

Literature Review

Air Pollution's Relationship to Asthma and Related Public Health Interventions in the US-Mexico Border Region

Introduction: In recent years residents along both sides of the United States-Mexico border have lived amidst the rapid growth associated with free trade and globalization. While beneficial to corporations, economic growth has negatively impacted the environment, health, and quality of life of these residents (Dahl, 2004). This review focuses on one environmental threat along the border, rising air pollution, and the impact on respiratory disease of border residents. First, evidence for the linkage between air pollutants and respiratory disease will be reviewed, followed by an examination of interventions that have addressed this growing problem.

Many factors contribute to air contamination on the border including industry, lack of vehicular emission controls, dirt roads, poor fuel quality, open burning (Crespin, 1994), agricultural dust and pesticides, and an expanding maquiladora industry (English, 1998). Especially vulnerable to these environmental problems is the large low-income population that lives along the border. In its 2001 annual report, the US-Mexico Border Health Commission estimated that 35 percent of the 11.5 million people residing in the 42 United States counties and 39 Mexican counties that line the border live below the poverty line. Like many low-income minority groups, low income border residents are more likely to be exposed to outdoor air pollutants and live in substandard housing with inadequate air circulation and filtration (Alexander et al, 2000).

According to the University of Maryland Medical Center, exposure to both outdoor and indoor air pollution can cause, aggravate, and trigger certain respiratory diseases such as asthma, emphysema, bronchitis, pulmonary fibrosis, pneumonia, tuberculosis, and lung cancer (See Table 1). Because the lung diseases listed in Table 1 differ greatly in their nature and treatment, the primary focus of this literature review will be on issues related to asthma in order to best support subsequent activities involving federally funded Migrant Health Centers along the US-Mexico Border. Asthma is thought to be caused by a combination of environmental, genetic, and socio-economic factors and is potentially fatal if left untreated. Studies have shown that high levels of certain ambient air contaminants, tobacco smoke, indoor allergens, and agricultural pesticides aggravate asthmatic symptoms (Crespin, 1994).

Table 1

Respiratory Disease	Causes and triggers
Asthma	<u>Original cause</u> - Genetic factors combined with allergens in the environment; occupational exposures. <u>Triggers</u> - Cold air, dust, strong fumes, exercise, inhaled irritants, tobacco smoke, allergens, pesticides
Bronchitis	<u>Chronic</u> - Cigarette Smoking, bacterial or viral infections, air pollution and occupational exposures, heredity

	<u>Acute</u> - bacteria, virus, physical or chemical agents such as dusts, allergens, strong fumes, chemical cleaning compounds, or tobacco smoke
Pulmonary Emphysema	Smoking, exposure to air pollution, occupational exposures, heredity
Pulmonary Fibrosis	Environmental pollutants, sarcoidosis, certain drugs or medications, radiation, connective tissue or collagen diseases, family history
Pneumonia	Bacteria, viruses, or chemical irritants
Tuberculosis	Airborne bacteria, poor ventilation
Lung Cancer	Tobacco smoke, marijuana, recurring inflammation from TB or pneumonia, asbestos exposure, talcum powder, cancer-causing agents in the workplace, radon, family history, personal history of lung cancer, personal history of lung cancer, air pollution.

Lower socioeconomic status impedes the management of chronic illness due to barriers to health care such as transportation problems, limited health literacy, language barriers, few local health care providers, and inadequate or absent health insurance (Alexander et al, 2000). Exposure to air pollution combined with barriers to health care poses serious and potentially fatal consequences for asthmatic residents of the US-Mexico border region, especially vulnerable groups such as children. Chronic obstructive pulmonary diseases such as asthma were the fourth leading cause of death in United States border communities between 1992 and 1994, causing five percent of deaths from defined causes (PAHO 1999). In addition to a huge toll in decreased quality of life, asthma is responsible for enormous direct and indirect monetary costs, estimated at \$ 6.2 billion in the United States in 1990 alone (Weiss, 1992). This literature review will summarize the existing academic research on the relationship between air pollution and asthma as well as research on public health interventions that address asthma in the US-Mexico border region. Gaps in the literature and unanswered questions will be addressed and discussed. The findings of this literature review will provide guidance for future efforts to assess needs and design interventions to address the pressing issue of asthma on the US-Mexico border.

