**Environmental justice for all: Assessing cumulative impacts to understand the relationship between environmental burden, social vulnerability and disease***

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**Abstract**

The prevailing school of thought is that environmental injustices exist even as the debate continues over the mixed results from studies investigating environmental exposure, race and poverty. With the advent of cumulative impact models, a scoring system based on geographic, socioeconomic, public health and environmental hazard criteria from publically available data shows promise in identifying areas of environmental burden and social vulnerability. However, tests of cumulative impact models have hindered the impact of environmental justice centered research due to the continual creation of new models instead of testing existing ones. Our study will 1) investigate the CalEnviroScreen model currently used in California to assess cumulative impacts in the Houston Metropolitan Area 2) incorporate medical records to better understand the impact of environmental modeling on the distribution of heart and respiratory illness and 3) integrate spatial and statistical analysis using impact scores derived from the CalEnviroScreen model. Expanding current models and methods has the potential to address current issues in environmental justice research and provide conclusive results that have proved elusive.

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Disparities in exposures to environmental hazards are important in understanding the complex and persistent patterns of negative health status yet, these exposures are often times poorly understood (Morello-Frosch, Pastor Jr, Porras, & Sadd, 2002). There is ongoing debate that the science of environmental justice is underdeveloped and that there is conflicting scientific evidence of geographic patterns of disproportionate environmental exposure, race, and socioeconomic status (Bowen, 2002). For example, numerous studies show that neighborhood social and physical environmental contexts determine one's health outcomes (Berkman, Glass, Brissette, & Seeman, 2000; Galea, Nandi, & Vlahov, 2004; Gee & Payne-Sturges, 2004; Marmot, 1999; Sampson, 2003; Susser, 1998), poor neighborhoods are disproportionately affected by socioeconomic, demographic and environmental burdens (Lee, 2002; Sexton, 2000; Yen & Syme, 1999), and that racial/ethnic minorities are more likely to live in areas with elevated environmental hazard exposure levels (Adeola, 1994; Anderton, Anderson, Oakes, & Fraser, 1994; Bullard & Johnson, 2000; Crowder & Downey, 2010; Downey & Hawkins, 2008; Gilbert & Chakraborty, 2011; Landrigan, Rauh, & Galvez, 2010; Mohai & Saha, 2006; Sexton, 2000; Wilson et al., 2012; G. Young et al., 2012). Yet, despite these results, there are inconclusive reports regarding the relationships between race/ethnicity, SES, and environmental exposure (Bevc, Marshall, & Picou, 2007; Bowen & Mark, 1995; Downey & Hawkins, 2008; Maranville, 2009; Mohai & Saha, 2006; Stretesky & Hogan, 1998) and that these relationships no longer exist or are insignificant (Anderton et al., 1994; Bowen, 2002; Bowen & Mark, 1995; Downey & Hawkins, 2008; Oakes J. M., Anderton D. L., & Anderson B. A., 1996). One explanation involves the possibility that regression techniques do not always provide the necessary insights into complex relationships between geography, sociodemographic characteristics, and environmental exposures because multivariate regression models do not take into consideration locality or the spatial relationships between factors (Guo, Gahegan, MacEachren, & Zhou, 2005; L. J. Young & Gotway, 2010).

Therefore, the current trend in environmental justice research is to move beyond chemical-by-chemical or facility-by-facility analysis toward a cumulative exposure approach that can account for exposure realities of diverse populations incorporating concepts of race and class into assessments of community susceptibility to environmental pollutants (Morello-Frosch et al., 2002). There are several models assessing cumulative impacts that were designed for a particular geographic region such as the Faber & Krieg Model in Massachusetts (Faber & Krieg, 2002), the California Collaborative Model in Southern California (Morello-Frosch et al., 2002), and most recently the CalEnviroScreen Model in the state of California (*Draft California communities environmental health screening tool, version 2.0*, 2014). Although these models focus on a particular geographic area, a common thread among them is the use of geographic information systems (GIS) using both environmental and health data to create a relative ranking system to identify environmental burdened and vulnerable populations. Environmental exposure risks with their distributional patterns and effects on population health might benefit from a geographic perspective to better understand the spatial relationships of disparities and health outcomes (Margai, 2010).

