# HHS Public Access

Author manuscript

*Soc Sci Med*. Author manuscript; available in PMC 2018 July 01.

Published in final edited form as:

*Soc Sci Med*. 2017 July ; 185: 71–80. doi:10.1016/j.socscimed.2017.05.042.

# Asian Americans and disproportionate exposure to carcinogenic hazardous air pollutants: A national study

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## Abstract

Studies have demonstrated disparate exposures to carcinogenic hazardous air pollutants (HAPs) in neighborhoods with high densities of Black and Hispanic residents in the US. Asians are the fastest growing racial/ethnic group in the US, yet they have been underemphasized in previous studies of environmental health and injustice. This cross-sectional study investigated possible disparities in residential exposure to carcinogenic HAPs among Asian Americans, including Asian American subgroups in the US (including all 50 states and the District of Columbia, $n$ = 71,208 US census tracts) using National Air Toxics Assessment and US Census data. In an unadjusted analysis, Chinese and Korean Americans experience the highest mean cancer risks from HAPs, followed by Blacks. The aggregated Asian category ranks just below Blacks and above Hispanics, in terms of carcinogenic HAP risk. Multivariate models adjusting for socioeconomic status, population density, urban location, and geographic clustering show that an increase in proportion of Asian residents in census tracts is associated with significantly greater cancer risk from HAPs. Neighborhoods with higher proportions (as opposed to lower proportions) of Chinese, Korean, and South Asian residents have significantly greater cancer risk burdens relative to Whites. Tracts with higher concentrations of Asians speaking a non-English language and Asians that are US-born have significantly greater cancer risk burdens. Asian Americans experience substantial residential exposure to carcinogenic HAPs in US census tracts and in the US more generally.

### Keywords

environmental injustice; Asian Americans; Hazardous Air Pollutants

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## Introduction

Air pollution is a significant international public health threat, causing more than seven million deaths per year. Outdoor air pollution exposure is linked with heart disease, stroke, respiratory diseases and cancer (World Health Organization, 2014). In cities and countries worldwide, the burden of outdoor environmental exposures is more often borne by low-income and minority people (Crouse, Ross, & Goldberg, 2009; Jephcote & Chen, 2013; Pearce, Richardson, Mitchell, & Shortt, 2011). In the United States, Black and Latino/a populations experience greater exposure to environmental toxics than do Whites (Bell & Ebisu, 2012; Clark, Millet, & Marshall, 2014; Jones et al., 2014; Mohai, Pellow, & Roberts, 2009). This uneven exposure is termed 'environmental injustice' and is a contributing factor to disparities in health (Coker et al., 2016; Payne-Sturges & Gee, 2006; Pearce et al., 2011). Asians are the fastest growing racial/ethnic group in the US (Pew Research Center, 2016), yet they have been underemphasized in previous studies of environmental health and injustice. Currently, there are over 18 million Asian Americans in the US. They comprise 6% of the total population and three-quarters of Asian adults are foreign-born (Pew Research Center, 2016).

The lack of attention paid to the environmental health of the nation's fastest growing racial/ethnic group likely relates to the model minority label, which has been applied to Asian Americans, since they have the highest incomes and levels of education of all racial groups in the US. Specifically, half of Asian American adults have a college degree compared to one-quarter of all Americans, and their median annual household income is $66,000 compared to the national average of $49,800 (Pew Research Center, 2016). The model minority label was originally constructed in a context of Black-White race relations in the 1960s and used to undermine arguments for race-specific policies to promote the status of disadvantaged minorities (Yi, Kwon, Sacks, & Trinh-Shevrin, 2016). The claims underpinning the label are that the failures of non-Asian minorities are attributable to personal shortcomings, such as laziness, rather than socially-structured disadvantages, and that Asian minorities are hard-working individuals whose success reflects the unfettered opportunities available to everyone in the US.

The model minority label has diverted attention away from health disparities experienced by the Asian American population. For example, cancer is the leading cause of death for Asian Americans (CDC, 2010; Chen, 2005), yet physicians recommend preventative cancer screenings to Asian patients at a lower rate than other groups, in part because of the model minority stereotype (Ibaraki, Hall, & Sabin, 2014). The neglect of health disparities experienced by Asian Americans has only recently been highlighted in the political arena. In 2009, President Obama signed an Executive Order on the Asian community, which included calling for strategies to improve the health of Asian Americans and to redress health disparities impacting them (Obama, 2009).

It is likely that the model minority label has informed conventional wisdom within the research community regarding who in the US is likely to experience environmental health disparities. Asians are included less often than Blacks and Latinos/as in studies of environmental health disparities and injustice, based on the conventional presumption that they would have similar risk profiles to Whites. Sometimes, their population size in a given study area is too small for them to be considered. When Asians are examined, results indicate that they face higher risk from environmental health hazards than Whites (Clark et al., 2014; Cushing et al., 2015; Liam Downey, DuBois, Hawkins, & Walker, 2008; Houston, Li, & Wu, 2014; Lievanos, 2015; McKelvey et al., 2007; Morello-Frosch & Jesdale, 2006; Payne-Sturges & Gee, 2006) [see Jones et al. (2014) for an exception]. However, results indicative of disproportionate risk for Asian Americans have been de-emphasized in many studies.

The model minority label has obfuscated understanding of environmental health disparities experienced by Asian Americans in varied ways. First, the population-level statistics documenting high levels of education and income among Asian Americans conceal the systemic racism that Asians have experienced in the US over the past 150 years (Chou & Feagin, 2015). Greater recognition of this racism would lead to more research on its effects, including those related to environmental health.