Methodology: A bilingual search for academic, peer-reviewed literature using the Google Scholar and ALADIN database search engines was performed using combinations of the following keywords: border, United States, Mexico, respiratory, intervention, public health, air pollution, asthma, *frontera*, *Estados Unidos*, *México*, *respiratoria*, *intervención*, *salud publica*, *contaminación ambiental*, and *asma*. A scan of the bibliographies identified any pertinent articles overlooked by the search engines. The articles were divided into two groups: 1) the relationship between air pollution and asthma in the US Mexico border region, and 2) public health intervention strategies and case studies in the border region. In this review, these two groups will be examined separately in the Results section.

Although initial article selection criteria excluded asthma studies without a control group, the scarcity of research in this area made it necessary to be more inclusive. The first

exception involved including studies that lacked either a control group or statistical tests of significance because the articles still provided useful qualitative insights and information. The second exception was to include other chronic disease intervention case studies under the assumption that these case studies might provide insights about successful asthma interventions in the culturally, economically, and socially unique border region. It should also be noted that some of the articles were based on the same data set or intervention programs, which could skew the results of the literature search.

Results: Tables 2 and 3 contain the year, author, and location of each study included in the literature review. The search yielded 9 studies on the effects of air pollution and respiratory disease and 10 health intervention assessments. The majority of the articles was published between 2000 and 2005 and described studies conducted in the states of Texas, Arizona, and California on the United States side and in Chihuahua and Sonora on the Mexican side.

Table 2: Air Pollution Studies by Location, Date, and Author:

Location	Year	Author
Ciudad Juarez, CHI	2001	Barraza-Villareal
San Diego & Imperial Counties, CA	1998	English
Southern California	2002	Guaderman
Southern California	2000	Guaderman
Southern California	2007	Gauderman
Ciudad Juarez, CHI	2000	Hernandez-Cadena
Southern California	1999	McConnell
Nogales, AZ & Nogales, SON	2003	Stephen
Ciudad Juarez, CHI	2004	Romieu

Table 3: Intervention Studies by Location, Date, and Author:

Location	Year	Author
El Paso, TX	2005	Alexander
Starr County, TX	1999	Brown
San Diego County, CA	2002	Hovell
Agua Prieta, SON & Douglas, AZ	2004	Hunter
Yuma & Santa Cruz Counties, AZ	2005	Ingram
San Diego County, CA	2001	Jones
Ciudad Juarez, CHI & El Paso, TX	2005	Lorig
El Paso Lower Valley, TX	2002	Ochsner
Yuma & Santa Cruz Counties, AZ	2005	Staten
Yuma & Santa Cruz Counties, AZ	2005	Teufel-Stone

Graphic 1 displays the geographical distribution of the studies. Air pollution studies were concentrated in communities in Southern California; Ciudad Juarez, Chihuahua; and Ambos Nogales, Arizona. None of the air pollution studies were located in Texas or New Mexico. Intervention case studies were more evenly distributed. Four articles were based on studies in Texas, four in Arizona, and two in California.

Air Pollution and Respiratory Disease - Geographical and Chronological Distribution:

The search resulted in nine studies that provided quantitative research data on the relationship between air pollution and asthma. Seven other articles were selected for qualitative and supplemental information. The seven studies examining the relationship between air pollution and asthma took place in urban, suburban and rural settings on both sides of the border. Mexican locales included Ciudad Juarez in Chihuahua and Nogales in Sonora while United States locations included Nogales in Arizona, Imperial County in California, San Diego County in California, and twelve unnamed communities in Southern California. All of the studies except English's archival study in San Diego and Imperial Counties were carried out between 1990 and 2000.

Graphic 1: Geographic Distribution of Studies



Background: In a study of asthma prevalence among Puerto-Ricans, Mexican-Americans, and Cubans, Carter-Pokras et. Al. (1993) found that Hispanics of Mexican descent have a much lower prevalence of asthma than other Hispanic groups. Nevertheless, poverty is the number one determinant of poor health outcomes, which places the predominately low income US-Mexico border population at an elevated health risk. According to the Sierra Club, there has been a sharp increase in exhaust emissions resulting from heavy duty diesel truck traffic on international bridges since the beginning of NAFTA in 1994. These emissions release particles and compounds that interact to form ground level ozone, one of the many air pollutants linked to asthma prevalence in the border region. A consistent finding in epidemiologic studies is that ozone is associated with asthma hospitalizations and emergency room visits (Walker,

2003). Ozone is just one of many air pollutants identified in the border region that has been linked to asthma prevalence.

