asthma ED Visit Rates (*n*)**	**Neighborhoods with Low Asthma ED Visit Rates (*n*)**
Alameda	1	6
Contra Costa	-	3
Fresno	12	1
Los Angeles	2	50
Monterey	-	1
Orange	-	34
Riverside	-	2
Sacramento	25	-
San Bernardino	-	12
San Diego	6	49
San Francisco	3	6
San Mateo	-	4
San Joaquin	2	-
Santa Clara	-	20
Solano	7	-
Ventura	-	4
Yolo	-	2

Data: 5-year ACS, US Census Bureau (2015-2019)
1 Asian segregated neighborhoods classified according to Location Quotient value: $LQ_{im} = (x_{im}/X_i) / (X_m/X)$ and identified with a Local Indicators of Spatial Association (LISA) analysis.

Figure 1. Effect Measure Modification by Neighborhood Characteristics on the Association between Asthma ED Visits and Asian Segregation Level in California, 2015-2019



Sample Sizes:

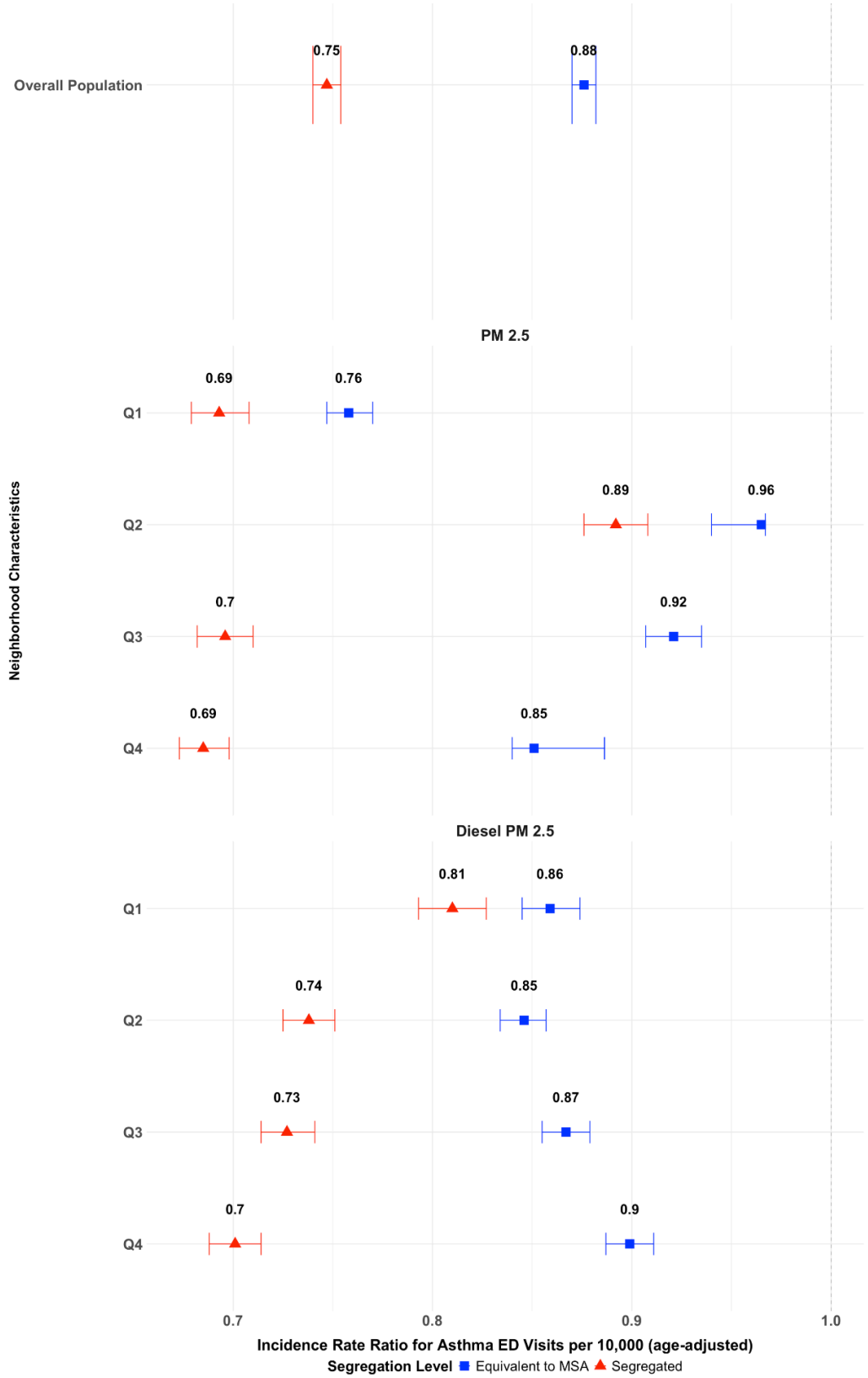
MHI Quartiles
n = 1829 for < $53,000;
n = 1813 for $53,000 - $74,5000;
n = 1829 for $74,500 - $102,500;
n = 1829 for >$102,500

Educational Attainment
n = 5171 for < 33% Bachelor's Degree;
n = 2129 for ≥ 33% Bachelor's Degree

Nativity
n = 3524 for <27% Non-US Born; *n* = 3776 for ≥ 27% Non-US Born

Data:
5-year ACS, US Census Bureau (2015-2019); CalEnviroScreen4.0 (2015-2017)

Figure 2. Effect Measure Modification by Neighborhood Environmental Air Pollution on the Association between Asthma ED Visits and Asian Segregation Level in California, 2015-2019



Sample Sizes

PM 2.5 Quartiles ($\mu g/m^3$)
n = 1815 for 3.94-8.63;
n = 1830 for 8.63-10.43; *n* = 1812 for 10.43-11.96; *n* = 1843 for 11.96 - 16.39

Diesel PM2.5 Quartiles (tons/year)
n = 1558 for 0-0.07;
n = 1938 for 0.07-0.15;
n = 1974 for 0.15 - 0.30;
n = 1830 for 0.30-14.61

Data:
5-year ACS, US Census Bureau (2015-2019); CalEnviroScreen4.0 (2015-2017)