In April 2014, the California Environmental Protection Agency released the CalEnviroScreen Model 2.0, a comprehensive and updated screening tool that uses a relative ranking system and GIS methods to identify disadvantaged communities based on geographic, socioeconomic, public health and environmental hazard criteria (*Draft California communities environmental health screening tool, version 2.0*, 2014). This comparative scoring system moves away from the health risk assessment to provide a picture showing communities that have higher environmental exposures, minority populations and low SES.  The benefit of this most recent model is the creation of pollution burden and population characteristics scores based on numerous variables in each category derived from publicly available data that can be easily replicated in other geographic areas.  In our study, we will test the CalEnviroScreen Model in the Houston Metropolitan Area to identify communities that have higher pollution burden in relation to SES factors.

Houston is the fourth largest city in the United States and is at the site of a demographic revolution with one of the most ethnically diverse cities in the US with a "majority minority" population. Houston has a growing minority population with over 60% of the population composed of Hispanic (38%), Black (18%) and Asian (5%) residents. The city of Houston has well-documented issues associated with health and environmental disparities.  Highlights from the City of Houston Health Disparities Data Report (*The city of Houston health disparities data report*, 2008) include:  Hispanics have the greatest obstacles to health care access and have a larger percentage of uninsured individuals; black populations have worse health for a wide-range of indicators than any other racial group; and Hispanics experience worse health outcomes compared to whites.

The Houston Ship Channel is one of largest petrochemical and refinery corridors in the world with extensive studies examining the effects of air pollution on residents, however; there is very limited research looking at health disparities, environmental burden and social vulnerability. Linder, Marko and Sexton (Linder, Marko, & Sexton, 2008) discovered that the poorest Houston neighborhoods have a 4 to 10 times greater chance of living with higher cumulative cancer risk compared to neighborhoods with the fewest poor residents (Linder et al., 2008). Also, census tracts with the highest proportion of Hispanics are 6 times more likely to live in high cumulative risk areas compared to other races (Linder et al., 2008). NATA-1999 and 2000 Census data results show statistical association between increased cancer risk, education level, ethnicity and poverty level (Linder et al., 2008).

**Objectives**

Our first objective is to investigate an existing cumulative assessment model, the CalEnviroScreen model, which examines exposure and environmental effect factors and sensitive population and socioeconomic factors created from public data sources. Each category is ranked and scored resulting in an overall score in which a higher scoring area would be expected to experience higher impacts than areas with low scores. We will use this approach to look at the Houston Metropolitan Area to develop scores by census tract which include indicators such as particulate matter, ozone, poverty, education and unemployment to compare areas of high pollution burden to see if this burden disproportionately impact areas with high social vulnerability.

Our second objective is to incorporate medical records into the assessment to better understand the distribution of illness. Currently, we have over 90,000 patient records for a two year period aggregated by census tract and coded by diagnosis for an array of heart and respiratory diseases. Two of the major concerns in the application of GIS are data availability and data quality (Kistemann, Dangendorf, & Schweikart, 2002) requiring investigators to use data that were collected for other purposes. For example, in California, asthma rates for the model were age-adjusted rates of asthma emergency department visits averaged over three years calculated per zip code (*Draft California communities environmental health screening tool, version 2.0*, 2014). Our study captures asthma diagnosis from emergency room, inpatient and outpatient visits for the years 2011 and 2012 that are individually geocoded and then aggregated by census tract.

Our third objective is to integrate statistical and spatial analysis using the CalEnviroScreen scores. We believe these scores are conducive for not only mapping to identify areas of vulnerability and burden but can be used in statistical analysis such as multi-level modeling. We can then compare these results to outcomes generated through spatial analysis to determine if conflicting findings are actually due to methods that do not incorporate geography.

**Data and Methods**

To calculate $PM_{2.5}$ concentrations ($PM_{2.5}$ are particles that have a diameter of 2.5 micrometers or less), historical data was gathered from the Texas Commission of Environmental Quality for the years 2010 – 2013 from twenty-two air station monitors in the Houston-Galveston, Austin and San Antonio areas. Following the approach in the CalEnviroScreen model, we conducted ordinary kriging. Ordinary kriging is a geostatistical approach to modelling which relies on the spatial correlation structure of the data to determine the weighting values. Quarterly mean concentrations were then estimated at the centroid of each census tract. Annual averages were calculated for each to generate 3-year $PM_{2.5}$ concentration averages. For example, for the year 2012, a 3-year average was generated from 2011, 2012 and 2013. Percentile ranks were then assigned by census tracts based on the distribution of $PM_{2.5}$ to create maps of the Houston area.

