



Asthma prevalence and school-related hazardous air pollutants in the US-México border area

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ABSTRACT

Background: Asthma is the most common chronic disease in children and has been linked to high levels of ambient air pollution and certain hazardous air pollutants (HAPs). Outdoor pollutants such as benzene, released by car emissions, and organic chemicals found in diesel exhaust, as well as particles and irritant gases, including nitrogen dioxide (NO₂), sulfur dioxide (SO₂), and ozone (O₃), contribute to an increased prevalence of respiratory diseases such as asthma.

Objectives: The objectives of this study were to: 1) conduct a screening survey to identify high risk for asthma among school-age children in Hidalgo County, and, 2) study the potential health impact of school-related exposure to HAPs pertaining to asthma risk.

Methods: We carried out a quantitative cross-sectional study combining a school-based asthma screening survey across 198 schools in Hidalgo County, Texas, with information on school neighborhood environments, including census tract-level information on hazardous air pollutants (HAPs) and socioeconomic status (SES) in the respective school neighborhoods. HAPs levels were assessed based on the EPA 2011 National-Scale Air Toxics Assessment (NATA) while SES information was assessed using data from the 2010–2014 American Community Survey.

Results: 2930 students completed the asthma screening survey and results showed an overall asthma prevalence of 9.4%, slightly higher than the national and state prevalence. Participants in the 14–18 years old age group showed a much higher asthma prevalence of 16.7%. When assessing school-neighborhood characteristics, our results revealed no significant differences in asthma prevalence across census tracts with different SES levels. For HAPs, in the single-pollutant model, chlorine levels showed a significant linear trend for prevalence of asthma ($p=0.03$) while hydrochloric acid had a marginally significant linear trend ($p=0.08$). The association with chlorine remained significant in the multi-pollutant model.

Conclusions: Asthma prevalence among school-age children in Hidalgo County, Texas, is 9.4%, which is slightly higher than the state rate, especially among young adults, ages 14–18 years who had an asthma rate of 16.7%. Results support an association between exposures to school-neighborhood HAPs and risk for pediatric asthma, especially as related to chlorine. No significant effects of school-level SES on asthma risk were observed.

1. Introduction

Asthma is a chronic respiratory condition that can be life threatening and is characterized by inflammation and narrowing of the airways resulting in less air to flow into the lungs (National Heart Lung

and Blood Institute, 2016). Asthma is a leading cause of illness and hospitalizations among children and has a significant impact on their health and quality of life. In 2015, the Centers for Disease Control and Prevention (CDC) reported the prevalence of asthma among children in the United States to be 8.4%, ranging from 7.4% among Non-Hispanic

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Whites to 13.4% among Non-Hispanic Blacks. Hispanic children under 18 years old have a current asthma prevalence rate of 8.0% (Krieger et al., 2003a).

In Texas, the most recent data from 2013 shows an asthma prevalence of 9.1% among children less than 18 years, slightly higher than the national rate. Non-Hispanic Black children in Texas had asthma rates more than twice as high as Non-Hispanic Whites (19.2% vs. 8.5%), while Hispanic children had an asthma prevalence of 7.5% (Texas Asthma Control Program, 2014). Among children in Texas, children ages 5–9 and 10–14 had the highest prevalence of asthma, with rates of 10.8% and 10.7% respectively, compared to young adolescents ages 15–17 who had an asthma prevalence of 9.8% and children under five with the lowest rate of 4.5%. In Hidalgo County, situated along the Texas-Mexico border, and within the state's Health Service Region (HSR) 11, children had an asthma prevalence of 11.7% in 2011 (Texas Asthma Control Program, 2013). While this is higher than the asthma prevalence among children in Texas, the difference is not statistically significant.

Growing research supports the role of outdoor air pollutants in aggravating diseases such as asthma and other respiratory diseases among children, as well as, adverse neonatal conditions and congenital anomalies (World Health Organization, 2017). Outdoor pollutants, such as benzene, which is released by car emissions, organic chemicals found in diesel exhaust, as well as, particles and irritant gases including nitrogen dioxide (NO₂), sulfur dioxide (SO₂), and ozone (O₃) contribute to the increased prevalence of respiratory diseases such as asthma (Trasande and Thurston, 2005).