Second, internalization of the model minority label by many Asian Americans has produced individuated understandings and experiences of racial oppression. As compared to Black Americans, Asian Americans more often suffer alone and in silence after being victims of discriminatory incidents, which disables them from collectively mobilizing based on their shared experiences of oppression (Chou & Feagin, 2015). In Black communities, there is a stronger collective memory of racism and resistance culture. This contributes to lower levels of social movement organizing by Asians as compared to Blacks (Chou & Feagin, 2015).

Third, the label was strategically created and circulated in the Civil Rights era in order to drive a wedge between other minorities and Asians, as dominant Whites upheld Asians as an example of minority success and evidence for the existence of equal opportunity (Yi et al., 2016). The logical extension of accepting this discourse as fact is that the prevalence of environmental health disparities among Asians in the US appears highly improbable (and, in any case, inexplicable), since it is taken for granted that Asian Americans share high status with Whites. Relatedly, it should be recognized that the environmental justice (EJ) movement itself—and the attendant research on environmental health disparities that the EJ movement spawned—is a political-racial project connecting Civil Rights concerns about racial equality to environmental conditions (Pulido, 1996). It should thus come as no surprise that the dominant framing of EJ in the US has been one of low-income Blacks, and more recently Latino/as, facing environmental injustices in their neighborhoods, with Whites being environmentally privileged. As a result, Asian EJ organizing has been poorly documented in the academic literature and rarely recognized by the wider EJ community, which Sze (2004) terms “the problem of Asian invisibility” (p. 155). In cities across the US, Asian communities have mobilized against hazards in their communities, winning a multilingual warning system and halting an expansion at a Chevron Refinery in Richmond, CA (Asian Pacific Environmental Network, 2012); saving Boston’s Chinatown from demise (Leong, 1995/1996); and providing emergency relief to Vietnamese Americans following Hurricane Katrina (Community-Wealth, 2017). While there is some evidence of Asian EJ activism, the lack of coverage of their organizing feeds back into a lack of focus on Asians in environmental health disparities research.

The discourse of Asians as a model minority group also masks substantial diversity that exists within the US Asian population, and may conceal disparate environmental health risks experienced by particular Asian subgroups. The importance of disaggregating the US Hispanic/Latino population in studies of environmental health disparities has been recognized, and significant differences in exposure to toxics have been uncovered between Latino/a subgroups (Chakraborty, Grineski, & Collins, 2017; Collins, Grineski, Chakraborty, & McDonald, 2011; Grineski, Collins, Chakraborty, & Montgomery, 2016; Grineski, Collins, & Chakraborty, 2013). In one of the only studies of its kind, Korean and Japanese women in California were found to face substantial exposure to mammary gland carcinogens in their neighborhoods, even though the risks for White women as compared to Asian women aggregated into one category were similar overall (Quach et al., 2014). Another study found that over 40% of the Japanese population and 30% of the Filipino population in the US lived in counties that exceed PM2.5 air quality standards; when aggregated together, they found that 20% of the US Asian population lived in exceedance counties (Gordon, Payne-Sturges, & Gee, 2010). Weaknesses in both of these studies include their bivariate study designs that did not adjust for other known factors influencing environmental exposures, e.g., population density and socioeconomic status, and their reliance on data from 2000.

This is the first study to focus on environmental health disparities among Asian Americans and Asian American subgroups in terms of cancer risks from HAPs. We conduct a national-level study at the census tract level using the recently released 2011 National Air Toxics Assessment. We assess the disproportionate risk of Asian Americans to carcinogenic HAPs before disaggregating the Asian category into ancestry, language and nativity subgroups in order to examine risk disparities exhibited within this heterogeneous population.

## Materials and Methods

### Study Population

We conducted our investigation across all 50 states and the District of Columbia using a set of socio-demographic variables derived from the 2010 Decennial Census and the 2008–2012 American Community Survey (ACS) estimates at the census tract level. To ensure stable proportions for all our variables, we use the 71,208 census tracts with at least 500 people, 200 households, and complete data for all analysis and clustering variables.

### Assessment of Exposure to Carcinogenic HAPs

We used the US EPA's 2011 National Air Toxics Assessment (NATA), which was released in 2015 (Environmental Protection Agency, 2016) to measure tract-level cancer risk exposure estimates in the US. The NATA includes 187 specific substances identified in the Clean Air Act Amendments of 1990 that are known or suspected causes of cancer and other serious health problems. Inputs on HAP emissions in the NATA come from the 2011 National Emissions Inventory and a multi-step methodology is used to generate estimates of cancer risk (Environmental Protection Agency, 2016). The 2011 NATA estimates potential cumulative risks to public health from HAP exposure following the EPA's risk characterization guidelines that assume a lifelong exposure to 2011 levels of emissions.

Cancer risks in the 2011 NATA, which we use here, are derived using unit risk estimates (URE), an upper bound estimate of an individual's probability of contracting cancer over a lifetime of exposure to a concentration of one microgram of the pollutant per cubic meter of air. For each census tract, the individual lifetime cancer risk associated with each HAP is calculated by combining exposure concentration estimates with available UREs and inhalation reference concentrations. Although the type of cancer and available evidence varies by pollutant, the cancer risks of different HAPs are assumed to be additive and are summed to estimate an aggregate lifetime cancer risk for each census tract, measured in persons per million. These risk estimates are considered to be upper-bound estimates of the probability that an individual will contract cancer over a 70-year lifetime as a result of exposure to HAPs. A lifetime cancer risk of one in a million, for example, implies that one out of a million equally exposed people would contract cancer if exposed continuously to that specific concentration over 70 years. This would be an excess cancer risk in addition to other cancer risks borne by a person not exposed to these HAPs.