Study Design: The nine studies of the relationship between air pollution levels and asthma had differing research designs. Five of the studies used a cross sectional experimental design, one used a case crossover design, one used a longitudinal cohort design, and two studies used cross sectional archival data. One of the studies included a control group. Subjects ranged from newborns to 15 years of age, reflecting the fact that asthma is the most common chronic disease among Latino children (Jones 2001). Studies varied widely in the dependent and independent variables that were used and the methods used to measure these variables.

These differences make it difficult to directly compare the findings of the seven studies. Although some studies collected their own air pollutant data, others utilized historical data taken from the Environmental Protection Agency (EPA), which limited the variety of pollutants included. For example, the English et al (1998) archival study only examined the effects of particulate matter less than 10 microns in diameter (PM₁₀) and ground level ozone because the EPA only monitored these two air pollutants over the entire study period. The two cross sectional cohort studies carried out by Gauderman et al (2000 & 2002) and the McConell et al (1999) study examined the effects of a broader scope of air pollutants including particulate matter less than 2.5 microns in diameter PM_{2.5}, PM₁₀, nitrogen dioxide (NO₂), acid vapor, and elemental carbon, by setting up its own air pollution monitoring stations.

Dependent variables also varied among studies. For example, the lack of consensus in the medical field regarding the definitions of asthma used complicated comparisons. For example, Stephen et al (2003) used an operational definition for asthma that included either a doctor diagnosis or the demonstration of certain asthmatic symptoms, English (1998) and Hernandez-Cadena (2000) used the International Classification of Diseases codes for asthma, and Guaderman (2000 & 2002) and McConnell (1999) based their definition on physiological data related to lung function collected directly by field technicians.

Results: Table 4 provides a summary of the results of the seven studies that examine air pollution's relationship to asthma prevalence. PM_{2.5}, PM₁₀, ozone, NO₂, acid vapor, and elemental carbon PM had statistically significant correlations with asthma symptom prevalence or lung function growth in at least one of the experiments. Five of the seven articles reported a statistically significant relationship between PM₁₀ and asthma prevalence. Three of the seven articles reported a strong association between acid vapor and NO₂ and asthma prevalence. PM₁₀, ozone, NO₂, acid vapor, and elemental carbon were found associated to asthma prevalence in just one of the seven articles.

Table 4- Statistically significant relationships found for various air pollutants

Author	PM _{2.5}	PM ₁₀	O ₃	NO ₂	Acid Vapor	Elemental Carbon
Barraza-Villarreal	--	--	--	--	--	--

English	--	n.s.	n.s.	--	--	--
Gauderman 2000	X	X	n.s.	X	X	n.s.
Gauderman 2002	n.s.	X	n.s.	X	X	X
Gauderman 2007	Details of air pollutants included in study not included in article					
Hernández-Cadena	--	X	X	--	--	--
McConnell*	n.s.	X	n.s.	X	X	--
Romieu	--	X	n.s.	--	--	--
Stephen	n.s.	X	--	--	--	--

* Studies based on data collected through the Children's Health Study project

-- Contaminant not measured

n.s. Contaminant measured but no statistically significant relationship found

X Statistically significant relationship found

Other risk factors: Asthma manifests its most severe forms in early childhood (Bäcklund, 2006). Consistent with this finding, several studies report that the effects of air pollution were most pronounced among younger children and infants (Barraza-Villarreal, 2001 & English, 1998). No information on the effects of air pollution on asthma prevalence among the elderly in the border region was found in the search. Low socioeconomic level and family history of asthma also constituted asthma risk factors (Romieu, 2004). For example, the Barraza-Villarreal et al (2001) study of asthma prevalence among school children in Ciudad Juarez found that while private school children had a higher rate of asthma diagnosis, public school children, presumably of a lower socioeconomic level, displayed a higher rate and severity of asthma symptoms. Barraza-Villarreal et al (2001) and Stephen (2003) found that family history of asthma represented another significant risk factor, which is supported by evidence from prior studies in the general population (Burke, 2003).

Intervention Strategies and Case Studies: The nature of the asthma and chronic disease interventions involved educational activities delivered in the form of home visits and workshops by a nurse, social worker, or community health worker. The length of the interventions varied from a single meeting to weekly meetings over the course of a year. The interventions aimed to decrease symptoms through improving the participant's disease management skills.