Individuals with asthma may have an added health risks from exposures to hazardous air pollutants (HAPs). Moreover, linkages with respiratory diseases and hospitalizations had been reported due to exposures of complex mixtures (fine particulate matter and tobacco smoke) (Leikauf, 2002). Specific HAPs have been identified to assist during sensitization and have been reported to exacerbate asthma because once exposed, individuals respond quickly to low concentrations producing bronchoconstriction due to a decrease in the sensibility to respiratory antigens. Individuals often respond adversely after exposure to complex mixtures, which are at low concentrations, and have been associated with asthma in occupational environments. Furthermore, certain HAPs may interact with criteria pollutants in ambient air to exacerbate asthma (Leikauf, 2002). High home or school traffic density (particularly trucks) have been associated with asthma symptoms, allergic rhinitis symptoms, and prevalence of asthma among children (Delfino et al., 2003). Reports have been published regarding associations among asthma attacks, particles and indoor volatile organic compounds (VOCs) (Weisel, 2002).

In Hidalgo County, 90% of the total population and 95% of the population under 18 years of age, is of Hispanic origin. Hidalgo County is one of the poorest counties in the United States, with 1/3 of its population living below the poverty line, including 47% of those under age 18, and has a large uninsured population (41% in 2007) (Zuniga et al., 2012; Center for Disease Control and Prevention CDC, 2016b). Hispanic families, primarily those who are low-income, are more likely to have an asthma diagnoses than their counterparts in a higher socioeconomic status, given their propensity to live in sub-standard neighborhoods with higher exposure to environmental asthma triggers. These areas are known as “colonias” and are defined as “residential areas along the Texas-Mexico border that may lack potable water, sewer systems, electricity, paved roads, and safe and sanitary housing.” Additionally, many do not have access or means to solid waste management and burn their trash in their backyards (Texas Secretary of State, 2016). Childhood asthma might be particularly higher in Hidalgo County because of certain environmental factors. Agriculture is still prominent in the area and the process of cultivating lands, raising crops, and feeding, breeding and raising livestock results in environmental impacts such as irrigation problems, pollutants, soil degradation, and waste. Factories, locally known as *maquiladoras*, contribute to

airborne and water pollution due to a lack of suitable waste storage and treatment facilities. Furthermore, local harvesting of sugarcane in the region produce ash and smoke that can trigger an asthma attack. Due to these factors, children living in these areas might be at higher risk for developing asthma due to the exposure to air pollution and indoor asthma triggers. However, the prevalence of child asthma in this area remains unknown because of high mobility, language barriers and lack of health care access among this population. Yawn et al. (2003) reported that, “school-based screening or case identification increased the number of physician asthma-related visits and changes in asthma therapy”. Thus, the need to conduct asthma screenings in schools will help to identify those children with high risk of asthma and to take measures to better diagnose, treat and manage possible undiagnosed asthma. The purpose of this study was two-fold: 1) to conduct a screening survey to identify high risk for asthma among school-age children in Hidalgo County, and, 2) to study the potential health impacts of school-related exposure to hazardous air pollutants (HAPs) as pertaining to asthma risk.

2. Methods

We carried out a quantitative cross-sectional study combining a school-based asthma screening survey across 198 schools in Hidalgo County, Texas, with information on school neighborhood environments, including census tract-level information on hazardous air pollutants (HAPs) and socioeconomic status (SES) in the respective school neighborhoods. HAPs levels were assessed based on the 2011 EPA National-Scale Air Toxics Assessment (NATA), while SES information was assessed using data from the 2010–2014 American Community Survey. The Institutional Review Board of Texas A&M University Health Science Center reviewed and approved the study protocol. Informed consent was obtained from parents or legal guardians of children attending the targeted schools.

2.1. Subjects and recruitment

This study focused on elementary, middle, and high schools located in Hidalgo County. The research team obtained authorization from the Independent School Districts in the County before sending consent forms to the homes through the schools nurses' office. From October of 2014 to May of 2016, a total of 2930 students from 198 schools were screened. This represents more than 50% of the schools in the County across 15 different school districts. Although this is a large sample size, the schools were not selected at random and only those that agreed to participate in the study were included. Children with signed consent forms were interviewed by a Respiratory Therapist (RT) from a local hospital using a validated questionnaire from the American College of Asthma, Allergy and Immunology (ACAAI) to identify children with high risk of developing asthma (Amin et al., 2013; Winder et al., 2000; Fonseca et al., 2004). Children 8 years and older completed the survey offered by the RT themselves, while parents and guardians answered the survey for younger children. If a child was absent during the survey application, the RT returned to the school to complete missing questionnaires.

2.2. Asthma screening questionnaire and asthma status ascertainment

A validated questionnaire developed for the American College of Asthma, Allergy and Immunology was used in the study (Table 1). It has been widely used to determine if participants have a high risk for developing asthma or, for those children already diagnosed with asthma, to determine if their disease is under control (Winder et al., 2000). It is important to note that, while it is useful as a predictor, the scores should not be used as the sole criterion in screening individuals for asthma. For this study, we followed the procedure described by Amin et al., 2013, where students who had more than three positive responses

Table 1
Questions in the ACAAI asthma screening questionnaire.