Figure 3. LISA Scatterplot for Age-adjusted Asthma ED Visit Rates, California

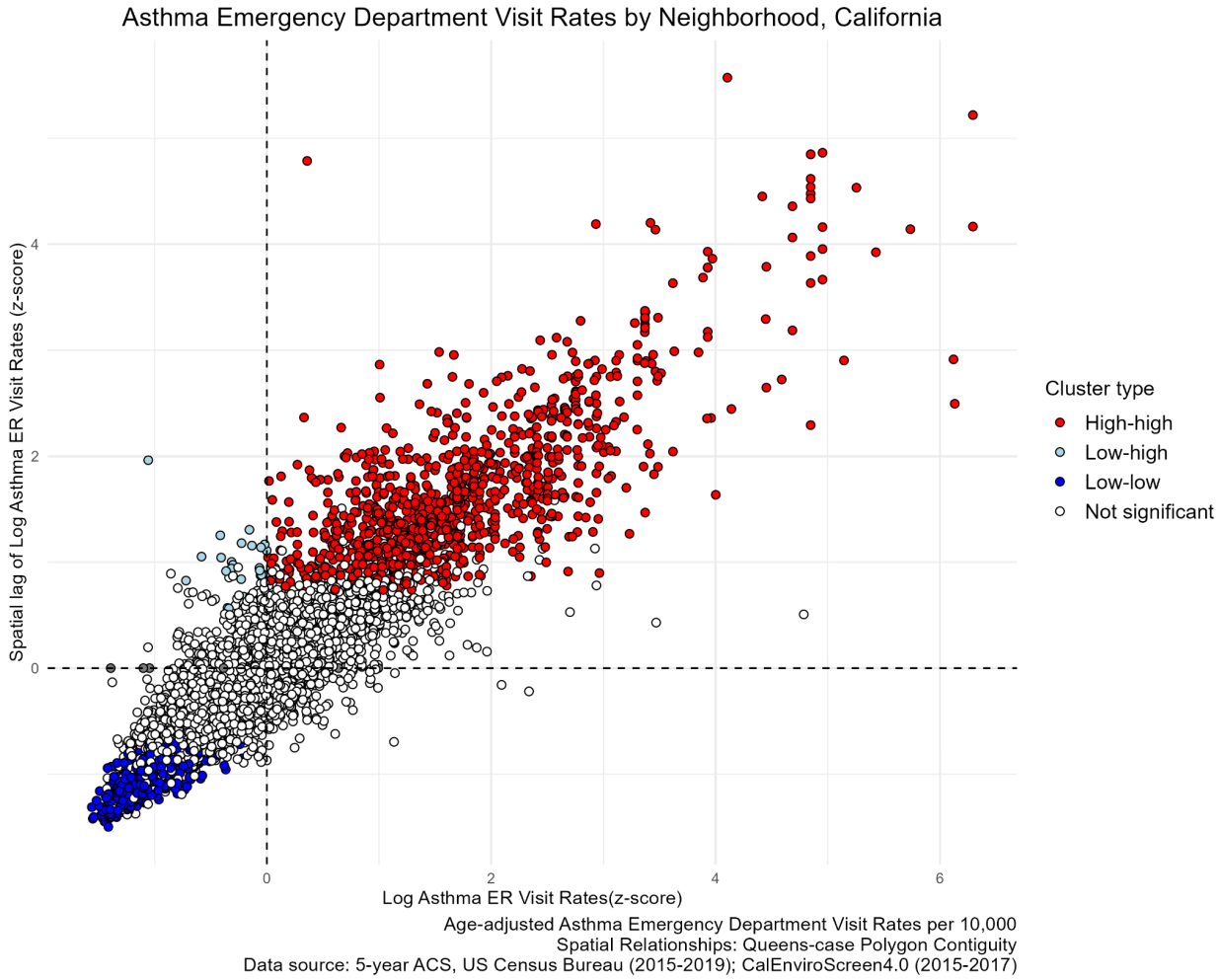


Figure 4. LISA Scatterplot for Asian Segregated Neighborhoods, California

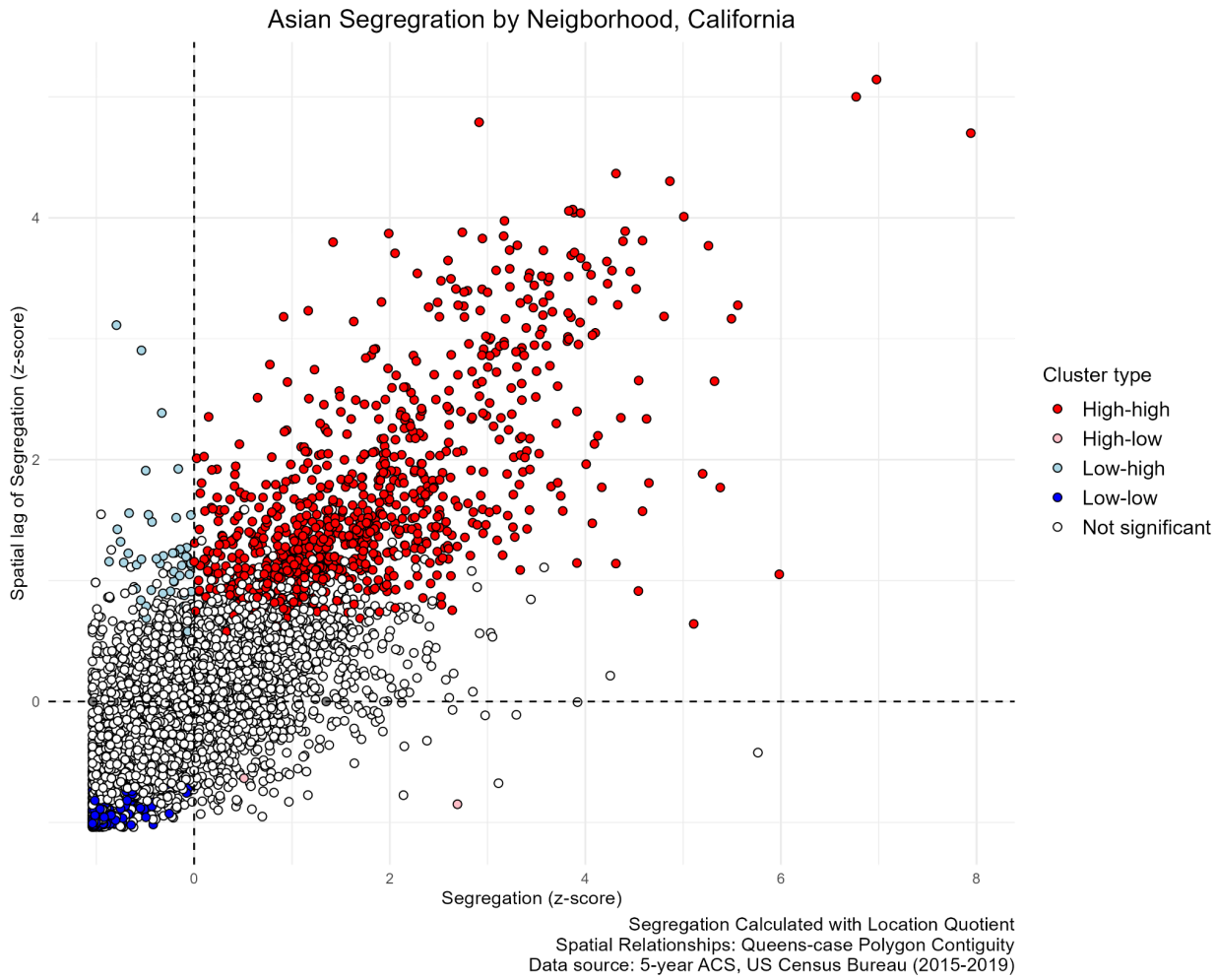


Figure 5. LISA Analysis Map: Neighborhoods for Future Study, Sacramento County, CA

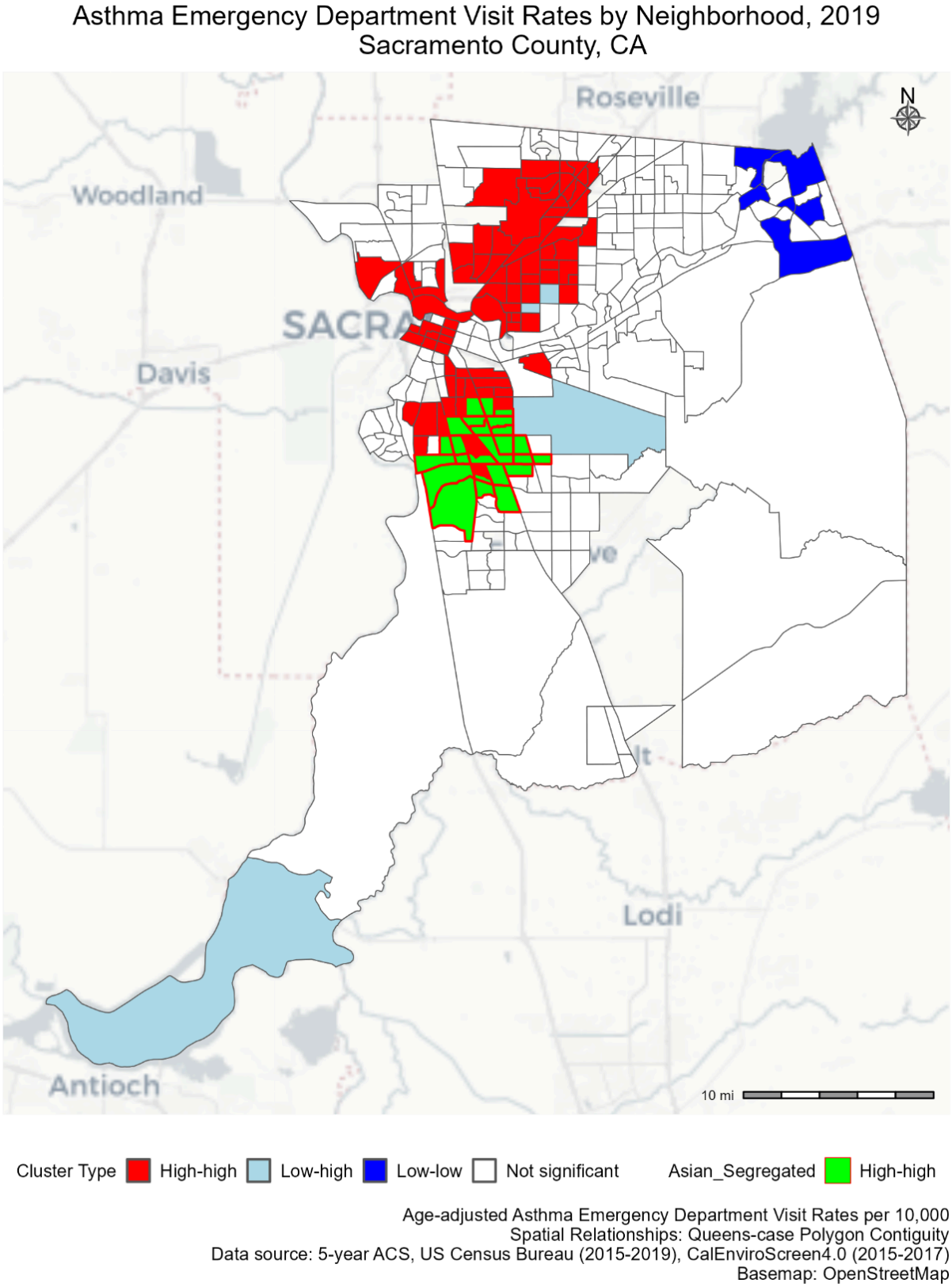
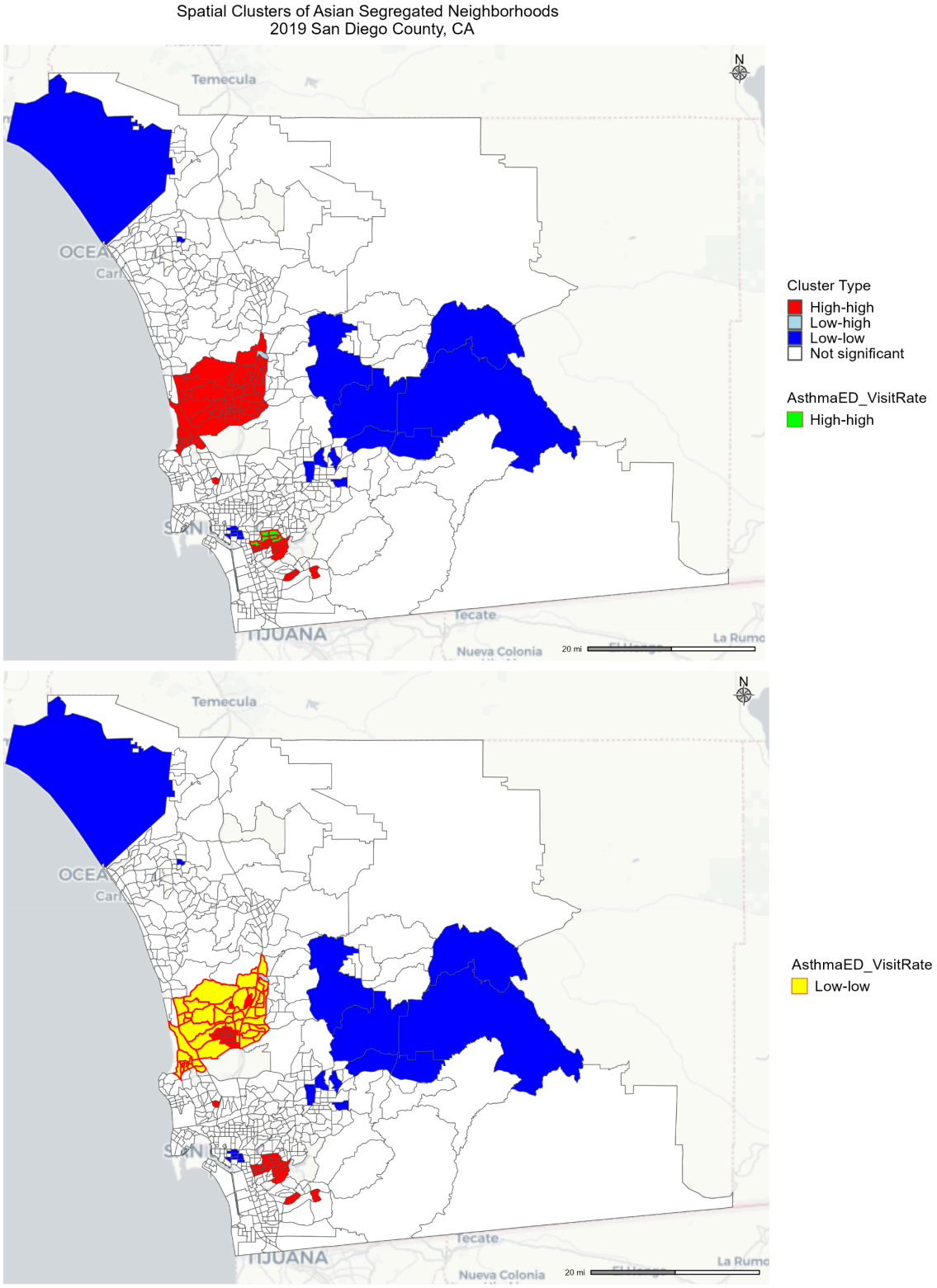


Figure 6. LISA Analysis Map: Neighborhoods for Future Study, San Diego County, CA



Age-adjusted Asthma Emergency Department Visit Rates per 10,000
Spatial Relationships: Queens-case Polygon Contiguity
Data source: 2015-2019 5-year ACS, US Census Bureau (2015-2019), CalEnviroScreen4.0 (2015-2017)
Basemap: OpenStreetMap

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Paper 3. A Narrative Review of Racial Residential Segregation in Asthma Research (2003-2021): Where are the Asian People?