Geographical and chronological distribution: After an initial search for asthma intervention case studies in the border region yielded only 4 case studies, the literature search was widened to include interventions of other types of chronic disease. The widened search yielded 8 additional articles for a total of 11 publications. These articles were published between the years 1997 and 2005 and describe chronic disease interventions studies in El Paso, Starr, Yuma, Santa Cruz, Imperial, San Diego, and Douglas counties on the US side of the border and in the town of Agua Prieta on the Mexican side. Of these articles, four were asthma interventions, four were diabetes interventions and three were chronic disease interventions.

Study designs: Each study used a pre/post test design to determine the effects of an educational intervention on knowledge, behavior, and/or health measures. All but one study reported statistically significant improvements in at least some outcome measures. Most studies did not include a control group. Although the absence of a control group impeded the ruling out of alternative explanations, the use of multiple studies and replications allowed the interpretation of the changes in the experimental group in some of the articles.

Recruitment of participants: The majority of interventions used identified subjects via school and community clinic nurse referrals, hospital emergency rooms referrals, and rosters of former health interventions. The environmental tobacco smoke (ETS) reduction intervention in San Diego County used more conventional marketing methods to recruit from the general population through radio announcements, print ads, and flyers, in addition to health fairs, schools, clinics, and WIC offices. The same methods used for recruiting adult subjects could be extended to studies of asthma interventions with the assumption that most asthma interventions depend on the participation of the asthmatic's parents or caretakers.

Demographics of Asthma Intervention Subjects: Due to the pediatric nature of asthma, all asthma interventions targeted school aged children and most involved parent participation. Parents were included in many of the studies because of the vital roll of parents in teaching children to manage asthma (Parker-Oliver, 2005). The diabetes and chronic disease intervention subjects were mostly low income Hispanic adults in urban or suburban settings.

Intervention Settings: The majority of the asthma and chronic disease interventions took place in community based locations such as churches, schools, county agricultural extension offices, adult day care centers, health clinics, neighborhood community centers. In four cases either part or all of the intervention was delivered in the patient's home and in one case in a hospital setting. Community based locations were effective in overcoming transportation barriers and creating a familiar setting for participants.

Best Practices and Challenges: A reoccurring success factor in the majority of interventions was the involvement of lay community health workers (CHWs), also called 'promotoras', 'trained Latina assistants' and 'trained peer workers'. CHWs are indigenous to the communities in which they work and provide a bridge between the health care delivery system and the community (Ingram 2005). The role of the CHW varies depending on the nature and design of the intervention. In the reviewed literature, promotoras helped develop educational material, recruited intervention participants, facilitated and administrated classes, provided moral and technical support via phone calls and home visits, and offered transportation and child care when needed. In addition to bridging the gap between communities and health services, CHWs also augment the drastically under-staffed and under-funded border health system. For example, in the year 2000 there was only one registered nurse per 259 persons along the Texas-Mexico border compared to a ratio of 1 to 169 statewide (Begley et al, n.d.).

All interventions mentioned the inclusion of culturally tailored approaches and educational materials. Such cultural tailoring included presenting asthma recommendations without refuting alternative health beliefs, using local terminology for diseases and symptoms, appropriately addressing gender roles in child care in Hispanic families (Jones 2000), including a family member in a supportive role, and using bilingual staff and materials.

Collaboration between community organizations also contributed to intervention success and quality. For example, the three-year comprehensive Border Health ¡SI! program in Yuma and Santa Cruz Counties created a synergy between eight community organizations including the local university, community health and education centers and civic organizations (Cohen 2005). Collaboration aided in leveraging extremely limited funds and resources in the US Mexico border region and creates a synergy between governmental, nongovernmental, and civic organizations and the community residents.

Various barriers to success included attrition in participation due to the transient nature of low income border residents, lack of transportation to the meeting sites, high costs of cost of medication, lack of health coverage and lack of health care professionals in the region.

Discussion: Analysis of the results of the search provided a summary of the existent literature on the relationship between air pollution and asthma as well as research on public health interventions that address asthma in the US-Mexico border region. This review suggests several weaknesses in the previous research that need to be addressed in future studies, including lack of attention to the diversity of the border region, a focus on factors not under the control of the asthmatics, the underreporting of asthma prevalence, a lack of attention to asthma intervention programs implemented by Mexican institutions or organizations, and a focus on children to the neglect of adult populations.