1. When I walk or play hard with friends, I have trouble breathing or I cough.
2. When I walk up hills or stairs, I have trouble breathing or I cough.
3. I don't like to run or play sports because I have trouble breathing or I cough.
4. Sometimes I wake up at night with coughing or trouble breathing.
5. Sometimes I have trouble taking a deep breath.
6. Sometimes I make wheezing sounds in my chest.
7. Sometimes my chest feels tight or hurts.
8. Sometimes I cough a lot.
9. Being outdoors or around dust or pets makes my breathing worse.
10. It's hard to breathe in cold weather.
11. It's hard to breathe when people smoke or there are strong odors.
12. Cold makes me cough or wheeze.
13. I went to the doctor's office or emergency room for asthma or trouble breathing this year.
14. I stayed in the hospital overnight for asthma or trouble breathing this year.

Students with > 3 “yes” responses to ACAAI's questions are considered to have a positive asthma screen.

to the 14 ACAAI's asthma screening questions were considered positive for asthma risk (Amin et al., 2013). For those children, a referral to a primary care provide (PCP) or pulmonologist was provided to his/her parents or guardians (Winder et al., 2000; Fonseca et al., 2004). Children that are susceptible to developing asthma may have some trouble breathing and therefore, are less likely to play sports, sometimes cough a lot, especially at night, and make wheezing sounds. Additionally, being close to pets, dust, cold weather and, smoke can cause their breathing difficulties to worsen.

2.3. Demographic characteristics

Students' age and school grade were obtained through the screening questionnaire. While the screening survey did not include questions about race and ethnicity, the most recent population estimates show that 90.1% of the population in Hidalgo County is Hispanic, 7.4% is non-Hispanic White, and the remaining 2.5% is from other races. Among the population under 18 years of age, 95.1% is Hispanic (Texas School District Demographic Profiles, 2009; Texas Population Estimates and Projections Program, 2016).

2.4. School neighborhood environment assessment

Information on the school neighborhood environment, including HAPs levels and socioeconomic status (SES) was obtained for all 84-census tracts in which the participating schools were located. Specifically, HAPs levels, by census tract, for designated school were assessed based on the EPA National-Scale Air Toxics Assessment (NATA), which provides modeled estimates of air toxics in specific years for all census tracts in the U.S, using the Assessment System for Population Exposure Nationwide (ASPEN). The ASPEN uses annual national toxic inventory emission data of HAPs, emissions from background and mobile sources, and other data as inputs to produce census tract level HAP modeled estimates after accounting for climatic factors and characteristics of release of pollutants. In this study, we used the 2011 NATA data and selected a total of 43 respiratory-related HAPs including acetaldehyde, acrolein, diesel particles and hydrochloric acid for analysis (Environmental Protection Agency, 2016). SES at the school census tract locations was assessed using data from the 2010–2014 American Community Survey (United States Census Bureau, 2016).

The SES index was computed based on the well-established method reported by the Agency of Healthcare Research and Quality (Bonito et al., 2012). Specifically, a principal component analysis on a set of seven measures was conducted across the entire set of 211,267 U.S. census block groups. These seven measures include unemployment rate among persons aged 16 years or older (pct_unemp), percentage of persons below the US poverty line (pct_poverty), median household

Table 2
Prevalence of childhood asthma in participants from Hidalgo County, Texas, in 2016.

Variables	Levels	Number of Subjects	Asthma cases	Prevalence of Asthma (%)
Age	2–5	291	19	6.53%
	6–10	1919	188	9.80%
	11–13	636	54	8.49%
	14–18	84	14	16.67%
SES_Index	(34.1,40.4]	1013	83	8.19%
	(40.4,45.3]	950	103	10.84%
	(45.3,65.4]	967	89	9.20%
Total	–	2930	275	9.39%

income (hhinc100), median value of owner-occupied homes (prop100), percentage of persons with less than a 12th-grade education (low_educ), percentage of persons aged > 25 years with at least 4 years of college (high_educ), and percentage of households containing one or more person per room (crowded). Then, principal components were determined. As the first principal component accounts for most of the variance common to the seven measures, the loading scores of these seven measures on the first principal component was determined and used to estimate the SES index. The formula used to compute the SES index in this study is below:

$$\begin{aligned} \text{SES Index Score} = & 50 + (-0.07 * \text{crowded}) + (0.08 * \text{prop100}) \\ & + (-0.10 * \text{pctpoverty}) + (0.11 * \text{hhinc100}) \\ & + (0.10 * \text{higheduc}) + (-0.11 * \text{loweduc}) \\ & + (-0.08 * \text{pctunemp}) \end{aligned}$$

The Index Score was divided in tertiles and included in the models. The range of SES score values, as well as the number of participants and asthma prevalence per SES tertile, are shown in Table 2.