Abstract

Racial residential segregation has been identified as a fundamental cause of health inequities, such as asthma. Ecological studies that examine this relationship often focus on Black populations, and occasionally Latino/Hispanic populations, in comparison to white populations. However, recent health statistics from California suggest that underrepresented subgroups, like Asian populations, could also benefit from inclusion in these studies. This paper uses a narrative review to build upon recommendations from previous reviews on racial residential segregation and assesses the conceptualization, measurement, and examination of how segregation has been utilized in asthma research. It also investigates the extent to which Asian people have been included in such studies. This review of peer-reviewed research (2003-2021) from public health, sociology, and geography reveals that there is a likely relationship between segregation and asthma; however, there is variability in the covariates included in studies, with some including variables like air pollution. Future research should focus on including Asian populations and nativity variables. I discuss the research and practice implications as segregation research shifts and adjusts to population diversification in the United States.

Introduction

Social epidemiological research has identified racial residential segregation (segregation) as a fundamental cause of health inequities in the United States (US).[1] Segregation is defined as "the physical separation of the races in residential contexts,"[1] and functions as a mechanism that prevents some groups from accessing resources that would otherwise benefit their health.[2] Chronic health conditions such as asthma, diabetes, obesity, and cardiovascular disease have been associated with segregation in ecological investigations.[1,3] This research has historically focused on Black populations in comparison to white populations[1,4] because the US's history of Black enslavement and subsequent structural racism against Black people shaped segregation patterns throughout the country, with documentation of this phenomenon dating to at least the 1880s.[5] As a result, Black people in the US have experienced the most extreme degree of segregation, for the longest time, compared to all other racial/ethnic groups.[1,6] Today, there is a need to move beyond these comparisons to understand how structural racism also impacts other racial/ethnic minority groups. This has rendered the need to re-examine the theoretical and empirical approaches to modern segregation research.

Asthma is a chronic health condition that has been associated with segregation, and it has become a severe health problem in the US over the past 35 years.[7] Asthma is a respiratory disease that causes wheezing and difficulty breathing.[8] While medications can control the symptoms, there is no cure for this potentially deadly disease.[8] Prevalence rates have remained between 7.3-8.5% since 2011,[7,9] yet asthma affects nearly 25 million people each year.[10] Asthma is responsible for over $81 billion in health care costs, [11] and it is the cause of missed school, lost work, and has myriad other social implications.[8] People of all ages and backgrounds can have asthma, yet there are significant racial/ethnic and socioeconomic disparities.

At the national level, people of color are more likely to have asthma, with Black, Native American, and multi-racial people having the highest prevalence rates of current asthma (over 10%).[9] These trends in asthma inequities are consistent with state-level data in California (CA) where Black and Native American people have the highest lifetime asthma prevalence rates.[12] With regard to Asian people, the Office of Minority Health (OMH) states that Asian people "...generally have lower rates of asthma than the white population."[13] However, evidence suggests that Asian children experience disproportionate asthma morbidity. The US Centers for Disease Control and Prevention's asthma surveillance program reports that Asian children have the highest prevalence of asthma emergency department visits (27.4%), when compared to all other racial/ethnic groups and all other age groups.[14] Although Asian people do not have elevated current asthma prevalence rates in comparison to other racial/ethnic groups, the statistics for emergency department visits indicate that there may be underlying drivers of an inequity.[7]

Research suggests that there is a general lack of studies that examine structural and ecological drivers for health inequities experienced by Asian people.[4] Advances in public health theory, the development of new methods for segregation analysis,[15,16] and changes in the demographic composition of the US have rendered the need to extend research on the potential structural and ecological drivers of asthma inequities to populations that have been previously underrepresented. Fields of study beyond public health, such as geography and urban planning, have made notable contributions to research on race, residential segregation, and health inequities that may not be captured in public health research.

In this paper, I use the narrative review format to synthesize research from multiple academic disciplines.[17] In the next section, I briefly review the relationship between racial residential segregation and health. I discuss segregation and health research for Asian people and how it may differ from research focused on other racial/ethnic groups. After a description of search methods, I present the findings in two stages. First, I discuss common themes among the articles' research aims and major findings. Next, I describe current trends in 1) segregation conceptualization ("who" is segregated), 2) segregation measurement ("how" is segregation operationalized in different fields of research), and 3) segregation analysis ("what" methods are used to identify or quantify relationships between segregation and asthma). I also assess how and if Asian people were included in the articles. I present directions for future research with an emphasis on segregation conceptualization and measurement. Finally, I discuss implications for public health practice in terms of data collection and theory utilization.

Background

Theoretical Background and Gaps in Research

Research indicates that segregation is a fundamental cause of racial/ethnic health inequities because it prevents residents from accessing resources that would otherwise benefit their health.[1,2] In their seminal work, Williams and Collins identify and describe the mechanisms by which segregation functions as a fundamental cause of health inequities for Black people. First, segregation is associated with numerous health outcomes such as heart disease, tuberculosis, low birthweight, lead poisoning, and asthma.[1] Second, segregation is linked to health outcomes through multiple pathways and upstream risk factors such as educational opportunities, employment opportunities, housing quality, neighborhood violence, and access to

health care.[1] Third, the effects of segregation are reproduced and persist in the same neighborhoods over time. Williams and Collins state that the "divestment of economic resources in these neighborhoods has led to a decline in the urban infrastructure, physical environment, and quality of life in these communities."[1] Finally, segregation prevents access to flexible resources such as quality public school education, economic purchasing power, and political power. The body of evidence in their paper exclusively comes from research on the differences between Black and white neighborhoods; however, Williams and Collins conclude that efforts to reduce racial/ethnic inequities in health must move beyond individual interventions to the inclusion and consideration of socioeconomic conditions and geographic contexts.[1]

Further reviews on segregation and health have found that current research has inconsistencies beyond the conceptualization of who experiences segregation and who suffers health effects from it. Aside from continuing research on the impacts of segregation on the health of Black communities, Acevedo-Garcia et al. make four recommendations for future public health research: (1) the development of multilevel research designs to examine effects of individual, neighborhood, and metropolitan-area factors on health outcomes, (2) the examination of the health effects of segregation among Hispanic/Latino and Asian people, (3) the consideration of income and poverty segregation, and (4) the development of conceptual frameworks that link dimensions of segregation to specific health outcomes.[4] These recommendations seek to incorporate a relational view of place and health that captures the interplay between context (the place) and composition (the people).

Research from the geographical perspective also identifies the need for segregation research to (1) utilize spatial statistics for data that is known to cluster in space over time and (2) extend segregation research beyond neighborhoods of residence.[16] Thus, this review will build upon reviews by both Acevedo-Garcia et al.[4] and Park and Kwan,[16] and I define current literature as being published between 2003 and 2021. This paper will describe how segregation is conceptualized (such as the races/ethnicities examined) and measured (such as utilizing the dissimilarity index). It will then detail how segregation is examined, such as with regression models, multi-level analyses, or geographic information systems (GIS).

Contemporary Shifts in Segregation and Lasting Health Effects

Human migration and integration patterns have changed the nature of US segregation over time, and it has caused the field to grapple with theoretical approaches to research.[18,19] Massey et al. describe a late twentieth-century shift from macro- to micro-level segregation in the US by which Black-white segregation changed from a state- and county-level distribution to a city- and neighborhood-level distribution.[18] They also assert that the immigration of Asian and Hispanic/Latino people increased diversity such that it moderated Black-white segregation.[18] Hwang's research on gentrification supports this notion by describing how Asian and Hispanic/Latino immigrants settled in low-cost areas, including predominantly Black neighborhoods.[20] Hwang notably finds that the influx of Asian and Hispanic/Latino residents in predominantly Black neighborhoods did not lead to substantial financial investment or cultural changes associated with gentrification.[20] Massey et al. ultimately argue that contemporary segregation occurs through the interaction of both race/ethnicity and social class, and it manifests in the form of covert, institutionalized discrimination.[18]

A combined life course and ecological perspective supports the idea that historically segregated Black communities and their residents experience persistent adverse living conditions due to discriminatory development of their physical, social, economic, and service environments.[19,21] For example, predominantly Black ZIP codes have 67% higher odds of primary care physician shortages,[22] as well as limited access to health-related organizations when compared to other races/ethnicities.[23] This low-quality service environment can, therefore, affect all residents of affected areas. As such, there is new evidence to suggest that living in historically segregated Black areas may negatively impact health regardless of race/ethnicity. A recent study by Meeker et al. reports that rates of severe maternal morbidity (SMM) increase for women of all races/ethnicities for every 10% increase in census tract residents who identify as Black.[24] In contrast, SMM rates are lower in median-income census tracts with higher percentages of white or Asian people.[24] A separate study also found that children of all races/ethnicities with low birthweight had a higher incidence of asthma if they lived in a predefined "Black ZIP code" compared to all other ZIP codes.[25] These findings suggest that persistent structural inequities stemming from segregation can impact people of other races and ethnicities, and that additional research is needed to understand the relationship between segregation and health for Asian and Hispanic/Latino people.

Segregation versus Ethnic Enclaves

Asian people in the US have had unique experiences with segregation due to a complex history of immigration and settlement. Two notable examples of national laws that dictated settlement include the Chinese Exclusion Act of 1882, which that prevented Chinese immigrants from entering the country, and President Roosevelt's Executive Order for the Internment of Japanese Americans during World War II, which dispossessed Japanese people of their homes and placed them into concentration camps as a purported national security precaution.[26] Furthermore, the context of immigration by foreign-born Asian people has continued to have substantial social, economic, and political variation among subgroups. For example, US colonization efforts in the Philippines in the 1890s created a long-term labor pipeline by which significant numbers of college-educated Filipino adults immigrated to the US to staff hospitals as nurses.[27] In contrast, other Southeast Asians, including Vietnamese and Cambodian people, came to the US as war refugees in significant numbers starting in the 1970s.[26] Despite these significant events and a fast-growing Asian population, there are comparatively few robust studies examining the impacts of segregation on Asian health.[4]

Cummins et al. caution that health research on neighborhoods with high ethnic density may be prone to the pitfall of examining composition (the people) versus context (the place) rather than focusing on how the interplay between both can result in differential health outcomes.[28] These neighborhoods have also been referred to as ethnic enclaves or "geographical area[s] where a particular ethnic group is spatially clustered and socially and economically distinct from the majority group."[29] While the definition is similar to that of segregation, this research perspective and terminology suggest that ethnic enclaves are qualitatively different beyond compositional attributes, such as having large populations of foreign-born residents.[30] Ethnic enclaves may also entail some degree of voluntary move-in, and they may have a positive effect on health outcomes due to proximal social and cultural resources.[29–31] These unique attributes have caused discourse regarding how to measure or understand segregation in health

research, with some scholars suggesting the use of time-space biographies or fine-scale spatiotemporal approaches over more-widely used static measures.[16,28]

Research suggests that living in ethnic enclaves may only apply to certain Asian subgroups[32] and that the health benefits associated with ethnic enclaves may only apply to foreign-born Hispanic/Latino people in certain contexts. A national study indicates that Chinese and Vietnamese people are overrepresented in ethnic enclaves, while Filipino people are distributed across all neighborhood types, and all other Asian subgroups are underrepresented in ethnic enclaves.[32] Nevertheless, extreme heterogeneity in historical immigration and settlement patterns among Asian subgroups poses a significant challenge for neighborhood research in Asian communities.