Failure to take into account the diversity of the border region: The existing literature fails to address the implications of the substantial sociological, environmental, cultural and residential diversity of the border region on future asthma interventions. The majority of researchers chose urban experimental settings most likely due to three factors: 1) significantly higher levels of air pollution in cities due to motor vehicle emissions and industrial processes and 2) higher rates of doctor diagnosed asthma and 3) 86% of the border population lives in one of the fourteen sister cities on the border (US-Mexico Border Health Commission 2001). Nevertheless, rural areas experience other types of air pollution such as particulate matter from dust on unpaved roads and pesticide exposure from agricultural spraying. Population distribution and living conditions on the US-Mexico border range from densely crowded sister cities such as San Diego/Tijuana and El Paso/Ciudad Juarez to uninhabited stretches of desert and rural agricultural communities (NIEHS 2000). Moreover, the socioeconomic and psychological characteristics of residents, such as openness to outsiders, vary widely as do

geographic features and environmental health risks. Future studies should focus on this topic in order to guide successful chronic disease interventions.

Focus on factors not controlled by individual asthmatics: Unfortunately, many groups are at risk for exposure to air pollutants that trigger asthma merely because of their socioeconomic status, which influences where they live (Walker 2003). The air pollutants associated with asthma prevalence identified in this literature review were primarily caused by the burning of diesel and fossil fuels in motor vehicles and industrial processes, which could be related to rapid industrial growth in the past decade. Solutions to these environmental problems lie at the state and federal policy level and are largely out of the control of the asthmatic individual. In the face of environmental contamination and inadequate health care resources, the most feasible way to address the problem of asthma is through educating the patient to manage their condition.

Underreporting of Asthma Prevalence: Based on evidence from several studies, asthma prevalence on the US-Mexico border is most likely underreported among groups of lower socioeconomic status. For example, Stephen et al (2003) found a higher rate of serious respiratory symptoms in a sample of children in the Mexican city of Nogales than among a sample in its sister city, the US city of Nogales. Barraza-Villarreal et al (2001) found that lower socioeconomic level was positively related to the presence of asthma symptoms but negatively related to the prevalence of a doctor diagnosis of asthma, which reflects that not all of the population has access to health care and that the real number of asthma prevalence when using a definition of diagnosis can result in underestimating.

A possible explanation for underreporting among lower socioeconomic groups is that these groups are less likely to utilize health services for cultural and financial barriers. The differences in the structure of the health care systems and the procedures for diagnosis in the US and Mexico might also influence the rate of asthma diagnosis in each country.

Failure to examine the relation between specific types of air pollution and asthma
The literature search came across no documentation of asthma intervention programs implemented by Mexican institutions or organizations in the border region. A comparison of intervention designs and outcomes might yield interesting insights for both the Mexican and US entities that address this issue.

Neglect of Asthma Prevalence in adult populations: No information was found regarding the prevalence and nature of asthma among other vulnerable groups such as the elderly and workers in hazardous occupations such as agriculture. These groups clearly merit different intervention approaches than those described in the studies of children included in this literature review and further research is needed.

Conclusions: Asthma poses a public health threat to the U.S.-Mexico border population and compromises the health and quality of life of those that suffer from the disease. Studies on the public health effects of air pollution suggest that increased exposure to

certain air pollutants aggravates asthma symptoms. The most concrete outcome of the studies of air pollution's relationship to asthma in the border region is that PM₁₀ was significantly associated with the prevalence of asthma symptoms in children. A review of the research on respiratory disease interventions in the area revealed key success factors such as collaboration with community health workers, the inclusion of culturally tailored educational content, and the use of community sites as meeting places.

Although the field of research on air pollution's relationship to asthma prevalence and asthma interventions is well developed, most of what is known comes from research on persons and settings far different than those found in the US-Mexico border region. The scarcity of published research and the inconsistency of study designs, terminology, and experimental outcomes make it difficult to draw decisive conclusions to guide future policies and public health interventions. Unknown factors in the literature include 1) the prevalence of asthma in populations other than children such as agricultural workers and the elderly and intervention strategies for these groups, 2) comprehensive information on air pollution and asthma interventions on the Mexican side of the border and in rural areas on both sides of the border, 3) the strength of the relationship between specific types of air pollution and asthma, and 4) the influence of the social, economic, cultural, environmental and residential diversity of the border region on effective asthma intervention strategies.

Given the cross-border nature of air pollution and its negative health effects, research on these policies will require bi-national cooperation. Policy makers and public health professionals on both sides of the border should explore ways to control types of air pollution suspected of aggravating asthma symptoms such as PM₁₀, acid vapor and NO₃ as well as educate border residents about protecting their health. Furthermore, both governmental and non governmental organizations should educate border residents about protecting themselves against the harmful effects of air pollution and the detection and management of asthma and other respiratory diseases.

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