2.5. Statistical analysis

2.5.1. Selection of HAPs

We examined the distribution of 43 respiratory-related HAPs levels. If the levels of air toxics lacked spatial variation across the 84 census tracts where the screened schools were located, these chemicals were not selected for further analysis. For example, if the pollutants had the same or similar concentrations in all census tracts, they were not selected for further analysis. For all selected air toxics, the census tracts were grouped in tertiles indicating low, medium and high levels of concentration (see Table 3). In sensitivity analyses, we also fitted them as continuous variables or quartiles to assess potential impacts of an arbitrary selection of cut-off points for categorization of pollutants. To examine the susceptible population, we further evaluated the potential interactions between pollutants and other factors such as age and SES index score.

2.5.2. Correlation and collinearity diagnostics

Correlations among air pollutants and other covariates were evaluated using Spearman's rank correlation. Correlation matrix of different variable was created. If evidence of collinearity in the selected variables existed, the multicollinearity of these variables was addressed before we fitted them into a model.

2.5.3. Single and co-pollutant models

Mixed-effects logistic regression models were applied to evaluate the association between HAPs and asthma in children. The effects of HAPs on childhood asthma were estimated using the referent category of census tracts with the lowest SES tertile. For each air pollutant, we examined its effects on asthma risk in single pollutant models. P-value for linear relationships between pollutants, measured as a continuous variable, and asthma risk was also performed and z-test was used to test

Table 3

Associations between nine selected HAPs and child asthma from single-pollutant models in Hidalgo County, Texas.

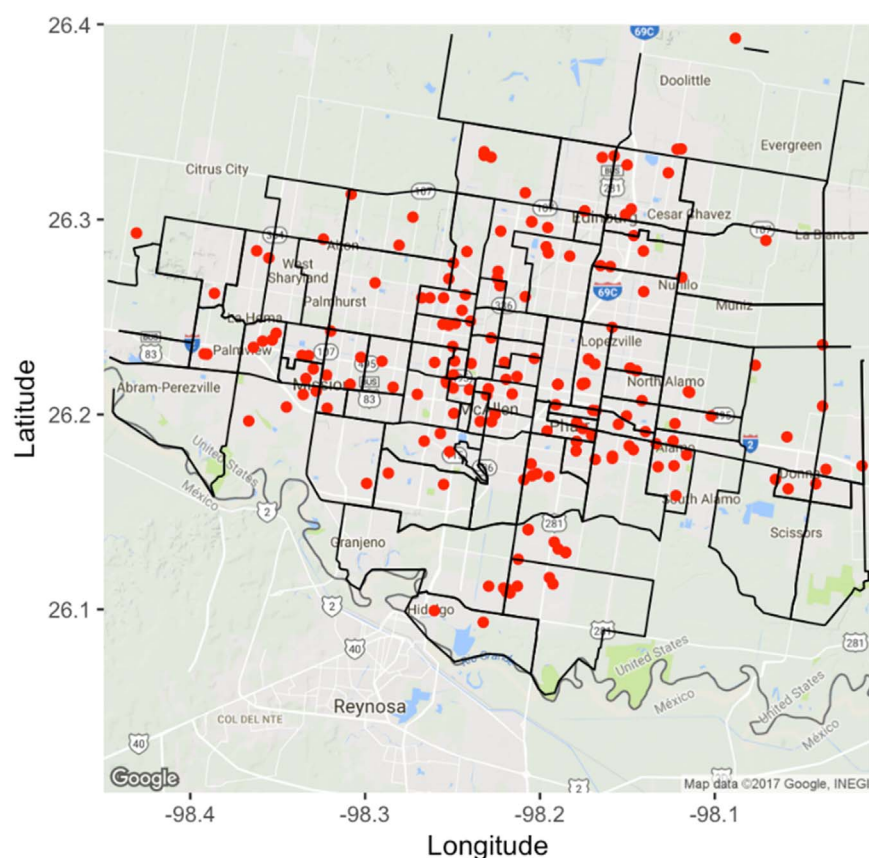
HAPs	Concentration Intervals	Number of Subjects	Asthma cases	% of Asthma	odds ratio (95% CI)	P-value for linear trend
Acetaldehyde	(0.143,0.148]	977	80	8.19%	1.00	0.295
	(0.148,0.153]	1053	109	10.35%	1.29 (0.96, 1.77)	
	(0.153,0.167]	900	86	9.56%	1.18(0.86, 1.63)	
Acrolein	(0.27,0.411]	841	75	8.92%	1.00	0.833
	(0.411,0.503]	1116	110	9.86%	1.12(0.82, 1.52)	
	(0.503,0.868]	973	90	9.25%	1.04(0.76, 1.44)	
Chlorine	0	753	58	7.70%	1.00	0.032 ⁺
	0.001	1407	133	9.45%	1.25(0.91, 1.74)	
	> 0.002 ⁺	770	84	10.91%	1.47(1.04, 2.09) ⁺	
Diesel Pm	(0.016,0.022]	997	98	9.83%	1.00	0.261
	(0.022,0.036]	962	96	9.98%	1.02(0.76, 1.37)	
	(0.036,0.078]	971	81	8.34%	0.83(0.61, 1.14)	
Formaldehyde	(0.137,0.144]	1032	101	9.79%	1.00	0.538
	(0.144,0.149]	995	93	9.35%	0.95(0.71, 1.28)	
	(0.149,0.17]	903	81	8.97%	0.91(0.67, 1.23)	
Hydrochloric Acid	(0.002,0.005]	1162	116	9.98%	1.00	0.084
	(0.005,0.007]	434	52	11.98%	1.23(0.86, 1.73)	
	(0.007,0.027]	1334	107	8.02%	0.79(0.6, 1.04)	
Naphthalene	(0.001,0.003]	1013	87	8.59%	1.00	0.642
	(0.003,0.004]	947	99	10.45%	1.24(0.92, 1.68)	
	(0.004,0.01]	970	89	9.18%	1.08(0.79, 1.47)	
Nickel Compounds	0	2188	200	9.14%	1.00	0.435
	0.001	742	75	10.11%	1.12(0.84, 1.47)	
	> 0.001 ⁺	1775	175	9.86%	1.15(0.89, 1.50)	