The 2011 NATA risk estimates for this study were obtained directly from the EPA for all census tracts (based on 2010 boundaries). Estimates of cumulative lifetime cancer risk (persons per million) include risks associated with inhalation exposure to HAPs released by major stationary sources (e.g., factories), smaller stationary sources (e.g., small manufacturers), on-road mobile sources (e.g., trucks), non-road mobile sources (e.g., trains, construction vehicles), and background concentrations (i.e., contributions from distant or natural sources). The NATA risk estimates do not consider residents' length of residence in census tracts, nor do they consider the space-time patterning of residents' movements across a range of outdoor and indoor environmental contexts within and beyond their census tracts of residence. Thus, while NATA risk estimates are quantified in terms of cumulative lifetime exposure to HAPs, for the purposes of this analysis, they provide estimates of relative cancer risk attributable to outdoor residential HAP exposures. Figure 1 is a map of the cancer risk dependent variable used in the multivariate analyses.

### Assessment of Tract-level Sociodemographics

To assess tract-level sociodemographic characteristics, we used the 2010 US Decennial Census to construct analysis variables whenever possible, since the Decennial Census includes the total population and is not a sample. To construct analysis variables that lacked corresponding data in the Decennial Census, we used 2012 American Community Survey (ACS) 5-year estimates, which center on 2010. These data are collected by the US Census Bureau, and are based on a sample of the population.

In terms of race/ethnicity, we analyzed seven indicators derived from Decennial Census data, including the proportions of census tract residents identified as being Hispanic or Latino (any race), White non-Hispanic, Black non-Hispanic, American Indian non-Hispanic, Pacific Islander/Native Hawaiian non-Hispanic, Multi-racial/Other non-Hispanic and Asian non-Hispanic (see Figure 2). Henceforth, we do not add "non-Hispanic" after every mention of the non-Hispanic racial/ethnic groups (e.g., we use the term "White", instead of "White non-Hispanic").

We also examined several variables related to Asian ethnic heterogeneity, constructed from ACS data, including indicators of ancestry, language, and nativity. For ancestry, we used the coded open-ended responses to the ACS question "What is your ancestry or ethnic origin?". The ACS codes responses into 18 categories for Asians. Based on small counts and regional similarities, we created seven ancestry categories: Chinese, South Asian (i.e., Indian, Pakistani, Bangladeshi, and Sri Lankan), Filipino, Southeast Asian (i.e., Cambodian, Laotian, Hmong, and Vietnamese), Korean, Japanese, and Other Asians (including Thai, Malaysian, Indonesian, and Taiwanese). Using census tract population counts for those Asian ancestry categories as numerators and the total tract population as the denominator, we constructed seven proportion variables. Note that these variables gauge ethnic identity and heritage rather than place of birth. For language, we used the proportion of the Asian alone population over age five that speaks another (not English) language. For nativity, we used the proportion of the Asian alone population in the tract that is foreign-born. These variables enable us to examine possible disparities in cancer risk from HAPs within the Asian population, based on ancestry, language, and immigrant vs. US-born status.

We also adjusted for the effects of other variables commonly included in quantitative EJ studies. For socioeconomic status (SES), we included median household income from the ACS and the proportion of renter-occupied housing units from the Decennial Census. We included median income, which maps to wealth, power and political clout (Mohai & Saha, 2006); we also included median income squared in the model because the relationship between income and hazard exposure may be curvilinear. This is because low income neighborhoods tend to have fewer economic activities and hence fewer sources of pollution, while high income neighborhoods typically have the political power to resist pollution sources; thus, more air pollution risks are expected in middle income neighborhoods (Pastor, Morello-Frosch, & Sadd, 2005). While education is an important component of SES, an education variable (e.g., percent with a high school diploma or less) was not included as a separate indicator in this study due to collinearity with income. Instead, we conducted a sensitivity analysis using a SES factor combining income and education. Housing tenure was included because renter occupancy indicates greater housing instability, political disengagement, and reduced household resources compared to owner occupancy (Chakraborty, Collins, Montgomery, Grineski, & Hernandez, 2014; Pastor et al., 2005).

We adjusted for crude population density, which was calculated by dividing the total census tract population for 2010 by the area of the tract in square kilometers, because densely populated areas are more likely to contain emission-generating activities that increase estimates of cancer risk from HAPs (Chakraborty et al., 2014). Finally, we included a dichotomous urban location variable given that pollution risks tend to be higher in urban areas. After creating a percent urban housing units variable using Decennial Census data, we employed k-means cluster analysis to naturally break census tracts between urban vs. rural categories. Descriptive statistics of all analysis variables are included in Table 1.

## Statistical Analysis

We began by calculating national population-weighted mean cancer risks for race/ethnicity and ancestry groups by multiplying the number of people in each race/ethnicity and ancestry group by the cancer risk value in each tract, and then summing those values and dividing by the total US population in that group (Clark et al., 2014). Then, we specified four generalized estimating equations (GEEs). GEEs expand the generalized liner model to accommodate clustered data (Liang & Zeger, 1986; Nelder & Wedderburn, 1972; Zeger & Liang, 1986). We defined clusters of census tracts based on median year of housing construction ("2000 or later", "1990 to 1999", "1980 to 1989", "1970 to 1979", "1960 to 1969", "1950 to 1959", "1940 to 1949", and "1939 or earlier") by county (n=3,101), which yielded 10,455 clusters. This cluster definition method was selected because it corresponds with temporal dimensions of the built-environment across urban space that are associated with the historical-geographical formation of environmental injustice (Bolin, Grineski, & Collins, 2005; Pulido, 2000) and a similar approach has been used previously in similar studies (Collins, Grineski, & Chakraborty, 2015; Collins, Grineski, Chakraborty, Hernandez, & Montgomery, 2015).