Segregation and Health Discourse for Asian Communities

Research on Asian communities and health has revealed heterogeneous and, at times, inconclusive results.[29] For example, a recent study suggests that there is heterogeneity in the relationship between segregation and health-seeking behaviors among Asian subgroups.[33] Carreon and Baumeister report that Korean and other Asian people have a higher probability of obtaining an annual medical exam when living in a predominantly Asian neighborhood, which contrasts with Chinese and Vietnamese people having a lower probability of obtaining an annual medical exam when living in a predominantly Asian neighborhood.[33] Studies on Asian group-level health outcomes have also rendered inconclusive results, which suggests the need to disaggregate health outcomes research by subgroup. For example, Lim et al. found that living in Asian ethnic enclaves in New York City does not impact smoking outcomes beyond individual-level factors,[29] yet in contrast, Yang et al.'s national study found that living in Asian ethnic enclaves is associated with a lower probability of smoking during pregnancy.[30] Future segregation research can incorporate qualitative or detailed histories and perspectives,[28] to disentangle and capture a relational view of health outcomes in Asian communities.

In a notable contribution to segregation and ethnic enclave research, Walton creates a theoretical typology of Asian ethnic enclaves and explores their relationships to self-rated health status for Asian people in CA. Walton synthesizes scholarly perspectives on segregation/stratification, assimilation, and immigration and identifies three types of Asian ethnic neighborhoods: 1) immigrant enclaves, 2) communities of constraint, and 3) resurgent communities.[31] Immigrant enclaves have high proportions of foreign-born residents with low socioeconomic position (SEP) who tend to move away as they obtain upward social mobility.[31] Communities of constraint have high proportions of US-born residents with low SEP who experience systemic discrimination and lateral/downward social mobility.[31] Finally, resurgent communities have residents with high SEP regardless of birth origin who choose to live among others of the same ethnicity.[31]

Walton reports that living in resurgent communities is associated with a higher likelihood of reporting good health and that most Chinese and Korean people live in resurgent communities.[31] In contrast, a slight majority of Filipino people live in communities of constraint, while a slight majority of Vietnamese people live in immigrant enclaves.[31] Walton utilizes a relational approach with contextual histories to hypothesize why Filipino and Vietnamese people

do not mostly live in resurgent communities in CA. She suggests that first-generation Filipino people are less reliant on ethnic enclaves due to higher SEP and English language skills, so subsequent generations do not have access to social/ethnic resources to overcome systemic discrimination and lateral/downward social mobility.[31] Furthermore, many Vietnamese people arrived in the US under severe circumstances, and hostile reception from US residents may have caused them to assimilate into the "underprivileged segment of society."[31]

These heterogeneous findings emphasize that segregation and/or ethnic enclave research for Asian people in the US should disaggregate analyses by subgroup, incorporate local histories, and parse how structural racism differentially impacts Asian subgroups. This review paper contributes to the literature by answering the question, "How is residential segregation conceptualized, measured, and examined in studies that explore its relationship with asthma status?" I also ask, "How are Asian populations included in this research, if at all?" In the next section, I utilize the narrative format to describe the state of the literature on residential segregation and asthma while providing insight into the extent to which Asian American, immigrant, and refugee subgroups are included in this research.

Methods

Data Retrieval

Data retrieval for this review occurred through a stepwise process. First, I conducted a scoping review on research that explores the relationship between segregation and asthma. Next, I verified that studies included a measure of asthma and a measure of segregation, with proxies being acceptable. Acceptable proxy measures for segregation include measures for redlining and composite scores that consider segregation and socioeconomic position. The research topic's multidisciplinary nature required access to several academic fields, which included, but were not limited to public health, urban planning, geography, sociology, ecology, and demography. PubMed, SCOPUS, Sociological Abstracts, and Web of Science were the databases utilized to inform this review.

Search Techniques

The same literature search string was utilized on all databases (Table 1). This search required several search term combinations because academic fields approach the same research results with slightly different terminology. After each initial search, the results were then filtered with the following inclusion criteria: (1) research occurred in the US, (2) article was written in English, (3) study includes measurement of segregation, (4) study includes measurement of asthma status, (5) article is a peer-reviewed publication, and (6) the article was written between 2003 and 2021. We included research articles and utilized review articles to examine their bibliographies for additional papers that fit the inclusion criteria. Articles were excluded from the review if they described research conducted outside the US due to differences in the historical context of racial residential segregation. Relatedly, articles were excluded if they were written in a language other than English due to my language limitations.

Results

Summary of Findings

Table 1 provides a breakdown of results returned from searches on each database. After cross-comparing the final list of articles, one article appeared across all four databases, five appeared in three databases, two appeared in two databases, two appeared in one database, and three were derived from reference lists of articles returned in the search results. This summary provides a descriptive overview of the 13 peer-reviewed articles included in the review (Table 2). First, we briefly discuss common themes among the articles' research aims and major findings. Next, we provide review updates to the works of Acevedo-Garcia et al.[4] and Park and Kwan,[16] highlighting how segregation is conceptualized, measured, and examined among the articles (Table 3).

Associations between race/ethnicity, residential location, and asthma outcomes are the central foci of the articles in this review. Asthma is the primary health outcome examined in twelve articles, while Galster and Santiago's approach includes asthma diagnosis as one of several common childhood outcomes that result from the consequences of segregation and neighborhood effects.[34] Although all articles cite literature regarding the impacts of segregation on health and include a measure of segregation in their studies, the language of how they approach segregation in their aims and methods differs. Two articles directly present segregation as a specific and central aspect of their investigation on asthma outcomes,[25,34] while Smiley and Nardone et al. represent segregation through examinations of "racial/ethnic composition[35] and redlining,[36] respectively. The vast majority of articles incorporate the concept of segregation as part of more broad ecological investigations on the impact of neighborhood effects, characteristics, or correlates on asthma.[37–45]

An overview of the major findings reveals a consensus that segregation is associated with asthma. Eight articles report that living in a Black,[25,34,35,45] redlined,[36] or segregated area [38,39,44] is associated with higher odds, risk, or incidence of asthma, and Kranjac et al. report similar findings when they integrate measures of segregation in their neighborhood disadvantage composite scores.[40] However, there is some heterogeneity in that two studies did not find significant associations between measures of segregation and asthma outcomes,[37,41] and Shankardass et al. report somewhat inconclusive results.[42] Conversely, Wilhelm et al.'s analysis suggests that the odds of asthma are elevated for children in census tracts where there is not one predominant race/ethnicity compared to census tracts with a predominant race/ethnicity that is white, Black, Hispanic, or other.[43] A detailed analysis regarding the heterogeneity of these overall findings will follow in the discussion section below.

Multilevel Research Designs

Research on the relationship between segregation and health outcomes strongly suggests that a relational view of place and health is necessary to capture the effects of and interplay between individual and group-level factors. Acevedo-Garcia et al. argue that multilevel research designs are ideally suited to accommodate this relational approach by allowing individual-level data to be nested within group-level data in regression analyses.[4] In this review, segregation analysis examination represents the type of statistical analysis utilized to examine the

associations between segregation and asthma. Two of the 13 studies utilized an ecological approach to examine the associations between segregation and asthma at the census tract level. Eight of the 13 studies utilized multilevel research designs.

The eight studies with multilevel research designs differed in terms of (1) types of multilevel models used, (2) number of levels assessed, (3) geographic scale of segregation assessed, and (4) covariates assessed at the individual and group levels. The differences in covariates will be discussed further in the "income and poverty segregation" and "conceptual frameworks linking segregation and asthma" sections. Four studies used variations of multilevel logistic regression models,[38,41,44,45] while the remaining studies used different approaches such as Bayesian profile regression models,[39] latent profile analysis models,[40] Cox proportional hazards models,[42] and factor analysis models.[43] Seven of the eight studies utilized two-level designs, while Shankardass et al. utilized a unique four-level design that nested individuals in neighborhoods, schools, and communities.[42] Furthermore, segregation is a group-level, contextual factor that can be assessed at different geographic scales. Six studies examined segregation at the census tract level because they identified it as the most appropriate proxy for neighborhood-level effects.[38–41,43,45] Shankardass et al. included this proxy in their analysis but also examined segregation at two larger geographic scales that they defined as the schools the children attended and the 13 Southern CA communities chosen for the Children's Health Study cohort.[42] Finally, Baltrus et al. examined segregation at the county level because they reported that the county level was the smallest geographic unit common to all the datasets in their analysis.[44]

Inclusion of Asian Groups

Articles were reviewed for the inclusion of Asian people in both study populations and measurements of segregation. In this review, segregation conceptualization represents "who" might experience the negative health effects of segregation, or who is included in the study population. Similarly, the measurement of segregation represents the details of "how" segregation is operationalized.

The study populations of four articles included a general category for Asian people,[36,38,41,44] while 11 out of 13 articles included a general category for Hispanic/Latino people.[34,36–45] Five studies included Asian people as part of their "other" category for race/ethnicity,[37,39,40,42,43] which was more common than incorporating a separate, general category for Asian people. Alexander and Currie combined Asian people with white people for their "other" category and removed Hispanic/Latino people from their analysis altogether.[25] In contrast, Smiley's analysis did not specify race/ethnicity in its study population.[35] In a notable departure from common racial/ethnic categories, two studies disaggregated their study populations into racial/ethnic subgroups. For Asian people, Rosenbaum disaggregated Chinese and South Asian people from their general Asian category.[41] For Hispanic/Latino people, Holt et al. disaggregated Puerto Rican and Mexican people from their general Hispanic/Latino category,[37] while Rosenbaum disaggregated Puerto Rican, Mexican, Dominican, and Central/South American people from their general Hispanic/Latino category.[41]

Another concept central to the inclusion of Asian and Hispanic/Latino populations in segregation research is the consideration of nativity. Two of out 13 articles included percent foreign-born, while one article used percent linguistic isolation as a proxy for nativity. Galster and Santiago, and Kranjac et al., incorporated percent foreign-born as a group-level variable in their analyses,[34,40] while Kane utilized percent linguistic isolation within a composite score for social and health vulnerability as a proxy in her analysis.[39] The overarching absence of nativity-related covariates, despite the increased consideration of Hispanic/Latino populations, is further discussed in the discussion section.