⁺ Chlorine 0.002 group contains 8 samples where Chlorine is 0.003, and Propionaldehyde 0.001 group contains samples where Propionaldehyde is 0.002.

* p < 0.05.

if the coefficient of linear regression was significantly different from zero. For multiple pollutant models, we used least absolute shrinkage and selection operator (Lasso) methods to select HAPs for modelling. Lasso method adds a penalty to the loss function of regression and shrinks the coefficient of insignificant variables to zero. If the variable is

the last one whose coefficient becomes zero, it suggests that this variable is the first one that needs to be selected when fitting the model. Further, we added each variable one time into the regression models by following the order of significant levels of these variables identified through the Lasso method. The number of variables in the models was

**Fig. 1.** Hidalgo County School's screening map (red dots).

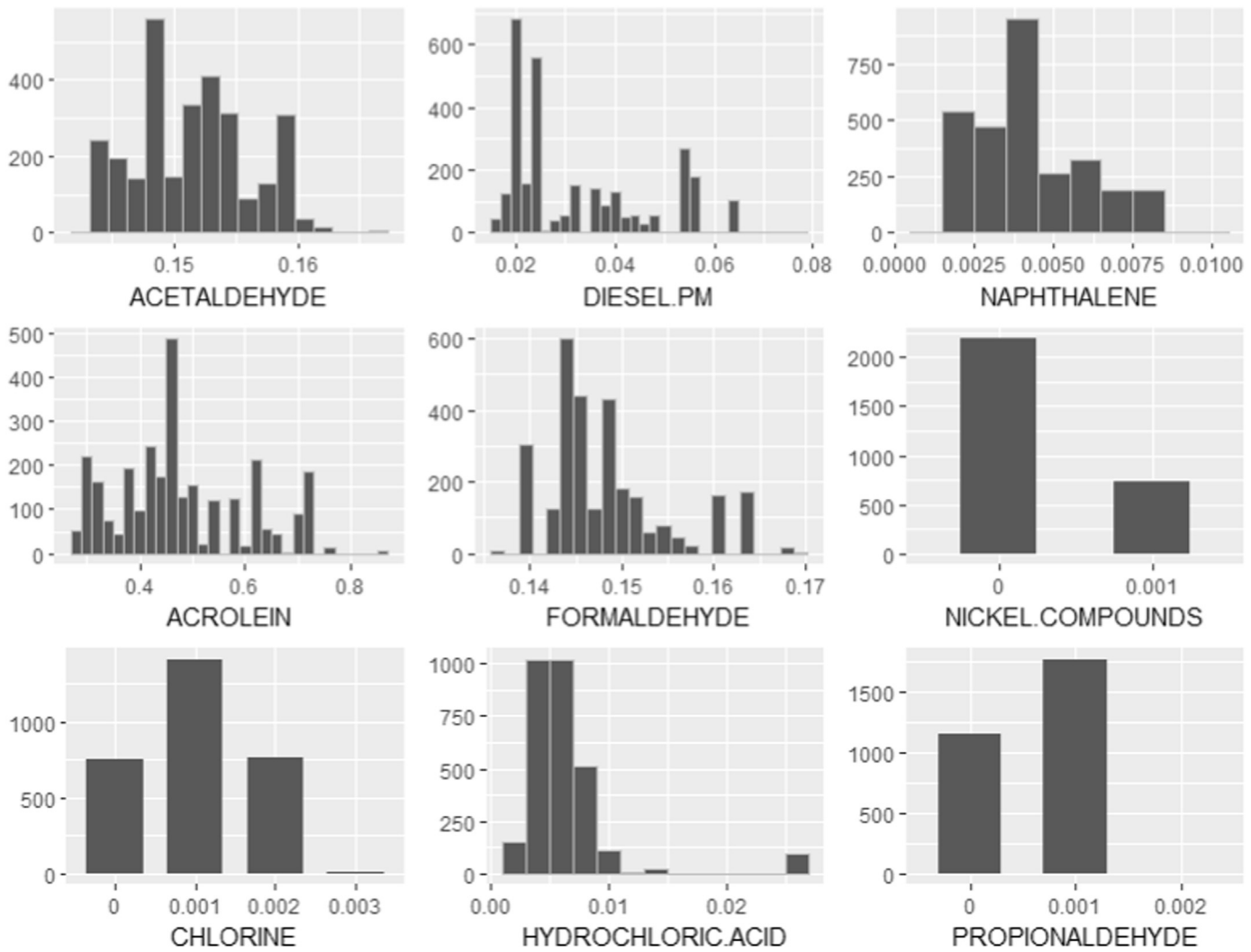


Fig. 2. Distributions of selected HAPs.

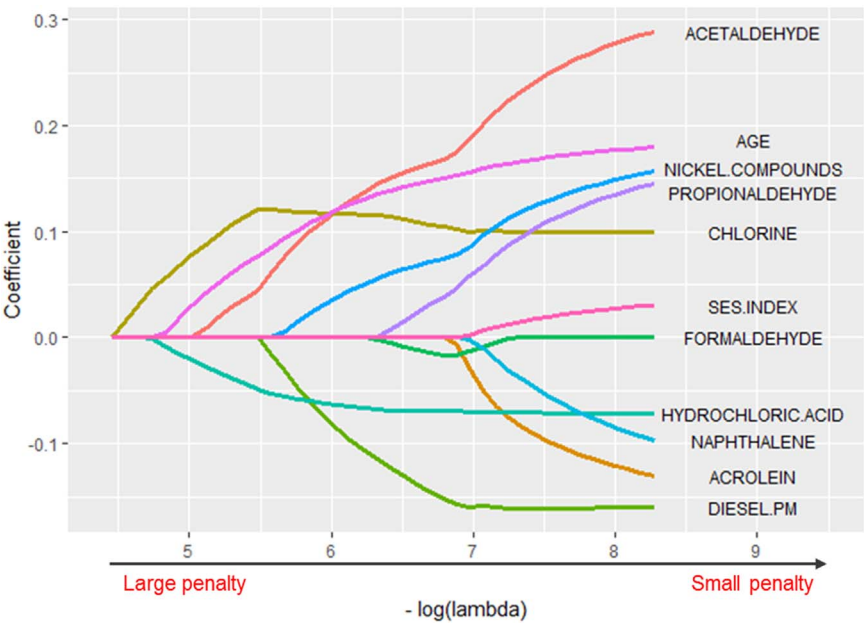


Fig. 3. Estimate of the coefficients of variables under different values of penalty parameter.

mainly determined based on the Akaike's Information Criterion of the regression models

3. Results

We screened 2930 students from 198 schools across 84 census tracts in Hidalgo County, Texas. Results from the asthma screening surveys show that overall, children and their families residing in the Hidalgo County, Texas border region have an asthma prevalence of 9.4%. Table 2 shows asthma prevalence across age groups and tertiles of school neighborhood SES. Children ages 14–18 had a higher asthma prevalence of 16.7% while asthma prevalence was not significantly different across census tracts with different SES levels.