GEEs also require the specification of an intracluster dependency correlation matrix (Liang & Zeger, 1986; Zeger & Liang, 1986). Three correlation structure specifications were substantive candidates (Garson, 2012): (1) *independent,* which assumes the nonexistence of dependency, so that all off-diagonal elements of the working correlation matrix are zero; and (2) *exchangeable*, which assumes constant intracluster dependency, so that all the off-diagonal elements of the correlation matrix are equal and (3) *unstructured*, which assumes a completely general correlation matrix, which is estimated without constraints. We modeled all GEEs (outlined below) with the three matrices, using goodness-of-fit coefficients to determine the best specification (Garson, 2012). The exchangeable specification performed better than the independent and unstructured, and so all reported results use that specification.

Model 1 is a traditional EJ model that includes the proportion of tract residents in each racial/ethnic minority group, socioeconomic status, population density, and urban location. The race/ethnicity covariates can be interpreted relative to proportional changes in the White population. In Model 2, we added the seven Asian ancestry proportion variables in place of proportion Asian and those coefficients are interpretable relative to proportional changes in the White population. Model 3 includes the language variable, and so proportion White is added and proportion Asian is removed to make the race/ethnicity covariates and language variable interpretable relative to the proportion of Asians that speak a non-English language. Model 4 includes the proportion of Asians that are foreign-born, in place of the language variable, and the covariates can be interpreted in the same way as in Model 3.

To select the best fitting models, we estimated a series of GEEs by varying the model specifications. We tested normal, gamma and inverse Gaussian distributions with logarithmic and identity link functions. Visual inspection of a histogram of our dependent variable suggested that these were the most appropriate options, given that the dependent variable was not normally distributed. For these four models, the inverse Gaussian distribution with an identity link function was the best fitting. Finally, we examined possible multicollinearity among the analysis variables; based on variance inflation factor, tolerance, and condition index criteria, inferences from the GEEs are not affected by multicollinearity. All independent variables were standardized before inclusion in the GEEs in order to make coefficients directly comparable. We define statistical significance as $p<.001$, due to the large sample.

## Results

Figure 3 reports population-weighted mean cancer risk from HAPs by racial/ethnic and Asian ancestry group. The mean excess cancer incidence attributable to ambient HAP exposures in the census tract of residence for Asian people in the United States is 44.4 per 1 million, which ranks them second of the seven racial/ethnic groupings (see the dark gray bars in Figure 3) and above the US mean (see black bar in Figure 3). Blacks face the highest risk in the United States and Hispanics the third highest. When considering the Asian ancestry groups (see the light gray bars in Figure 3), both Chinese and Korean populations face greater risks than Blacks in the US. After Blacks, 'other' Asians, Southeast Asians and South Asians face the next highest risks, ranking above Hispanics. All Asian ancestry subgroups are above the US mean.

Table 2 reports the GEE results for Models 1 and 2. In Model 1, as the proportion of Asian, Black and Hispanic residents in a neighborhood increases relative to the proportion White, cancer risk from HAPs increase significantly. Specifically, a one standard deviation increase (i.e., ~8%) in proportion Asian is associated with HAP cancer incidence risks that are 0.95 (95% CI: 0.76,1.14) persons per million greater than other census tracts, adjusting for the other variables and clustering. As the proportion of American Indian individuals and the proportion of Pacific Islanders/Native Hawaiians increases in a neighborhood, risk decreases significantly. The coefficient for Multiracial/other is also negative but not statistically significant. In terms of the control variables, income is negative and not significantly associated with risk, although the quadratic term suggests a non-linear association. The proportion of renter-occupants is positively and significantly associated with risk, as is residence in a predominately urban (vs. rural) tract. Population density is the strongest predictor, with more densely populated tracts facing greater risk. Urban, Black, Rented, and Asian are the next four strongest predictors of cancer risk. In terms of ancestry (Model 2), increases in the proportions of Chinese, South Asian, and Korean residents (relative to the proportion White) are significantly associated with greater cancer risk from HAPs, while relationships for the other groups are not statistically significant.

Table 3 presents results for Models 3 and 4. An increase in the proportion of Asians who speak a non-English language relative to those who do not (Model 3) and a decrease in the proportion of Asians who are foreign-born relative to US-born (Model 4) were significantly associated with increased cancer risk from HAPs.

As a sensitivity analysis, we ran the models without the clustering variables and found that the findings were generally consistent but more statistically significant, indicating that controlling for clustering produced more conservative estimates of relationships with HAP cancer risk. We also ran the models using the factor combining income and education. Results were nearly identical in terms of significance, suggesting that the findings are not sensitive to how SES is measured. There were three minor differences: in Model 1, Pacific Islander drops from $p<0.001$ to $p=0.003$; in Model 3, black becomes significant at $p<0.001$

instead of $p$=0.002; and in Model 4, foreign-born reduces in significance to $p$<0.01 from $p$<0.001.

## Discussion

This is the first focused examination of Asian Americans and distributive EJ in the US. The unadjusted and multivariate analyses reveal that Asians experience significant environmental health injustices nationwide, in terms of facing disparate residential exposures to carcinogenic HAPs. It is not simply the case that Asians face greater exposure to cancer-causing chemicals than Whites; they also face greater risks than Hispanics and have similar but slightly lower risks than Blacks. Nonetheless, they have been largely overlooked within the EJ movement and within the EJ research community (Sze, 2004). The lack of research on Asian Americans' environmental health makes us unable to determine if this pattern of disparate risk would be found nationwide for other environmental health hazards, such as respiratory toxics and diesel particulate matter, or for occupational exposures, which are beyond the scope of this study.

There are likely health consequences of unequal exposures to environmental health hazards for Asian Americans (Gordon et al., 2010). While heart disease is the leading cause of death in the US, cancer is the leading cause of death for Asian Americans (CDC, 2010). While some cancers known to impact Asians are less linked to air pollution (e.g., liver, stomach), lung cancer and breast cancer, which are among the leading causes of cancer death for Asians (Torre et al., 2016), have been linked to environmental conditions (Crouse, Goldberg, Ross, Chen, & Labrèche, 2010; Fajersztajn, Veras, Barrozo, & Saldiva, 2013). Many Asian Americans also face unhealthy levels of stress in their daily lives due to being the "model minority" as well as frequent victims of discriminatory acts (Chou & Feagin, 2015; Gee, Spencer, Chen, Yip, & Takeuchi, 2007). Stress can synergize with environmental exposures to worsen health (Gee & Payne-Sturges, 2004).