Medical records are from the University of Texas physicians group which consists of 20 clinics and hospitals throughout the Houston metropolitan area. The data includes inpatient, outpatient, and emergency room visits for all patients having visited a medical professional. From 2011 – 2012, the data consists of adults aged 18 and older who visited a UT physician at least once resulting in 90,000 patients. These patients were aggregated into census tracts using ICD-9 codes to create counts for respiratory and heart diseases to map the distribution of illness.

We generated maps in ArcGIS to identify population characteristics outlined in CalEnviroScreen, such as percent poverty, using the Census Bureau's American Community Survey 5-year estimates, 2006-2011 and 2010 Census.

**Preliminary Results**

The CalEnviroScreen has several indicators for both environmental exposures and population characteristics. Currently, we have completed analysis for $PM_{2.5}$ concentrations, preliminary counts for the distribution of illness by census tract, and rates for sociodemographic factors. Figure 1 show census tracts on the east and northeast side of Houston having a higher rank for $PM_{2.5}$ concentrations compared to the south and east side of the city. Figure 2 and Figure 3 are maps of percent Hispanic and percent black population, respectively, which present high percent of minority

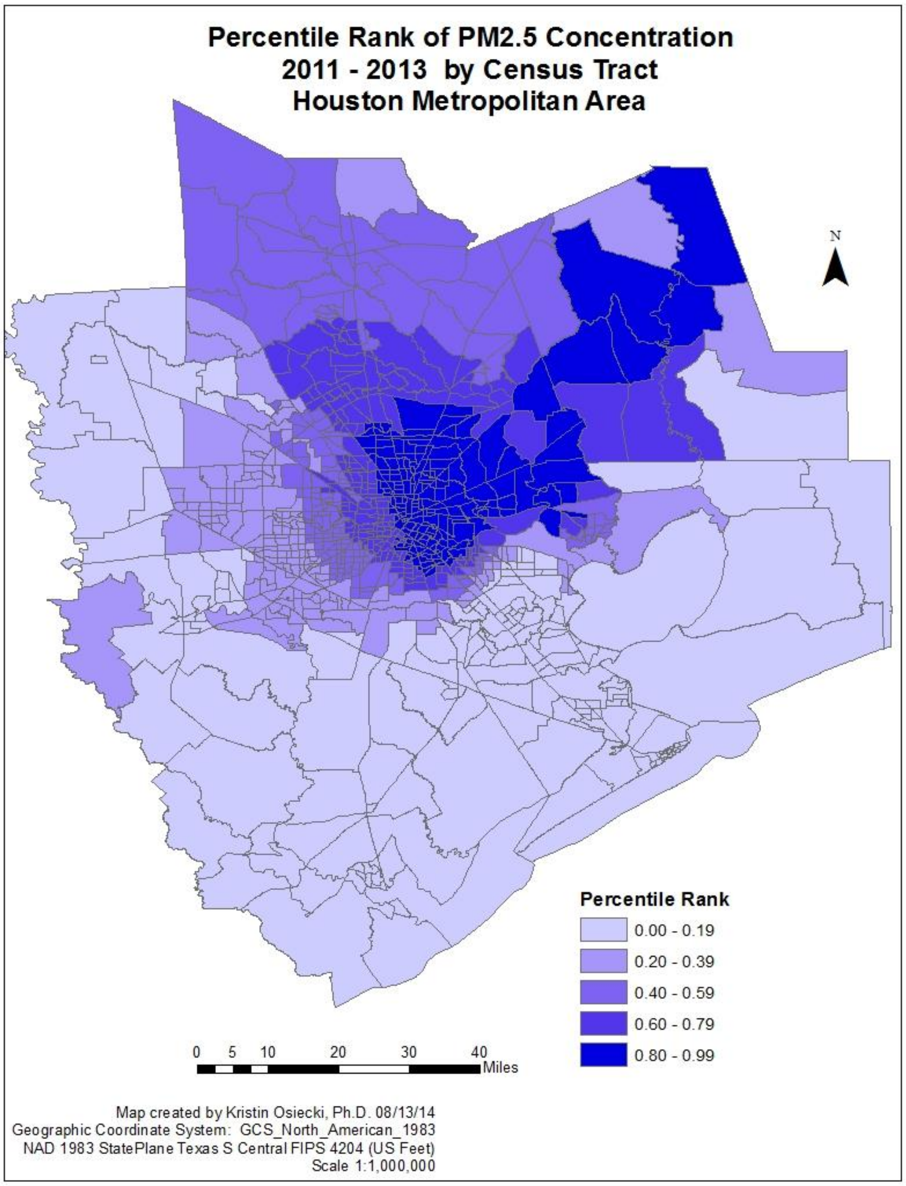


Figure 1. Percentile rank of $PM_{2.5}$ in the Houston metropolitan area

populations in areas of high ranking $PM_{2.5}$ tracts. It is important to note that these are preliminary findings and these maps are for hypothesis generation. Further investigation is needed to determine if there are clusters of significance within the data and will take place once we complete the analysis of the CalEnviroScreen model.

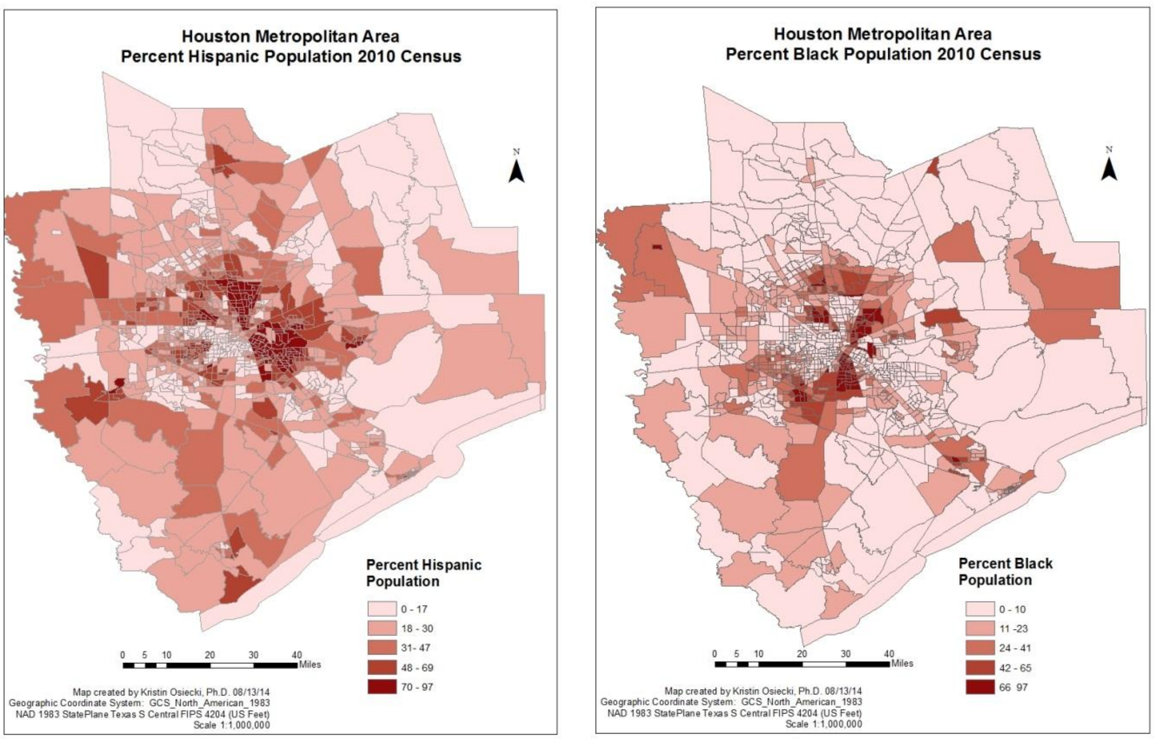


Figure 2. Percent Hispanic population and percent black population

Lastly, figure 3 highlights the percent of patients with heart disease. This map extends past the eight county Houston metropolitan area to incorporate five additional counties which is considered the Houston-Galveston area. Some caveats to examining this map are that not all census tracts had patients from our data sample, and that ten census tracts were not included because there was less than ten patients within the tract (shown as no data in yellow on the map).