Fig. 1 shows part of the Hidalgo County map. The red dots represent the schools that were screened and the lines represent the census tracts in the region.

Only 9 of the 43 air pollutants examined differed significantly among the 84 census tracts in the study area. Fig. 2 shows the distributions of these nine selected respiratory air pollutants. These chemicals included acetaldehyde, acrolein, diesel particles, formaldehyde, hydrochloric acid, naphthalene, propionaldehyde, and chlorine.

Table 3 shows the descriptive statistics of these selected HAPs including range, number of subjects, number of asthma cases, asthma prevalence, odds ratio and significance. We used single pollutant logistical regression models to compare different levels of HAPs. Chlorine had a significant linear trend for prevalence of asthma ($p=0.03$) while hydrochloric acid had a marginally significant linear trend ($p=0.08$).

Fig. 3 shows the result of Lasso. The X-axis represents the value of the penalty parameters (it decreases from left to right sides) and the Y-axis represents the coefficients of variables. In Lasso method, a large penalty is given at the beginning to make the coefficients of all variables as zero. Then, the penalty gradually decreases and the coefficients of variables successively turn into non-zero. This order of the non-zero coefficients indicates the importance of the predictors in the model. For example, Chlorine is the first variable whose coefficient turns into non-zero and needs to be considered first for modelling. Thus, in our analysis, when gradually decreasing the penalty, the coefficients of chlorine, hydrochloric acid, age, acetaldehyde, diesel PM and nickle compounds become non-zero successively. Using the Akaike information criterion, we chose to include the last four variables of chlorine, hydrochloric acid, age and acetaldehyde into the final model.

We examined the relationships between HAPs and prevalence of asthma using the multiple pollutant model (See Table 4). In the multiple pollutant logistical regression, the association between child asthma and chlorine remained statistically significant ($OR=1.22$, 95%CI: 1.02–1.16).

To test the susceptible population to HAPs, we also tested the interactions between HAPs and age groups as well as school-neighbor SES on asthma. However, no statistically significant interactions were found. The results were not presented.

4. Discussion

This study focused on an asthma screening survey among school-age

Table 4
Associations between HAPs and child asthma from the multiple pollutant model.

	OR	95% CI	P value
Acetaldehyde	1.134	0.967 1.331	0.122
Chlorine	1.219	1.019 1.460	0.031
Hydrochloric acid, hydrogen chloride, gas only	0.907	0.789 1.043	0.170
Age	1.168	0.959 1.416	0.118

All variables are numerical.

* $p < 0.05$.

children in Hidalgo County. It used census tract data to study the potential health impacts of school-related HAPs levels on the risk of asthma, while controlling for school neighborhood SES. Results from the 2930 screening surveys show that Hispanic children and their families residing in a border region have an asthma prevalence of 9.4%, which is slightly higher than the national prevalence (8.6%) reported by CDC in 2014 (Centers for Disease Control and Prevention, 2015). This is, however, very close to the 9.1% prevalence reported by the Texas Department of State Health Services (DSHS) in 2013 (Texas Asthma Control Program, 2010). Furthermore, young adults 14–18 years of age had a prevalence of 16.7% which is higher than the national (10%) and state (9.8%) rates for this age group (Texas Asthma Control Program, 2014). A hypothesis for this higher prevalence is that young adults in Hidalgo County often work in the agricultural industry with their families to increase household income, many times without the proper protective equipment (Cooper et al., 2001). Higher exposure rates to HAPs are common in this industry.

When looking at the impact of exposure to school-neighborhood HAPs on pediatric asthma risk, we found an association between HAPs levels and asthma, especially chlorine. This is consistent with previous findings in the literature (Leikauf, 2002; Delfino et al., 2003; Weisel, 2002). A relationship between outdoor HAPs from industrial sources, diesel trucks, and daily traffic, which may induce or exacerbate asthma among urban and inner-city children have been reported (Leikauf, 2002; Stoner et al., 2013). Children spend an average of 33 h per week in school, and there are nearly 17,000 schools in rural and urban areas across the U.S. located within 250 m (~820 feet) of a heavily traveled road (Kingsley et al., 2014). The Texas Department of Education has school districts that are geographical units for the local administration of schools under Chapter 11 of the Texas Education Code (Texas Department of Education, 1995). School attendance zones are geographic areas that a district uses to assign children to schools. Generally, a child must attend the school district in which he or she resides (Texas Education Agency, 2017).