### The Importance of Asian Ancestry

While Asian Americans as a group are burdened by cancer-causing HAPs independent of their ancestry, specific ancestry groups face heightened risks. Chinese, Korean, and South Asian Americans are associated with disproportionate risk across both analyses (Figure 3, Table 2). Southeast Asians have high risk, i.e., they were just behind Chinese and Koreans in the unadjusted analyses (Figure 3), but their coefficient is not significant in the multivariate analysis (Table 2). The differences between the two sets of results relate to the unit of analysis (individuals vs. census tracts) and the addition of control variables in the multivariate model. While findings indicate that these groups experience disparate risks, possible explanations for the processes contributing to those disparate risks differ between ancestry groups.

The Chinese have the highest risk from carcinogenic HAPs of all groups included in the unadjusted analysis and they also have the second strongest association with HAP risk (i.e., second largest "B") as compared to the other Asian ancestry groups in the multivariate model (Table 2). These findings are particularly troubling because the Chinese are the largest Asian ancestry group in the US. It is possible that their actual exposure is less than estimated, since emerging evidence from Los Angeles and Chicago shows that older Chinese adults spend less time outside than Black, White and Hispanic adults (Spalt et al., 2016). However, when examining blood concentrations of heavy metals, Chinese adults had higher levels compared to other racial/ethnic groups (McKelvey et al., 2007) and Chinese women face notably high rates of lung cancer, given their low rates of smoking (Torre et al., 2016). The risk for Chinese people uncovered in this study likely relates to their longstanding urban settlement in the US, racism and discrimination, and their continued desire to live near co-ethnics. Analyses of Chinese settlement in California have shown that even Chinese immigrants who are financially able to residentially integrate into other neighborhoods often choose to live among others of the same ethnicity. This means that Chinese immigrants' first neighborhood of residence is often their final, desired destination (Walton, 2015) and Chinese immigrants usually settle in urban contexts (Zhou, Tseng, & Kim, 2008). Although some highly educated new Chinese immigrants bypass inner cities to settle in the suburbs, traditional Chinatowns continue to receive newcomers and have expanded in recent years (Lin, 1998; Zhou et al., 2008). The long history of Chinese settlement in the US, combined with historical discrimination against Chinese people (Tsai, 1986), means that 'Chinatowns' are often in polluted central city districts.

Korean Americans have the second highest risk from carcinogenic HAPs of all groups (Figure 3) and the strongest association with HAP risk (i.e., largest "B") as compared to the other Asian ancestry groups (Table 2). There are distinctive reasons for the high risk experienced by Koreans, which were also noted in a California study (Quach et al., 2014). Koreans have tended to settle in poor, commercially underserved, central city neighborhoods, where they operate small businesses (Lee, 2000). Entrepreneurship has contributed to their upward social mobility (Lee, 2000), but their high risk suggests that it has come with an environmental health consequence of heightened residential exposure to carcinogenic HAPs.

Risks for South Asians (Figure 3 and Table 2) likely stem from their immigrant status and engagement in the science and engineering sectors. For example, 87% of South Indian adults are foreign-born and one-third are employed in science and engineering fields (Pew Research Center, 2016). Given that South Asians make up a sizable segment of the science and engineering workforce in the US and are continually migrating to the US to work, it stands to reason that they may be exposed to HAPs due to their desire to live near industrial and tech facilities where they may be employed.

Amplified cancer risks from HAPs among Southeast Asians (Figure 3) derive in part from their status as refugees upon entry to the US (Rumbaut, 2000). Refugees tend to settle in more socially disadvantaged neighborhoods than voluntary migrants (Phillip, 2010). Compared to other Asian Americans, Southeast Asians are more likely to be supported by government assistance programs, have minimum wage jobs, and work in the informal economy (Rumbaut, 2000). Their socioeconomic marginality and reliance on government assistance may lead them to highly polluted, central-city neighborhoods.

Japanese Americans appear to be relatively protected against cancer risks as compared to the other groups, although their unadjusted risk is higher than Whites (Figure 3). Their relative safety may be an outcome of the displacement and forced internment of Japanese Americans during World War II. After the War, the Japanese were dispersed throughout the US (Cho, Gimpel, & Dyck, 2006; Daniels, 2011). Filipinos have similar overall risks to the Japanese, which puts them on the low end of risk among Asians but still higher than Whites.

### The Importance of Language and US Nativity

Higher proportions of Asians speaking a language other than English and lower proportions of Asians who were foreign-born are important dimensions of social difference linked to greater cancer risk from air pollution. Speaking a language other than English was also a risk factor for exposure to air toxics in Hispanic populations in the immigrant gateways of El Paso, Texas (Collins et al., 2011) and Miami, Florida (Chakraborty et al., 2017). Speaking a non-English language may make it difficult for people to participate in environmental decision-making processes, which are traditionally English-only. In the case of nativity, researchers found that foreign-born Hispanics were at disproportionate risk (Chakraborty et al., 2017; Collins et al., 2011; Grineski et al., 2016), which is opposite of what we find here for Asians. While this pattern would likely vary based on ancestry group (e.g., between elite Cubans and poor Vietnamese refugees), the nativity divergence may more generally relate to the socially marginal status of Hispanic immigrants and the relatively elite status of well-educated Asian immigrants. The risk disparities based on nativity suggest that intergenerational adjustment to life in the US is actually associated with heightened risk for Asian Americans. This indicates that upward social mobility associated with longer term residence in the US may not protect Asian Americans from exposure to cancer-causing HAPs, as it may for Latino/as. These two findings for Asians taken together suggest that multigenerational Asian Americans may experience relatively high cancer risk to HAPs by remaining in the same (centrally located, ethnic enclave) neighborhoods as their immigrant parents and grandparents, while remaining linguistically connected with their ancestral roots.