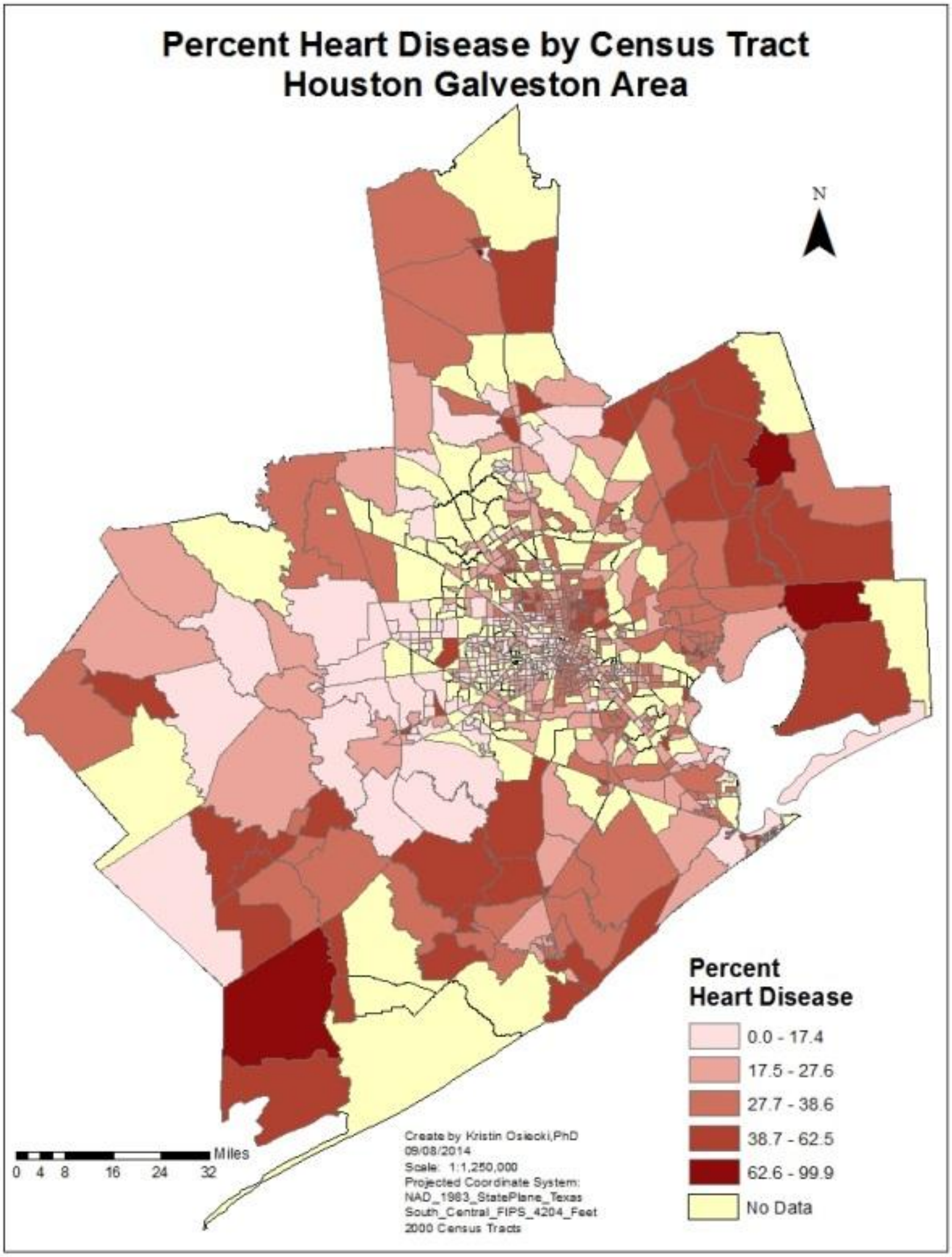


Figure 3. Percent of heart disease in the Houston metropolitan area

**Discussion**

This research projects is a work progress with very exciting potential as we move forward with the acquisition of data and using the CalEnviroScreen model to better understand environmental burden and social vulnerability. The process has taken considerable time on the front end especially with taking millions of records of raw data and preparing it for analysis. These preliminary maps show possible spatial patterns which require further spatial investigation. With the creation of indicator scores, we are simultaneously exploring the data in GIS and with multi-level regression. Our preliminary regression results suggest that high PM exposure in the neighborhood of residence increases the odds of both cardiovascular and respiratory disease even (not shown).

It is critical to demonstrate linkages between environmental burdens and adverse health impacts to develop solutions to existing environmental injustices and resulting health effects (Maantay, 2002). Cumulative assessments provide a wealth of information about environmental exposures and population characteristics, however; using an existing model should be the first step in the research process and not the only step. Integrating GIS methods with advanced statistical analysis using both impact scores and medical records is an opportunity to find the links that are currently missing in environmental justice research.

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