Maquiladoras, Air Pollution, and Human Health in Ciudad Juárez and El Paso

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Abstract

Ciudad Juárez, Chihuahua, is home to the U.S.–Mexico border's largest maquiladora labor force, and also its worst air pollution. We marshal two types of evidence to examine the link between maquiladoras and air pollution in Ciudad Juárez, and in its sister city, El Paso, Texas. First, we use a publicly available sector-level emissions inventory for Ciudad Juárez to determine the importance of all industrial facilities (including maquiladoras) as a source of air pollution. Second, we use original plant-level data from two sample maquiladoras to better understand the impacts of maquiladora air pollution on human health. We use a series of computational models to estimate health damages attributable to air pollution from these plants, we compare these damages to estimates of damages from non-maquiladora industrial polluters, and we use regression analysis to determine whether the poor suffer disproportionately from maquiladora air pollution. We find that air pollution from maquiladoras has serious consequences for human health, including respiratory disease and premature mortality. However, maquiladoras are clearly not the leading cause of air pollution in Ciudad Juárez and El Paso. Moreover, most maquiladoras are probably less important sources of dangerous air pollution than at least one notoriously polluting Mexican-owned industry. Finally, we find no evidence to suggest that maquiladora air pollution affects the poor disproportionately.

Key Words: maquiladora, air pollution, human health, environmental justice, U.S.–Mexico border, Ciudad Juárez, El Paso

JEL Classification Numbers: Q01, Q25, O13

Contents

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1. Introduction

Like most metropolitan areas on the U.S.–Mexico border, Paso del Norte, comprised principally of Ciudad Juárez, Chihuahua, and El Paso, Texas, has experienced exceptionally rapid population and economic growth during the last several decades.[1] Between 1990 and 2000, Ciudad Juárez's population grew by about 50% (from 0.8 million to 1.2 million), while El Paso's population grew by about 16% (from 0.6 million to 0.7 million), rates approximately twice those for Mexico and the United States (Desarrollo Económico de Ciudad Juárez 2002, Economist 2001). The maquiladora industry is partly responsible for the region's growth. Ciudad Juárez is home to approximately 300 maquiladora plants employing over 250,000 workers, the largest twin plant labor force on the border (Desarrollo Económico de Ciudad Juárez 2002).

Paso del Norte's growth has had serious environmental consequences, particularly for air quality, which is the worst on the U.S.–Mexico border. Ciudad Juárez exceeds national ambient air quality standards (official norms) for ozone, carbon monoxide, and particulate matter less than 10 microns in diameter (PM10), and El Paso exceeds national ambient air quality standards for ozone, PM10, and carbon monoxide. An overwhelming body of evidence links such air pollution to respiratory and cardiovascular disease, and to premature mortality (U.S. EPA 1999). In addition, air pollution damages visibility, materials, and agriculture. Surveys show that Paso del Norte's residents are more concerned about air pollution than any of the region's other environmental problems (Joint Advisory Committee 1999).

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This chapter examines the link between Paso del Norte's air pollution and its maquiladoras. To what extent are maquiladoras responsible for this pollution? What impacts does it have on human health? Are the poor disproportionately affected? Unfortunately, little reliable publicly available data exist to answer these questions. This chapter takes a first step toward filling this gap by marshalling two types of evidence. First, we use a publicly available sector-level emissions inventory for Ciudad Juárez to determine the importance of all industrial facilities (including maquiladoras) as a source of air pollution. Second, we use original plant-level data from two maquiladoras to better understand the impacts of maquiladora air pollution on human health.

We use a series of computational models to estimate health damages attributable to air pollution from these plants, we compare these damages to estimates of damanges from non-maquiladora industrial polluters, and we use regression analysis to determine whether the poor suffer disproportionately from maquiladora air pollution. Two important caveats are in order. The two maquiladora plants for which we estimate health damages were selected for idiosyncratic reasons, and therefore may not be particularly representative. Also, our plant-level maquiladora emissions data are estimated, not measured. Hence, care must be exercised in interpreting our results.

Nevertheless, the broad message of this analysis is fairly clear. Air pollution from maquiladoras has serious consequences for human health, including respiratory disease and premature mortality. However, maquiladoras are clearly not the leading cause of air pollution in Paso del Norte. Moreover, most maquiladoras are probably less important sources of dangerous air pollution than at least one notoriously polluting Mexican-owned industry. Finally, we find no evidence to suggest that maquiladora air pollution affects the poor disproportionately.

The remainder of the chapter is organized as follows. The next section presents sector-level emissions inventory data. The third section describes the sample plants and the methods

[1] Paso del Norte also includes southern Dona Aña County, New Mexico, which contains less than 2% of the metropolitan area's combined population.

used to estimate health damages, and presents the results of the modeling exercise and the environmental justice analysis. The last section summarizes the findings of the report and presents conclusions based on these findings.