### Limitations and Future Directions

This study is limited by the modifiable areal unit problem, which arises when the boundaries of the unit of analysis are modifiable and to some degree arbitrary (Fotheringham & Wong, 1991), e.g., census tracts. Sensitivity analyses show that changing the way data are aggregated can affect findings (Downey, 2006). We assumed, as is the convention in air pollution epidemiology, that residential outdoor HAPs are good proxies for individual exposure, even though most people spend the majority of their time indoors and how pollution infiltrates homes varies by location and season (Spalt et al., 2016). Future studies should use individual-level data and incorporate understanding of people's time-location patterns. Another limitation is our focus only on cancer-causing HAPs, even though HAPs can harm neurological, reproductive and respiratory systems. Related to the respiratory system, Asian Americans have rates of asthma that are similar to Whites, but Asians of Japanese and Filipino descent have significantly higher rates of asthma (Gordon et al., 2010), as do US-born Asians (Brugge, Lee, Woodin, & Rioux, 2007). The component of these elevated rates attributable to environmental exposures has not yet been investigated, but should be in future studies. Finally, future studies of factors that might reduce the cancer burden for Asian Americans should examine unequal exposure to HAPs, since smoking cessation, improved diets, more exercise, and reduced barriers to screening are more often the focus of those efforts (Chen, 2005).

## Conclusions

Nationally, Chinese and Korean populations experience the greatest mean cancer risks due to HAPs, followed by the Black population. Multivariate results reveal an association between higher proportions of Asian Americans in neighborhoods and greater exposure to carcinogenic HAPs. Neighborhoods with greater proportions Chinese, Korean, and South Asian Americans are also at increased risk, as are neighborhoods with greater proportions of Asians speaking a non-English language and US-born Asians. It seems that the model minority myth has exerted power over inquiry within the environmental health and EJ research communities, as analytical attention has long been diverted away from Asian Americans. These findings highlight the significant environmental health disparities experienced by Asian Americans, which have been previously overlooked, and speak to the urgent need to address them.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

## Acknowledgments

Research reported in this paper was supported by the National Institute of General Medical Sciences of the National Institutes of Health under linked Award Numbers RL5GM118969, TL4GM118971, and UL1GM118970. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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## Research Highlights

- Asians have been underemphasized in previous studies of environmental injustice
- Chinese and Korean Americans face notably high air pollution risks
- Higher % Asian in census tracts is associated with greater air pollution risks
- Tracts with higher % of US-born Asians have greater air pollution risks
- Tracts with higher % Asians not speaking only English have greater pollution risks

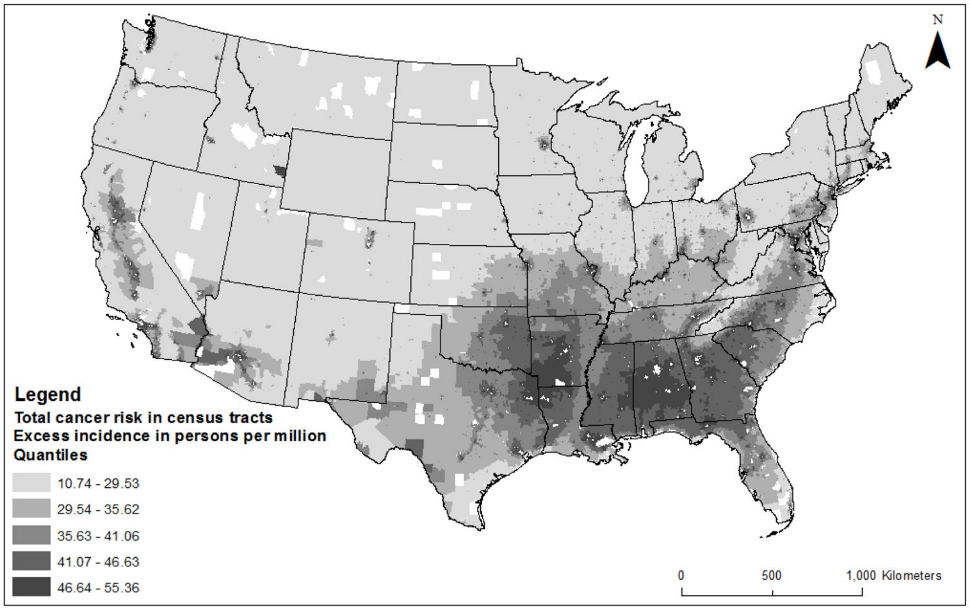


**Figure 1.**

Total estimated cancer risk for census tracts in the US, 2011

Note: The calculation of the quantiles includes analysis tracts in Alaska and Hawaii, which are not depicted in the map (see supplemental material). Tracts that were excluded due to missing data and small counts are not mapped.