Respiratory health and asthma disease has been well linked to chlorine exposure (Moore and S, 1991; Rothery, 1991; Leroyer et al., 1999). Although the mechanisms of the induction of asthma by chlorine remain unknown, chlorine exposure may cause desquamation of the airway epithelium, prolonged sub-epithelial inflammation and increased airway hyper-responsiveness through oxidative stress and inflammation (Lemiere et al., 1997; Martin et al., 2003). Acute exposures to chlorine due to rail accidents or spills can result in symptoms of acute airway obstruction including wheezing, coughing, chest tightness, and dyspnea (White and Martin, 2010). Chlorine has been widely used as an oxidizing agent in water treatment and chemical processes and particularly the food and paper industries could contribute to chlorine exposure (U.S. Environmental Protection Agency, 1992, 1999). Individual exposure to chlorine may also occur through chlorine-treated water. Chlorine is a potent irritant in the upper respiratory tract and the lung and acute exposure to a high dose of chlorine can lead to lung injury and death (Van et al., 2009).

When assessing the association between school-neighborhood exposures to HAPs and pediatric asthma risk, the school neighborhood SES was considered a confounder in this relationship. However, we did not observe significant effects of SES on asthma risk or, significant interactions between SES and pollutants. The SES index ranged between 34.1 and 65.4, going from (34.1, 40.4] in the first tertile, (40.4, 45.3] in the 2nd tertile, and (45.3, 65.4] in the 3rd tertile (see Table 2). Thus, the lack of association observed between neighborhood SES and asthma is unlikely to be due to lack of variability in the SES index in this study. However, our neighborhood SES assessment was generated based on the school location rather than individual residential address. Because almost half of the population under the age of 18 is below the poverty level in the study site (Hidalgo County), it is important to note that higher asthma rates may be a function of higher poverty in the region. Due to this factor, we considered school neighborhood SES as a

confounder in the relationship between HAPs and pediatric asthma risk regardless of its significance status. It is unclear if this methodological discrepancy may contribute to inconsistent findings with other studies regarding the effects of neighborhood SES index on asthma.

Our results show a higher prevalence of asthma in participants compared to the state prevalence, which suggests an impact of HAPs on the health of these children, in addition to SES and other risk factors. Criteria pollutants have been associated and demonstrated to cause exacerbation of children's asthma, but the role of air toxics in relation to asthma is less clear (Tzivian, 2011; Brauer et al., 2007; Delfino et al., 2006). The United States–Mexico border creates a problematic situation for individuals that have asthma due to the levels of environmental contamination in the region (Comrie, 1996; Sarnat et al., 2012). Air and water pollution, hazardous wastes improperly disposed, lack and shortages of potable water, and poor sanitation is among the long-standing public health problems for border communities (Mukerjee, 2001). In the Rio Grande basin, most water is used for irrigation purposes, which causes return flows with high levels of chlorides, phosphorus, and total dissolved solids (Li et al., 2005). Lastly, industrialization and agricultural development in the area have accelerated, which creates a more extensive environmental contamination by toxic industrial chemicals, air emissions, and agricultural pesticides (Mukerjee, 2001; Anderson and Gerber, 2008). Like with the SES index, HAPs information was obtained at the school census-tract level. We believe that many of the children screened are also exposed to HAPs in their home environments, particularly young adults who work in the agricultural sector alongside their parents to help their family financially and thus, increase their susceptibility for developing asthma (Cooper et al., 2001).

5. Conclusion

This study applied the asthma screening survey questionnaire to evaluate asthma status among a large population-based sample of children, which has rarely been done in this study area. A strength of the study was the number of participants ($N = 2930$) in the screening survey from different age groups and school locations. In addition, this asthma survey questionnaire has been well tested for validation (Texas Secretary of State, 2016; Amin et al., 2013). The data generated in this study provided important information for accurate estimation of asthma disease burden among children in the area. Furthermore, we were able to link this asthma survey data with other school-related environmental and neighborhood information, which provides a cost effective way to address the research questions.

Some of the limitations of the study are that due to the cross-sectional design and the nature of the survey, bias could occur from self-reported responses from participants. Overall, the asthma screening survey did not have a lot of information about family and individual level risk factors, which may act as confounders in our analysis. In addition, hazardous air pollutant exposures were obtained through census tract levels based on the school locations rather than at the individual level. Misclassification of exposure is possible to occur in this study. However, this is likely a non-differential misclassification, which would bias our findings toward the null hypothesis. Further, as the residential address of children was not available in this study, we were not able to account for exposures from residential neighborhood and other relevant environments.

Overall, our study suggests the potential association between air toxics exposure and asthma in children. Further research is needed to develop community studies with a focus on the toxicity that air pollutants could have in the respiratory system based on biological mechanisms, particularly irritant and immunological pathways, to asthma onset and exacerbation.

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Further reading

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