2. Evidence from sector-level emissions data

The best available emissions inventory for Ciudad Juárez is the 1996 Sistema Nacional de Información de Fuentes Fijas (SNIFF) for the state of Chihuahua (Gobierno del Estado de Chihuahua 1998). Unfortunately, these data are problematic. Although plant-level data exist, only data aggregated to the level of the industry subsectors is publicly available. Also, questions have been raised about the reliability of the data. Nevertheless, there is a general consensus that the SNIFF provides a good "back of the envelope" indication of the relative importance of different types of emissions sources.

The publicly available SNIFF data cover five different pollutants—particulate matter (PM), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_x), and hydrocarbons (HC)—from four different sectors—industry, services, transportation, and soils—and 34 subsectors. These data clearly show that industry is not a leading source of air pollution (Table 1). Industry only accounts for 17% of total SO_2 emissions, 5% of total NO_x emissions, 3% of total hydrocarbon emissions, and less than 1% of total PM emissions.

Table 1. Sectoral contribution to air pollution in Ciudad Juárez (%)

Sector	Pollutant					
	PM	SO_2	CO	NOx	HC	All
Industry	0	17	0	5	3	1
Services	1	44	0	3	25	4
Transport	2	38	99	92	72	88
Soil: wind erosion	31	0	0	0	0	2
Soil: unpaved roads	65	0	0	0	0	5
All	100	100	100	100	100	100
Total (tons)	46,607	4,146	452,760	26,115	76,132	605,760

(Source: Sistema Nacional de Información de Fuentes Fijas 1996
as reported in Gobierno del Estado de Chihuahua 1998)

A caveat is in order with regard to PM. Although soil PM from wind erosion and unpaved roads is listed as the source of 96% of total PM emissions, this statistic may overstate this source's importance as a human health hazard. Soil PM is principally comprised of large particulates, which are relatively benign epidemiologically. Smaller particulates related to combustion are much more dangerous because they are inhaled deeply into the lungs (Cifuentes et al. 2000, Laden et al. 2000). But note that even if particulate matter from soil is excluded, industry is still a relatively minor source of PM emissions, accounting for just 14% of remaining emissions.

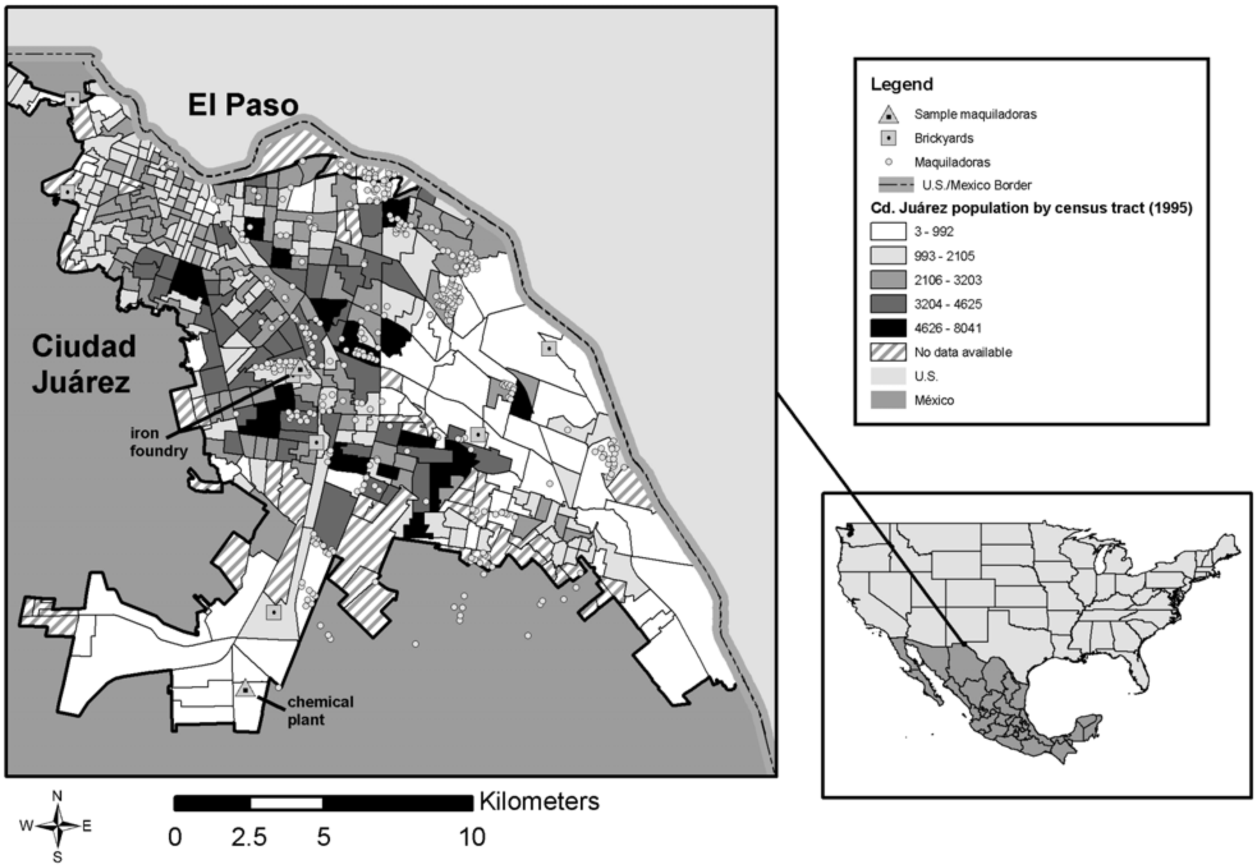
Even within the industry subsector, maquiladoras are not the leading source of two of the SNIFF air pollutants—PM and SO_2. That distinction belongs to small-scale brick kilns (Table 2).[2] (Note that, although the SNIFF does not include information on whether the emissions sources in its inventory are maquiladoras, for reasons discussed below, we can be certain that brick kilns are not).