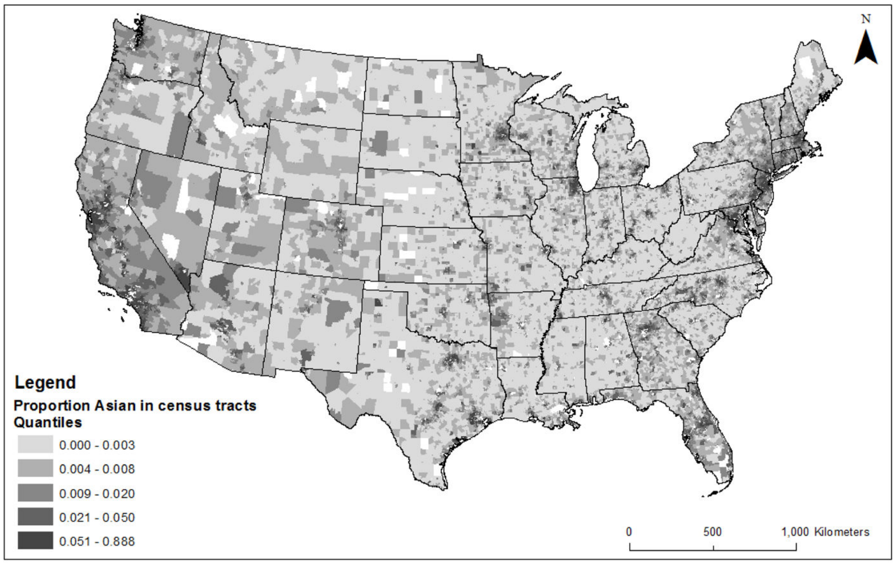


**Figure 2.**
Proportion non-Hispanic Asian residents in census tracts in the US, 2010
Note: The calculation of the quantiles includes analysis tracts in Alaska and Hawaii, which are not depicted in the map (see supplemental material). Tracts that were excluded due to missing data and small counts are not mapped.

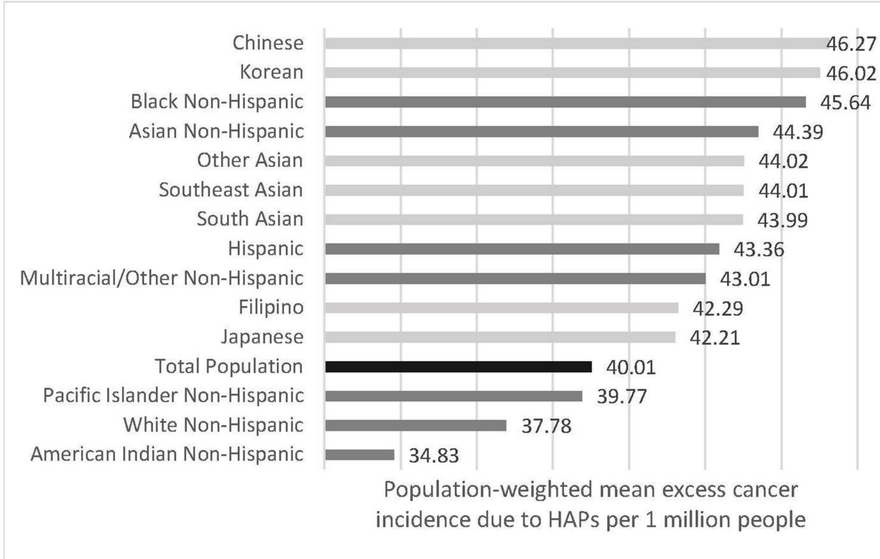


**Figure 3.**

Population-weighted estimated mean excess cancer incidence due to HAPs by racial/ethnic and Asian ancestry group in the US, 2011

Note: The black bar represents the national average. Dark gray bars represent broad racial/ethnic classifications and light gray bars represent Asian ancestry groups.

## Table 1

Descriptive statistics for census tracts in the United States (n=71,208)

| Variables | N | Min. | Max. | Mean | Std. Deviation |
|---|---|---|---|---|---|
| DEPENDENT VARIABLE | | | | | |
| **Total Cancer Risk** (excess incidence due to HAPs per million) | 71208 | 10.742 | 826.309 | 40.118 | 12.545 |
| INDEPENDENT VARIABLES | | | | | |
| Median **Household Income** | 71208 | 4092 | 247064 | 56342 | 27463 |
| Proportion of occupied housing units that are **rented** | 71208 | 0.005 | 1.000 | 0.356 | 0.222 |
| Proportion of population that is **White** | 71208 | 0.000 | 0.997 | 0.640 | 0.302 |
| Proportion of population that is **Hispanic** | 71208 | 0.000 | 0.994 | 0.153 | 0.209 |
| Proportion of population that is **Black** | 71208 | 0.000 | 0.992 | 0.134 | 0.220 |
| Proportion of population that is **American Indian** | 71208 | 0.000 | 0.982 | 0.008 | 0.045 |
| Proportion of population that is **Asian** | 71208 | 0.000 | 0.898 | 0.043 | 0.083 |
| Proportion of population that is **Pacific Islander or Hawaiian Native** | 71208 | 0.000 | 0.716 | 0.001 | 0.009 |
| Proportion of population that is **multi-racial or other** race | 71208 | 0.000 | 0.248 | 0.003 | 0.010 |
| **Population Density** (people per $km^2$) | 71208 | 0.012 | 196419 | 2021 | 4555 |
| **Urban** Location | 71208 | 0 | 1 | 0.797 | 0.403 |
| Asian Ancestry Groups | | | | | |
| Proportion of population that is **Chinese** | 71208 | 0.000 | 1.000 | 0.010 | 0.038 |
| Proportion of population that is **South Asian** | 71208 | 0.000 | 0.702 | 0.010 | 0.029 |
| Proportion of population that is **Filipino** | 71208 | 0.000 | 0.893 | 0.007 | 0.025 |
| Proportion of population that is **Southeast Asian** | 71208 | 0.000 | 0.639 | 0.007 | 0.024 |
| Proportion of population that is **Korean** | 71208 | 0.000 | 0.582 | 0.004 | 0.017 |
| Proportion of population that is **Japanese** | 71208 | 0.000 | 0.521 | 0.002 | 0.014 |
| Proportion of population that is **Other Asian** | 71208 | 0.000 | 0.248 | 0.003 | 0.010 |
| Asian Language and Nativity Variables | | | | | |
| Proportion of Asians over 5 that **speak a non-English language** | 71208 | 0.000 | 1.000 | 0.527 | 0.402 |
| Proportion of Asians that are **foreign-born** | 71208 | 0.000 | 1.000 | 0.538 | 0.375 |