There has also been an increase in analyses that include Hispanic/Latino populations. Seven out of 13 articles utilized a measurement of segregation that directly named and identified Hispanic/Latino people in the segregation variable.[34,38–40,42,44,45] Baltrus et al. and Brewer et al. took their analyses further with the inclusion of Asian people in their segregation variables.[38,44] Three analyses utilized non-specific race/ethnicity measures in their segregation variables. For example, Kane used percent minority population,[39] Rosenbaum used percent white population,[41] and Wilhelm et al. used predominance of a single race/ethnicity.[43]

In terms of significant findings that consider these populations, Alexander and Currie found that children with low birth weight, including Asian and Hispanic/Latino children who live in Black ZIP codes have a higher incidence of asthma.[25] Brewer et al. report that children who live in a neighborhood where residents share a higher percentage of their race is associated with higher odds of asthma for Black and Asian children.[38]

Income and Poverty Segregation

Acevedo-Garcia et al. suggest that income segregation, or related measures of poverty and inequality, should be examined simultaneously in studies that examine the relationship between segregation and health outcomes.[4] This would help to determine if income or other flexible resources mediate and/or moderate the negative effects of segregation on health. The simultaneous examination of income, poverty, or inequality was incorporated differentially among the articles reviewed, particularly at the individual and group levels. One reason is that socioeconomic position (SEP) is a latent construct that cannot be captured with just one measure, and different components of SEP cannot be used as proxies for one another.[46] Hence, multiple measures that contribute to SEP were often included in each study and are summarized below.

The inclusion of SEP in segregation research for Asian people is vital to understanding how structural factors may impact the health of different subgroups. Asian people have the highest median annual household income (MHI) ($85,800) when compared to all other households in the US ($61,800).[47] However, this masks differences among Asian subgroups where Indian ($119,000) and Filipino ($90,400) people have MHIs that are more than double those of Burmese people ($44,400).[47] Similarly, Asian people as a group appear to have some of the lowest poverty rates (13%), but Burmese (37.8%) and Bhutanese (34.3%) people have poverty rates that are more than quadruple those of Indian (8.1%) and Filipino (7.9%) people.[48] While Filipino people have higher MHIs and lower poverty rates, they tend to have worse chronic health outcomes when compared to other Asian subgroups.[49] While SEP can influence health outcomes, this suggests that other structural factors beyond SEP can impact health.

Individual-level variables for SEP included insurance status, parental educational attainment, household poverty measures, household use of public assistance, parental unemployment, household income measures, and parental home ownership. Insurance status was utilized in seven of 13 studies, and it was the most common variable utilized at the individual level. Insurance status was operationalized by possession of coverage [37,42,43] and type.[25,38–40] Notably, all seven studies that incorporated individual insurance status also examined group-level indicators of SEP in their analyses.[25,37–40,42,43] Five studies examined educational attainment at either the high school or college level, and it was the second most common variable utilized at the individual level.[25,37,41–43] In contrast to the other studies in this review, Rosenbaum exclusively examined the effects of SEP at the individual level, and they were not associated with increased odds of asthma.[41] The lack of other studies that exclusively examine SEP at the individual level indicates a shift toward assessing SEP as a group-level consequence of structural discrimination.

Group-level variables for SEP included social vulnerability composite scores, educational attainment, poverty measures, use of public assistance, unemployment, household income measures, home ownership, occupational prestige, and wealth measures. Poverty measures were utilized in six of 13 studies, and they were the most common variable utilized at the group level. Poverty measures were operationalized by the percentage of people living below the federal poverty level [25,35,37,40,44] and the percentage of people living below two-times the federal poverty level.[36] Of note, all studies that utilized poverty measures incorporated at least one other indicator of SEP, such as educational attainment and unemployment. Educational attainment and social vulnerability composite scores tied for the second most common SEP variables at the group level. Educational attainment was operationalized by high school degree,[25,37,45] college degree,[25,35,37] and a scale of years spent in school.[40] The use of social vulnerability composite scores is notable as composite scores may be an increasingly common way to capture the multiple component effects of SEP. Finally, five of 13 studies exclusively examined SEP at the group-level, and they each used at least two measures of SEP in their analyses.[34–36,44,45] The popularity of group-level composite scores and exclusive focus on group level SEP measures indicate an overall shift toward capturing SEP as a form of income and poverty segregation.

Conceptual Frameworks to Link Segregation to Asthma

In their final recommendation for future segregation research, Acevedo-Garcia et al. state that public health researchers should utilize conceptual frameworks that link segregation dimensions to health outcomes like asthma. Environmental justice research indicates that there is a relationship between segregation and excessive environmental exposure to pollutants and toxicants.[50] This section highlights the inclusion of air pollution variables in current segregation and asthma studies. Such variables are indicators of incorporating an environmental justice approach and/or cumulative impacts approach[51] to further establish the associations between segregation and asthma.

Eleven of 13 articles included air pollution in their analyses, which suggests that many researchers have adopted elements of an environmental justice framework into their theoretical approaches to segregation research. The operationalization of air pollutant variables differed across the eleven studies. They included the following base variables: particulate matter 2.5

(PM2.5),[25,36,38,40,43] diesel particulate,[25,36,39,42] ozone,[38,40,43] carbon monoxide,[43] nitrogen dioxide,[43] PM10,[43] the Environmental Protection Agency (EPA)'s exposure index scores,[34,35,39] and air quality index (AQI) scores.[44] There were also three proxies for air pollution: proximity to transportation facilities,[41] proximity to manufacturing facilities,[39,41] and exposure to wildfire smoke.[42] The most common air pollutant examined was PM2.5, with Alexander and Currie estimating PM2.5 exposure from emitting sources at the ZIP code level[25] and four other studies utilizing average PM2.5 estimates at the census tract level.[36,38,40,43] Four studies estimated exposure to diesel exhaust, with two providing direct measures of diesel particulate [36,39] and two utilizing proximity to traffic.[25,42] The EPA's respiratory hazard index was another common measure of air pollution at the census tract level.[34,35,39] This index utilizes the "ratio of exposure concentration to health-based reference concentration" to identify areas at increased exposure to toxic air pollutants.[52]

Air pollution was assessed at multiple geographic scales across the 11 studies, with the census tract level being the most common scale. Eight studies analyzed air pollutants at the census tract level, which is a common proxy for the neighborhood level.[34–36,38–41,43] Two studies analyzed air pollutants at larger geographic scales. Alexander and Currie utilized the ZIP code level[25] and Baltrus et al. utilized the county level.[44] Shankardass et al. took a unique approach and incorporated air pollutant variables at both the individual and group levels.[42]

Positive associations between segregation, air pollution, and asthma were confirmed in seven of 11 studies that included air pollutant variables, [34–36,39–42] while Wilhelm et al. only found a positive association between air pollution and asthma.[43] Two studies found initial associations between segregation, air pollution, and asthma; however, the associations were no longer present and/or significant in their final models. Alexander and Currie, and Baltrus et al., suggest that the geographic scales of their analyses (ZIP code and county, respectively) might have been too large and that the available data for their air pollutant variables may have impacted the inconclusive findings.[25,44] Finally, Brewer et al. did not find any associations between air pollution and asthma.

Incorporating the Geographical Perspective

Park and Kwan's review on segregation, environmental exposures, and health provides a critique of public health research from a geographical perspective. They argue that place and health research on segregation should incorporate a wider view of where, when, and how segregation impacts people and their subsequent health outcomes. Tangibly, there are two suggestions that this review considers: (1) the utilization of spatial statistics for data that is known to cluster in space over time and (2) the extension of segregation research beyond neighborhoods of residence.

Three of 13 studies utilize spatial statistics to analyze data that is known to cluster in space over time, and all three conduct their analyses at the census tract level.[35,36,45] Nardone et al. and Smiley use Global Moran's I to assess the residuals of their initial regression models for spatial autocorrelation.[35,36] In both studies, spatial autocorrelation was present, so spatial regressions were necessary to conduct their final analyses. Nardone used conditional autoregressive models, and Smiley used spatial lag regression models.[35,36] In the first part of their analysis, Gupta et al. utilize local Moran's I to identify, evaluate, and map spatial patterns of

asthma prevalence at the census tract level.[45] However, they do not proceed to utilize spatial statistics in their regression models. Finally, two studies utilize spatial statistics to prepare their variables for analysis. Kane utilizes a point density analysis to identify areas with high frequencies of acute care visits for asthma,[39] while Kranjac et al. utilize kriging interpolation to create air pollutant variables for PM2.5 and ozone.[40]

In terms of analyzing segregation effects beyond the neighborhood level, Alexander and Currie, and Baltrus et al., conduct their analyses at the ZIP code and county levels, respectively.[25,44] Both analyses found positive associations between segregation and asthma incidence. Shankardass et al. conducted the only study that considered the relationship between asthma and variables at multiple geographic scales and locations other than the home.[42] From smaller scale to larger scale, they examined variables at the home, neighborhood (census tract), school, and wider community levels. However, they found "borderline positive significant associations" between ethnic diversity index scores at the school level and asthma, which were reduced and insignificant in their final models.[42]

Discussion

Conceptualization of Segregation in Future Research

As population demographics in the US shift, the conception of who experiences the legacy contextual effects of segregation must also shift beyond the traditional Black versus white compositional effects paradigm. The results of this review revealed that some progress has been made when it comes to including Asian populations in study samples. Furthermore, there is a notable absence of nativity covariates in the studies examined for this review, and it is a significant gap in the current literature. Previous research on the differential negative health impacts and health benefits of segregation (or ethnic enclaves) suggests that nativity be considered in studies that examine the impacts of segregation on Asian[29–31,33] and Hispanic/Latino populations.[53,54] Currently, only three of 13 studies considered nativity in their analyses.

Evidence suggests that the negative health effects of segregation differentially impact specific Asian[29–31,33] and Hispanic/Latino subgroups,[53,54] which supports the need to disaggregate racial/ethnic data when possible. This review found that two studies disaggregated their Asian (Rosenbaum) and Hispanic/Latino (Rosenbaum and Holt et al.) study populations into racial/ethnic subgroups, but they were notably the two studies that did not report a relationship between segregation and asthma.[37,41] However, this may have been due to issues with the operationalization of their segregation variables. This lack of a relationship and segregation variable issue is further discussed below, in the section on the measurement of segregation. In this review, only Rosenbaum's paper examined data for at least two disaggregated Asian subgroups. The analysis utilized data from the 2002 panel of the New York City Housing and Vacancy Survey (HVS), and it included the following racial/ethnic categories: Non-Hispanic white, Non-Hispanic Black, Puerto Rican, Dominican, Central/South American, Mexican, Other Hispanic, Chinese, Asian Indian, and Other Asian.[41] Although this was the only paper that included disaggregated Asian subgroups, Rosenbaum did not discuss why or how the Chinese and Asian Indian subgroups were chosen for the study. There was no discussion about additional

Asian subgroups in the data set, so it is unclear which Asian subgroups were included in the "Other Asian" category.