## Table 2

GEE results for Models 1 and 2: Traditional environmental justice model (1) and Asian ancestry model (2) for census tracts in the United States (n=71,208)

| | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | B (95% Confidence Interval) | SE | Sig. | B (95% Confidence Interval) | SE | Sig. |
| Intercept | 35.471 (35.097, 35.846) | 0.191 | ** | 35.383 (35.007, 35.759) | 0.192 | ** |
| Income | −0.351 (−0.695, 0.065) | 0.194 | | −0.293 (−0.673, 0.086) | 0.194 | |
| Income Squared | 0.672 (0.381, 0.963) | 0.149 | ** | 0.632 (0.340, 0.923) | 0.149 | ** |
| Prop. Rented | 1.376 (1.185, 1.567) | 0.097 | ** | 1.356 (1.164, 1.549) | 0.098 | ** |
| Prop. Hispanic | 0.735 (0.545, 0.926) | 0.097 | ** | 0.750 (0.561, 0.939) | 0.097 | ** |
| Prop. Black | 1.801 (1.554, 2.047) | 0.126 | ** | 1.787 (1.539, 2.035) | 0.127 | ** |
| Prop. American Indian | −0.362 (−0.428, −0.296) | 0.034 | ** | −0.364 (−0.430, −0.298) | 0.034 | ** |
| Prop. Pacific Islander/Nat Hawaiian | −0.103 (−0.165, −0.041) | 0.032 | ** | −0.078 (−0.144, −0.012) | 0.034 | |
| Prop. Multiracial/Other | −0.081 (−0.171, 0.010) | 0.046 | | −0.076 (−0.167, 0.015) | 0.046 | |
| Prop. Asian | 0.952 (0.761, 1.143) | 0.097 | ** | NA | NA | NA |
| Pop Density | 5.508 (4.665, 6.351) | 0.431 | ** | 5.533 (4.684, 6.383) | 0.434 | ** |
| Urban Location | 4.776 (4.554, 4.998) | 0.113 | ** | 4.826 (4.604, 5.048) | 0.113 | ** |
| Prop. Chinese | | | | 0.394 (0.244, 0.545) | 0.077 | ** |
| Prop. South Asian | | | | 0.332 (0.240 0.424) | 0.047 | ** |
| Prop. Filipino | | | | 0.094 (0.003, 0.184) | 0.046 | |
| Prop. Southeast Asian | | | | 0.052 (−0.026, 0.130) | 0.040 | |
| Prop. Japanese | | | | 0.004 (−0.127, 0.134) | 0.067 | |
| Prop. Korean | | | | 0.413 (0.299 0.527) | 0.058 | ** |
| Prop. Other Asian | | | | 0.053 (−0.009, 0.115) | 0.032 | |

Note:

** p<.001; Models use an inverse Gaussian distribution with identity link and exchangeable correlation matrix. All independent variables are standardized, except Urban Location.

## Table 3

GEE Results for Models 3 and 4: Asian-specific models for language (3) and nativity (4) for census tracts in the United States (n=71,208)

| | Model 3 | | | Model 4 | | |
|---|---|---|---|---|---|---|
| | **B (95% Confidence Interval)** | **SE** | **Sig.** | **B (95% Confidence Interval)** | **SE** | **Sig.** |
| Intercept | 35.562 (35.189, 35.936) | 0.191 | ** | 35.527 (35.152, 35.902) | 0.191 | ** |
| Income | −0.378 (−0.759, 0.002) | 0.194 | | −0.288 (−0.667, 0.090) | 0.193 | |
| Income Squared | 0.714 (0.423, 1.006) | 0.149 | ** | 0.657 (0.367, 0.947) | 0.148 | ** |
| Prop. Rented | 1.324 (1.131,1.517) | 0.099 | ** | 1.350 (1.157,1.542) | 0.098 | ** |
| Prop. Hispanic | −1.673 (−2.174,−1.173) | 0.255 | ** | −1.776 (−2.281,−1.272) | 0.258 | ** |
| Prop. Black | −0.760 (−1.303, −0.216 | 0.277 | | −.0888 (−1.434, −0.342 | 0.279 | ** |
| Prop. American Indian | −0.911 (−1.032, −0.790) | 0.062 | ** | −0.932 (−1.054, −0.811) | 0.062 | ** |
| Prop. Pacific Islander/Nat Hawaiian | −0.265 (−0.345, −0.184) | 0.041 | ** | −.0270 (−0.352, −0.188) | 0.042 | ** |
| Prop. Multiracial/Other | −0.178 (−0.268, −0.088) | 0.046 | ** | −0.177 (−0.269, −0.084) | 0.047 | ** |
| Pop Density | 5.509 (4.669, 6.348) | 0.428 | ** | 5.530 (4.691, 6.369) | 0.428 | ** |
| Urban | 4.702 (4.482, 4.923) | 0.113 | ** | 4.758 (4.536, 4.979) | 0.113 | ** |
| Prop. White | −3.532 (−4.201, −2.862) | 0.341 | ** | −3.698 (−4.372, −3.042) | 0.344 | ** |
| Asian: Non-English language | 0.105 (0.045, 0.165) | 0.031 | ** | NA | NA | NA |
| Asian: Foreign-born | NA | NA | NA | −0.110 (−0.169, −0.050) | 0.030 | ** |

Note:

** p<.001; Models use an inverse Gaussian distribution with identity link and exchangeable correlation matrix. All independent variables are standardized, except Urban Location.