A brief review of literature that examines segregation and health among Asian subgroups identified two studies. These studies were not included in the overall analysis because they analyzed access to healthcare services and colorectal cancer rather than asthma. The studies share commonalities that differ from Rosenbaum's approach. First, both studies utilized datasets that included at least 5 different subgroups of Asian people. Carreon and Baumeister's analysis used data from Wave IV of the National Longitudinal Study of Adolescent Health (Add Health), and they included the following Asian subgroups in their analysis: Chinese, Filipino, Korean, Vietnamese, and other Asian.[33] Ladabaum et al.'s analysis used data from the National Cancer Institute SEER (Surveillance, Epidemiology, and End Results) program registries, and they included the following Asian subgroups in their analysis: Chinese, Filipino, Japanese, Korean, South Asian, and Vietnamese.[55] Second, both studies clarify the composition of vague subgroup variables and the reasons for dropping specific subgroups from their analyses. Carreon and Baumeister state that most respondents in their "other Asian" category were from Cambodia, the Pacific Islands, Laos, or Thailand.[33] They also discuss why they chose to drop Japanese and Asian Indian adults from their study sample.[33] Similarly, Ladabaum et al. specify that the South Asian subgroup in their analysis included people from India, Pakistan, Sri Lanka, and Bangladesh.[55] Finally, both studies focused their analyses on Asian people and included white people as a comparison group.

Rosenbaum's conceptualization of segregation for Asian people may have differed due to the limitations of the dataset; nevertheless, the two other studies discussed in this section provide transparent processes for discussing study samples with data disaggregated by Asian subgroups. The three studies share one key commonality in that they all included nativity as a variable to assess for "protective factors" associated with being born in a non-US country.[33,41,55] Overall, this review supports Acevedo-Garcia et al.'s suggestion to incorporate diverse immigrant populations in future segregation research.[4]

Implications for Measurement of Segregation in Future Research

The findings of this review suggest that segregation likely has an association with asthma outcomes. Segregation is associated with asthma in nine of the 13 articles in this review. However, two articles did not find a relationship between segregation and asthma,[37,41] and one article found a negative association between segregation and asthma.[43] A closer inspection of the segregation variables utilized in these three studies reveals potential pitfalls in their operationalization of segregation as study variables. These studies focus on a single race/ethnicity in their measure of segregation, while most of the other studies incorporate multiple races/ethnicities. Holt et al. measure the percentage of Black residents in a census tract,[37] Rosenbaum measure the percentage of white residents in a census tract,[41] and Wilhelm et al. measure one predominant race/ethnicity in a census tract.[43] Alexander and Currie, and Smiley, demonstrate that it is possible to measure segregation as the predominance of a single race/ethnicity, but only when that measurement is created in relation to that race/ethnicity's predominance at a larger geographic scale.[25,35] While this approach may be sufficient in capturing racial/ethnic residential patterns at a larger scale, it neglects to consider the population's

diversification. The US population has increased in diversity, particularly with the immigration of Asian and Hispanic/Latino populations.[18] While many studies included Hispanic/Latino people in their measures of segregation, the need to include Asian people in future studies remains.

The need for research that examines the impacts of segregation on health among Asian subgroups also includes the need to identify and develop methods for measuring segregation among racial/ethnic subgroups. As previously discussed, Rosenbaum utilizes percent white composition as a measure of segregation at the census tract level, which does not account for diversity or neighborhood segregation in comparison to racial/ethnic presence at a larger geographic scale.[41] Rosenbaum's approach to measuring segregation differs from the two studies identified in the brief review of literature on segregation and health among Asian subgroups. While Rosenbaum centers white people as the focal point of segregation measurement,[41] the other two studies focus on segregation measures specific to Asian people. Carreon and Baumeister measure segregation by percent Asian composition.[33] On the other hand, Ladabaum et al. frame their research as an attempt to capture ethnic enclaves rather than segregated neighborhoods. They take a novel approach with the creation of an index specific to Asian households: percent of Asian language-speaking households that are linguistically isolated," percent of all Asian language speakers who speak limited English, percent of recent immigrants, and percent Asian composition."[55] The growing Asian population and the diversification of the US renders segregation measures specific to Asian people more relevant than past practices, such as focusing on white populations.

As Acevedo-Garcia et al. suggest, there is an ongoing need for empirical studies to incorporate multiple races/ethnicities when they operationalize segregation as a study variable.[4] Social science research has utilized a myriad of segregation indices to measure segregation between and among multiple racial/ethnic groups.[56] These indices have long histories of being utilized in research; however, only two of 13 articles in this review utilized segregation indices for their segregation variables. Baltrus et al. used the isolation index,[44] and Shankardass et al. used the dissimilarity index.[42] Future public health research on segregation and health should incorporate conceptualizations of segregation beyond the predominance of a single race/ethnicity. One possible solution could be the widespread use of segregation indices to ensure multiple races/ethnicities are incorporated into segregation variables.

Implications for Public Health Practice: Data Collection and Theory Adoption

This review supports the notion that additional efforts must be made to capture health data for Asian people. When Asian people were included in study populations, they were rarely assigned to their own category for analysis due to insufficient data. Additionally, only two studies included Asian people in their segregation variables despite evidence [31,57–59] that Asian people experience negative effects associated with segregation. The US Asian population grew 81% from 10.5 million people in 2000 to 18.9 million people in 2019, and it is the fastest-growing single-race, non-Latino group in the country.[60] In the presence of known chronic health disparities among Asian populations,[49] future public health research must adopt focused data collective practices that accurately capture the diverse health experiences and needs of this rapidly growing population.

In addition to improving the collection and use of health data for diverse populations, the findings of this review suggest that public health researchers must continue to adopt theory from the social sciences. Public health researchers should refine their adoption of an environmental justice framework in segregation and health research. Air pollution was a significant covariate in the majority of studies reviewed for this paper. Nevertheless, a wide range of air pollutants was examined, and future research could benefit from narrowing the scope of which air pollutants are most relevant for specific geographic locations. For example, Kranjac et al. employed kriging interpolation to generate air pollution variables that were not publicly available in a format ready for use in research.[40] Relatedly, several studies utilized publicly available air pollution indices. If these indices render equivalent results to individual air pollutant variables, they could make this type of study more accessible for public health researchers who are unfamiliar with spatial statistics.

Finally, public health research can also benefit from adopting geographical theory for place-related studies. The use of spatial statistics was uncommon in the studies reviewed; however, their use could bring a well-rounded perspective to this research. For example, Kane's discussion includes qualitative observations about the data and subsequent maps she generated for her analysis.[39] However, the use of spatial statistics, like Moran's I, could quantitatively confirm her observations of data that already exists in spatial format. Ultimately, public health research can benefit from adopting theory and concepts from the social sciences in order to streamline future place and health research.

Strengths and Limitations

This review provided a general synthesis of research on segregation and asthma to improve understanding about the operationalization of segregation. The analysis incorporated theory perspectives from multiple disciplines to highlight the current state of knowledge, theory, and gaps in the literature, particularly regarding Asian populations. The interpretations and critique in this analysis are based on theory, yet they provide subjective direction for future research and public health practice. Therefore, a more comprehensive, or systematic, review would be necessary to identify evidence-based conclusions and create guidelines about the associations between segregation and asthma.

Conclusion

Additional research is needed to further understand the associations between racial residential segregation and asthma, particularly for Hispanic/Latino and Asian populations. There is a larger need to utilize a relational approach in future research so that public health studies are not overly reliant on segregation's compositional effects. A deeper examination of segregation's contextual effects, such as environmental exposures and income segregation, offers opportunities to clearly elucidate additional pathways for asthma outcomes in at-risk and under-studied populations. The implications of this review suggest that place and health research should continue to adopt and adjust conceptual frameworks on segregation measurement, ethnic enclaves, and environmental justice to better capture the impacts of segregation on health for diverse populations.

Tables

Table 1. Literature Review Search String by Database and Returned Results

Database	Search String	Filtered/Total Results	Chosen for Review
PubMed	(("residential segregation" OR "racial residential segregation" OR "ethnic residential segregation" OR "neighborhood segregation" OR "racial segregation" OR "housing segregation" OR "segregated neighborhoods" OR "neighborhood composition" OR "redlining" OR "redlined" OR "ethnic enclave" OR "ethnic enclaves" OR "neighborhood context" OR "racial segregation") AND ("asthma" OR "respiratory disease"))	26/26	5
Scopus		36/41	8
Sociological Abstracts		78/180	1
Web of Science		50/53	11

Table 2. Summary Table of Studies on Segregation and Asthma

Author(s) (Year)	Title	Study Aim(s)	Outcome Variable (Data Source)	Results	Multilevel	Covariates
Non-Multilevel Designs						
Alexander & Currie (2017)	Is it who you are or where you live? Residential segregation and racial gaps in childhood asthma	To examine the impact of race, birth weight, and residential location on the incidence of emergency room visits for asthma in early childhood	Pediatric asthma incidence (New Jersey Uniform Billing Records from 2006 to 2012)	Living in Black zip codes was associated with a higher incidence of asthma emergency room visits for all children with low birthweight, regardless of race	N	Individual: race, birthweight, insurance (type) Maternal: race, age, education, marital status, date of birth, residence at the time of the child's birth, and smoking status during pregnancy ZIP CODE: median age, mean household size, % less than high school (25+), % bachelor's or more (25+), % in labor force (16+), % households less than 20k, % households greater than 200k, median year structure built, % owner occupied, % vacant units, median value owner occupied, % families below poverty
Galster & Santiago (2017)	Neighborhood ethnic composition and outcomes for low-income Latino and African American children	To examine the impact of segregation on life chances and outcomes for low-income Latino and African American children	Pediatric asthma diagnosis (Denver Child Study)	Living in neighborhood with more African American residents was associated with a greater odds of receiving an asthma diagnosis by 52% for Low income, African American children	N	Census tract: % African American residents, % Latino residents, social vulnerability score, occupational prestige score, % foreign-born, % residents who moved in the last 12 months, % housing built before 1940, social capital

Holt et al. (2012)	Individual, Housing, and Neighborhood Correlates of Asthma among Young Urban Children	To examine the impact of individual, housing, and neighborhood characteristics on asthma outcomes	Pediatric asthma diagnosis by age 5 (Fragile Families and Child Well-being Study)	A child's race/ethnicity (Non-Hispanic Black, Puerto Rican, or other Hispanic race), lack of insurance coverage, male gender, allergies, the exterior condition of a child's home, mother's educational attainment, and the percent of neighborhood population with a bachelor's degree were associated with receiving an asthma diagnosis by age 5	N	Individual: asthma outcomes, sociodemographic and clinical measures, conditions of housing and block (household income as percentage of the federal poverty level), mother's race/ethnicity, education level, and marital status, child's gender, and symptoms of hay fever or allergy in the last 12 months, health insurance status (coverage), medical care, household tobacco smoke Census Tract: % population with at least a high school education, % civilian labor force unemployed, % households on public assistance, % housing units vacant, % housing units renter-occupied, % population non-Hispanic Black, % population with a bachelor's degree or higher, % families below federal poverty line
Nardone et al. (2020)	Associations between historical residential redlining and current age-adjusted rates of emergency department visits due to asthma across eight cities in California: an ecological study	To examine the impact of historical residential redlining on present-day asthma emergency department visits in California	Age-adjusted rates of asthma emergency department visits per 10k residents per year (2011-2013) (CalEnviroScreen)	Median age-adjusted rates of asthma emergency department visits were associated with census tracts that were previously redlined to the highest risk level (2.4 times higher than in tracts at the lowest risk level)	N	Census tract: % living below two-times the poverty level, 3-year average PM2.5, diesel exhaust emissions

Smiley (2019)	Racial and Environmental Inequalities in Spatial Patterns in Asthma Prevalence in the US South	To examine the impact of racial composition and air pollution on asthma prevalence within neighborhoods	Asthma prevalence (500 Cities, CDC)	Living in neighborhoods with more Black residents and/or more air pollution was associated with higher asthma prevalence Proportion of Black residents had stronger effect	N	Census tract: % college educated individuals, % residents whose household income is below the poverty line, % owner-occupied homes, tract population
Multilevel Designs						
Baltrus et al. (2018)	Individual and county level predictors of asthma related emergency department visits among children on Medicaid: A multilevel approach	To examine the effect of individual and county-level factors on asthma emergency department (ED) visits among children enrolled in Medicaid	Pediatric asthma emergency department visits (Centers for Medicare and Medicaid Services' 2009 Medicaid Analytic Extract)	Individual: Improper use of controller medications was associated with higher risk of asthma ED visits County: Increasing segregation was associated with increasing risk of asthma ED visits	Y	Individual: race, gender, age, preventive inhaler use County: rural/urban status, wealth of white population, wealth of Black population, Gini coefficient, unemployment rate, % children in poverty, % owner occupied units, health care providers per 10,000, hospital beds per 1,000, % days with bad air quality, median AQI
Brewer et al (2017)	Does neighborhood social and environmental context impact race/ethnic disparities in childhood asthma?	To examine the effect of neighborhood social and environmental characteristics on racial/ethnic disparities in childhood asthma	Pediatric asthma diagnosis (Health records from Texas Children's Hospital and Texas Children's Pediatrics Associates, 2011–2013)	Living in a neighborhood with more co-ethnic residents was associated with lower odds of asthma for white and Hispanic children, but higher odds for black and Asian children	Y	Individual: age, gender, race/ethnicity, insurance type Census tract: Air quality (Ozone, PM2.5), Concentrated disadvantage (index: % living below poverty line, % on public assistance, % unemployed, % female-headed households with children), Co-ethnic racial composition (% of neighborhood residents who share respondent's race/ethnicity)

Gupta et al. (2008)	Geographic variability in childhood asthma prevalence in Chicago	To examine the impact of neighborhood location on childhood asthma prevalence among neighborhoods in Chicago	Pediatric asthma prevalence (Chicago Initiative to Raise Asthma Health Equity (CHIRAH) study)	Living in majority Black neighborhoods was associated with higher asthma prevalence when compared to majority white neighborhoods and majority Hispanic neighborhoods	Y	Individual: age, sex, race, household member with asthma Census tract: % age 25 & over with high school ed., median household income, neighborhood race
Kane (2022)	Revealing the racial and spatial disparity in pediatric asthma: A Kansas City case study	To examine the impact of community characteristics on the distribution of pediatric asthma in the region	Pediatric asthma acute care visits (Children's Mercy Kansas City hospital network (CMH))	Living in a census tract clusters with: Environmental hazards & social disadvantage (esp. linguistic isolation) was associated with higher risk of asthma for one area; Social disadvantage (renters, education, poverty, home value, % minority) was associated with higher risk in another; Environmental hazards & social disadvantage (esp. renters) was associated with higher risk in a third cluster	Y	Individual: Age, Sex, Race/Ethnicity, Medical coverage (type) Census tract: Environmental justice screening for 3 aggregate measures - sensitive land use & hazard proximity (traffic proximity & volume; proximity to risk management sites and treatment, storage, & disposal facilities; walkability to transit) -health risk & exposure (individual lifetime cancer risk, diesel particulate matter, respiratory hazard index) -social & health vulnerability (% age 24 & over without high school ed., % linguistic isolation, % at or below 200% poverty, % minority, % renter, median home value, % age 6 & under, % age 60 & over

Kranjac et al (2017)	Comprehensive Neighborhood Portraits and Child Asthma Disparities	To examine the impact of neighborhood characteristics (demographics, economics, & air quality) on pediatric asthma diagnoses across neighborhoods in Houston, TX	Pediatric asthma diagnosis (Medical records from Texas Children's Hospital & Texas Children's Pediatric Associates clinics)	Living in increasingly disadvantaged neighborhoods was associated with a higher probability of asthma for Black children; their risk was higher across all neighborhood types Differences in pollution exposure composition were associated with asthma disparities between the Disadvantaged and the Middle-class	Y	Individual: Age (mean-centered, gender, race/ethnicity, insurance type) Census tract: community-level education, unemployment rate, median income, median year the house was built, % female-headed households, % foreign born, % receiving public assistance, % in poverty, % vacant homes, % of major racialized categories, air pollutants (PM2.5 and O3) (mean-centered)
Rosenbaum (2008)	Racial/Ethnic Differences in Asthma Prevalence: The Role of Housing and Neighborhood Environments	To examine the impact of housing and neighborhood conditions on asthma disparities	Asthma prevalence (New York City Housing and Vacancy Survey (HVS))	Exposure to deteriorated housing conditions and perceptions of low social cohesion were associated with higher odds of asthma Puerto Rican households had the highest levels of asthma, followed by Hispanic and Black households	Y	Individual: Race/ethnicity (non-Hispanic white, non-Hispanic black, Puerto Rican, Dominican, Central/South American, Mexican, other Hispanic, Chinese, Asian Indian, and other Asian); Housing (# maintenance deficiencies, crowding, tenure status, indoor tobacco smoke); age, educational attainment, & gender of householder; total household income per 10,000; household receipt of Temporary Assistance to Needy Families Census tract: Vacant homes, social cohesion, % white, violent crime rate, # transportation facilities per 100,000; # manufacturing facilities per 100,000

Shankardass et al (2010)	Social environment and asthma: associations with crime and No Child Left Behind programs	To examine the impact of the neighborhood, school and community social environment on new-onset asthma	Pediatric asthma risk (Children's Health Study (CHS), Southern California)	Attending disadvantaged schools (with Title I funds) and living in neighborhoods with higher rates of larceny crime were associated with increased risk for asthma	Y	Individual: Race/ethnicity, weight, health insurance coverage, parental education, parental stress, parental history of asthma, indoor tobacco smoke, carpet, mildew, cockroaches, water damage, musty odor, pets, gas stove, traffic air pollution, exposure to wildfires Group 1 (neighborhoods): Deprivation, racial composition, income inequality, population density Group 2 Schools: Deprivation, racial composition, academic performance, funding Group 3 communities: Deprivation, racial composition & segregation, population density, crime
Wilhelm et al. (2008)	Outdoor air pollution, family and neighborhood environment, and asthma in LA FANS children	To examine the impact of physical and social neighborhood characteristics on the associations between outdoor air pollution and asthma	Pediatric asthma diagnosis Los Angeles Family and Neighborhood Survey (LA FANS)	Living in a high O3, PM10, and CO area was associated with having worse asthma morbidity, after adjusting for social environment characteristics	Y	Individual: race/ethnicity, age, gender, health insurance status (coverage), source of childcare when sick, one or more well visits during previous 12 months Family level (individual): % of the federal poverty limit, homeowner status (yes/no), non-housing assets, public assistance in previous 12 months, PCG education (years), parents' employment status, neighborhood satisfaction, opinion of neighborhood safety, cohesion and support Census tract: Disadvantage score: % poor families, % households on public assistance, % female-headed families, % male unemployment

Table 3. Literature Review Findings: Conceptualization, Measurement, and Examination of Segregation

Author(s) (Year)	Title	Conceptualization (Study population: Who is included in the study)	Measurement (Who experiences segregation and to what degree?)	Examination (How is this quantified?)	Geographic Scale _____ GIS/spatial stat	Multilevel	Covariates	Air
Alexander & Currie (2017)	Is it who you are or where you live? Residential segregation and racial gaps in childhood asthma	Group 1: Black Group 2: White/Other "Other race category is 40.8% Asian Indian, 23.1% other and unspecified race, 11.5% Filipino, 9.8% Chinese, and 8.4% Korean (the remaining categories are Vietnamese, American Indian, Japanese, and Pacific Islander)"[22]	Black zip codes: defined zip codes with the highest fraction of black children	Ordinary least squares models	ZIP code	N	Individual: race, birthweight, insurance (type) Maternal: race, age, education, marital status, date of birth, residence at the time of the child's birth, and smoking status during pregnancy ZIP CODE: median age, mean household size, % less than high school (25+), % bachelor's or more (25+), % in labor force (16+), % households less than 20k, % households greater than 200k, median year structure built, % owner occupied, % vacant units, median value owner occupied, % families below poverty	PM2.5: Average distance from ZIP code centroids to the 25 largest point source emitters Vehicle emissions: Fraction of the population living in census blocks with centroids within 800 m or 400 m of a limited access highway
Galster & Santiago (2017)	Neighborhood ethnic composition and outcomes for low-income Latino and African American children	Group 1: Latino Group 2: African American	Standard deviation-higher % of African American or Latino residents	Stratified logistic regression	Census tract	N	Census tract: % African American residents, % Latino residents, social vulnerability score, occupational prestige score, % foreign-born, % residents who moved in the last 12 months, % housing built before 1940, social capital	EPA respiratory hazard index EPA Neurological hazards index

Holt et al. (2012)	Individual, Housing, and Neighborhood Correlates of Asthma among Young Urban Children	Group 1: white Group 2: Black Group 3: Puerto Rican Group 4: Mexican Group 5:Other Hispanic Group 6: American Indian/Asian	% Black	Logistic regression with maximum likelihood estimation	Census tract	N	Individual: asthma outcomes, sociodemographic and clinical measures, conditions of housing and block (household income as percentage of the federal poverty level), mother's race/ethnicity, education level, and marital status, child's gender, and symptoms of hay fever or allergy in the last 12 months, health insurance status (coverage), medical care, household tobacco smoke Census Tract: % population with at least a high school education, % civilian labor force unemployed, % households on public assistance, % housing units vacant, % housing units renter-occupied, % population non-Hispanic Black, % population with a bachelor's degree or higher, % families below federal poverty line	N/A

Nardone et al. (2020)	Associations between historical residential redlining and current age-adjusted rates of emergency department visits due to asthma across eight cities in California: an ecological study	Group 1: white Group 2: Hispanic, Group 3: Asian Group 4: Black Group 5: Other	Home Owners' Loan Corporation (HOLC) risk grades A-D (A-lowest risk, D-hazardous)	Ordinary least squares with random intercept and random slope models	Census Tract _____ Moran's I Conditional autoregressive models	N	Census tract: % living below two-times the poverty level, 3-year average PM2.5, diesel exhaust emissions	PM2.5: 3-year average ($\mu g/m^3$) (2012–14) Diesel exhaust particle emissions: (kg) for a summer day in 2012
Smiley (2019)	Racial and Environmental Inequalities in Spatial Patterns in Asthma Prevalence in the US South	Anyone living in a census tract in the study area: 32 Cities in the U.S. South with at least 250,000 residents	% Black residents (group mean centered in each city)	Spatial lag regression models with queen contiguity matrix	Census tract _____ Moran's I spatial lag regression models with queen contiguity matrix	N	Census tract: % college educated individuals, % residents whose household income is below the poverty line, % owner-occupied homes, tract population	EPA respiratory hazard index

Multilevel Designs								
Baltrus et al. (2018)	Individual and county level predictors of asthma related emergency department visits among children on Medicaid: A multilevel approach	Group 1: white Group 2: Black Group 3: Asian Group 4: Hispanic Group 5: Other	Isolation Index for white people	Multilevel multivariate logistic regression	County	Y	Individual: race, gender, age, preventive inhaler use County: rural/urban status, wealth of white population, wealth of Black population, Gini coefficient, unemployment rate, % children in poverty, % owner occupied units, health care providers per 10,000, hospital beds per 1,000, % days with bad air quality, median AQI	% days with bad air quality Median air quality index
Brewer et al (2017)	Does neighborhood social and environmental context impact race/ethnic disparities in childhood asthma?	Group 1: white, Group 2: black Group 3: Hispanic Group4: Asian	% co-ethnic	Cross-classified multilevel logistic regression	Census tract	Y	Individual: age, gender, race/ethnicity, insurance type Census tract: Air quality (Ozone, PM2.5), Concentrated disadvantage (index: % living below poverty line, % on public assistance, % unemployed, % female-headed households with children), Co-ethnic racial composition (% of neighborhood residents who share respondent's race/ethnicity)	Ozone: Daily maximum 8-hour concentrations PM2.5: average of quarterly means over three years (2010–2012)
Gupta et al. (2008)	Geographic variability in childhood asthma prevalence in Chicago	Group 1: white Group 2: Black Group 3: Hispanic	% white, % Black, % Hispanic	Multilevel logistic regression analysis	Census tract _____ Local Moran I	Y	Individual: age, sex, race, household member with asthma Census tract: % age 25 & over with high school ed., median household income, neighborhood race	N/A

Kane (2022)	Revealing the racial and spatial disparity in pediatric asthma: A Kansas City case study	Group 1: white Group 2: Latinx Group 3: Black Group 4: other/multiracial	% racial/ethnic minority (as part of Social & Health vulnerability index)	Bayesian profile regression	Census tract ____ Point density analysis for acute care visits	Y	Individual: Age, Sex, Race/Ethnicity, Medical coverage (type) Census tract: Environmental justice screening for 3 aggregate measures - sensitive land use & hazard proximity (traffic proximity & volume; proximity to risk management sites and treatment, storage, & disposal facilities; walkability to transit) -health risk & exposure (individual lifetime cancer risk, diesel particulate matter, respiratory hazard index) -social & health vulnerability (% age 24 & over without high school ed., % linguistic isolation, % at or below 200% poverty, % minority, % renter, median home value, % age 6 & under, % age 60 & over	EPA respiratory hazard index EPA individual lifetime cancer risk index Diesel PM2.5: (ug/m^3)
Kranjac et al (2017)	Comprehensive Neighborhood Portraits and Child Asthma Disparities	Group 1: white Group 2: Black Group 3: Hispanic Group 4: Asian/other	% white, % Black, % Hispanic	Maximum likelihood latent profile analysis (LPA) & Blinder-Oaxaca regression decomposition method	Census Tract ____ Kriging to estimate PM2.5 & O3 at the centroid of each census tract	Y	Individual: Age (mean-centered, gender, race/ethnicity, insurance type) Census tract: community-level education, unemployment rate, median income, median year the house was built, % female-headed households, % foreign born, % receiving public assistance, % in poverty, % vacant homes, % of major racialized categories, air pollutants (PM2.5 and O3) (mean-centered)	PM2.5: ozone (O3): daily 8-hour averages (Texas Commission on Environmental Quality, Texas Air Monitoring Information System)

Rosenbaum (2008)	Racial/Ethnic Differences in Asthma Prevalence: The Role of Housing and Neighborhood Environments	Group 1: white Group 2: black Group 3: Puerto Rican Group 4: Dominican Group 5: Central & South American Group 6: Mexican Group 7: other Hispanic, Group 8: Chinese Group 9: Asian Indian Group 10: other Asian	% white	Multilevel logistic regression models (with random intercepts and fixed slopes)	Census tracts	Y	Individual: Race/ethnicity (non-Hispanic white, non-Hispanic black, Puerto Rican, Dominican, Central/South American, Mexican, other Hispanic, Chinese, Asian Indian, and other Asian); Housing (# maintenance deficiencies, crowding, tenure status, indoor tobacco smoke); age, educational attainment, & gender of householder; total household income per 10,000; household receipt of Temporary Assistance to Needy Families Census tract: Vacant homes, social cohesion, % white, violent crime rate, # transportation facilities per 100,000; # manufacturing facilities per 100,000	Air pollution proxy: # transportation facilities per 100,000 Air pollution proxy: # manufacturing facilities per 100,000
Shankardass et al. (2010)	Social environment and asthma: associations with crime and No Child Left Behind programs	Group 1: Hispanic Group 2: white Group 3: African American Group 4: other	Dissimilarity index: - African American - Hispanic	Multilevel Cox proportional hazards models	Communities Schools Neighborhoods (census tracts) (3-level)	Y	Individual: Race/ethnicity, weight, health insurance coverage, parental education, parental stress, parental history of asthma, indoor tobacco smoke, carpet, mildew, cockroaches, water damage, musty odor, pets, gas stove, traffic air pollution, exposure to wildfires Group 1 (neighborhoods): Deprivation, racial composition, income inequality, population density Group 2 Schools: Deprivation, racial composition, academic performance, funding Group 3 communities: Deprivation, racial composition & segregation, population density, crime	Traffic-related air pollution: dispersion models for total oxides of nitrogen (NOx) Exposure to wildfires

Wilhelm et al. (2008)	Outdoor air pollution, family and neighborhood environment, and asthma in LA FANS children	Group 1: white Group 2: Hispanic Group 3: Black Group 4: Asian/other	One predominant race/ethnicity in census tract	Multilevel factor analysis for associations between air pollution and individual, family, and neighborhood characteristics Logistic regression to evaluate associations between outdoor air pollution and asthma	Census tract	Y	Individual: race/ethnicity, age, gender, health insurance status (coverage), source of childcare when sick, one or more well visits during previous 12 months Family level (individual): % of the federal poverty limit, homeowner status (yes/no), non-housing assets, public assistance in previous 12 months, PCG education (years), parents' employment status, neighborhood satisfaction, opinion of neighborhood safety, cohesion and support Census tract: Disadvantage score: % poor families, % households on public assistance, % female-headed families, % male unemployment	CO, NO2, O3: Annual average concentration of hourly measures for 1 year PM10 & PM2.5: Annual average concentration of 24-hour average measurements taken daily, or every 6 and 3 days South Coast Air Quality Management District (SCAQMD)

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Conclusion

This dissertation utilized a mixed-methods approach to examine how environmental racism and racial residential segregation may impact the health of Asian communities in CA. The first paper, a case study, used APEN 's regional campaign for "Regulation 12, Rule 16" and local campaign for "No Coal in Richmond" to describe how Asian community members protected their health and the environment after decades of disproportionate exposure to air pollution. The case revealed a persistent mismatch between the concerns of Richmond's community residents, those of the fossil fuel industry, and those of the state agencies and governments. Despite being at the forefront of EJ laws and regulations, CA and its local governments did not have air pollution or environmental policies to sufficiently protect low-income communities of color in Richmond from excessive PM2.5 exposure. Racial capitalism was a driver of environmental racism that perpetuated insufficient environmental policies and differing priorities of Richmond's stakeholders. APEN faced these challenges by employing critical EJ strategies of multi-scalar advocacy and intersectional coalition-building. These efforts ultimately yielded success in securing a city-level ordinance to reduce exposure to coal and pet coke PM2.5 in Richmond. APEN's strategies and resultant success highlight actionable pathways for future EJ advocacy in CA's Asian communities.

Paper two examined the association between racial residential segregation (measured with the location quotient) for Asian people in CA and the age-adjusted rates of ED visits for asthma per 10,000 in the neighborhoods where they live. I examined the impact of community-level contextual factors such as median household income, educational attainment, nativity status, and air pollution as modifiers of this relationship. I found that living in Asian segregated neighborhoods was protective against asthma ED visits compared to living in neighborhoods where the Asian population was underrepresented or equivalent to the greater MSA. The magnitude of protection varied by neighborhood characteristics such as median household income, college educational attainment, the composition of non-US born residents, and diesel PM2.5, with the composition of non-US born residents having the strongest protective effect. Although racial/ethnic segregation has been associated with health inequities for minority racial/ethnic groups, this ecological-level study found contradicting results for Asian segregated neighborhoods, which had overall lower asthma ED visit rates compared to neighborhoods with underrepresented Asian populations. I also identified locations of Asian segregated neighborhoods with varying asthma rates that would be ideal for future research on this topic. Subsequent research on the structural drivers of asthma inequities among Asian people can examine these areas for historical and social context that may not be captured in quantitative analyses, particularly those that are done at the ecological level.

The third paper was a narrative review that assessed the conceptualization, measurement, and examination of how segregation has been utilized in asthma research. It also investigated the extent to which Asian subgroups have been included. I found that there is a larger need to utilize a relational approach in future research so that public health studies are not overly reliant on segregation's compositional effects. A deeper examination of segregation's contextual effects, such as environmental exposures and income segregation, offers opportunities to clearly elucidate additional pathways for asthma outcomes in at-risk and under-studied populations. The review suggested that place and health research should continue to adopt and adjust conceptual

frameworks on segregation measurement, ethnic enclaves, and environmental justice to better capture the impacts of segregation on health for diverse populations.

Together, these studies made novel contributions to place and health research by focusing on Asian people in the US, a racial/ethnic group that has been underrepresented in health research. As the Asian population continues to grow, it is imperative for public health research to incorporate Asian people into structural racism research, which may identify the drivers of heterogeneous health outcomes like those for asthma. This dissertation provided several research and practice implications as public health research shifts and adjusts to the US population's diversification.