3. Evidence from a plant-level model of health damages

This section presents estimates of health damages from two maquiladoras and an indigenous Mexican industry. The first maquiladora is a U.S.-owned gray iron foundry that produces table bases for restaurant and hospitality industries. It employs about 140 workers and is located in an industrial park called Gema II in a densely populated central section of Ciudad Juárez (Figure 1). The second maquiladora is a Belgian-owned chemical plant that mainly produces hydrofluoric acid. It employs about 150 workers and is located in the sparsely populated southern section of Ciudad Juárez (Figure 1).

[2] The brickmaking *colonias* are Anapra, Division del Norte, Fronteriza Baja, Kilometro 20, Mexico 68, Satelite, and Waterfill. When brickmakers squatted in these *colonias* 25 or 30 years ago, all were situated on the outskirts of the city. Today, however, most have been enveloped by urban sprawl.

Figure 1. Population, maquiladoras and brick kilns in Paso del Norte



The indigenous Mexican industry is a collection of approximately 350 tiny family-owned brick kilns. The typical brick kiln is a 10-meter-square primitive adobe structure that holds 10,000 bricks, employs five or six people, and is fired two to three times a month with scrap wood, sawdust, and other rubbish (Blackman and Bannister 1997). The location of the traditional brick kilns exacerbates their adverse impact on human health. They are clustered in seven poor *colonias* (neighborhoods) scattered throughout Ciudad Juárez (Figure 1).[2]

3.1. Sample selection

The two maquiladoras in our sample were selected on the basis of two criteria: (i) each is reputed to be a leading industrial source of air pollution, and (ii) the detailed technical data needed to estimate their emissions are available. Some brief additional explanation may be helpful.

We began the process of selecting maquiladoras for this study with a list of Paso del Norte's leading industrial sources of air pollution, compiled from informal information provided by local stakeholders. We used U.S. Environmental Protection Agency (EPA) emissions factors to estimate emissions for these plants (U.S. EPA 1995). Based on engineering estimates and historical emissions data, the EPA methodology is widely used by regulatory agencies around the world to estimate plant-level emissions. It requires detailed data on plant characteristics, including the type of products or output, the scale of production, the type of production technology, and the type of abatement equipment used. In the summer of 2001, we interviewed managers and engineers of the plants on our list (both in person and by telephone) in an attempt to obtain these data. Only two of the industrial facilities on our list—the gray iron foundry and the chemical plant described above—provided all of the information needed to estimate emissions.

Because the two maquiladoras in our sample were selected from an informal list of the leading sources of air pollution in Paso del Norte, we can be fairly certain that they are more significant polluters than most other maquiladoras. However, among other leading sources of air pollution, these two plants are not necessarily representative since they were selected for idiosyncratic reasons.

3.2. Emissions and abatement in sample plants

For reasons discussed below, we focus on only one type of pollutant: PM10. According to U.S. EPA (1995), the principal sources of PM10 emissions for iron foundries are, in order of magnitude: pouring and cooling of molten iron, handling of sand used to make molds, shaking sand from the molds, cleaning and finishing of cast iron, and operating an induction furnace. The bulk of the chemical plant's PM10 emissions come from the use of fluorspar, the principal material used in the manufacture of hydrofluoric acid. In particular, PM10 is emitted in drying, handling, and transferring fluorspar. The principal source of PM10 from traditional brickmaking is combustion of fuels used to fire the kiln.

Unfortunately, data on the installation and use of pollution control equipment at our two sample maquiladora plants is limited. While the two plants claim to use emissions abatement devices, regulatory inspection and monitoring data is not available, and there is no easy way of verifying these claims. To account for this issue, we present estimates of health damages given: (i) emissions that would result if the plants used no pollution control devices whatsoever, and (ii) emissions that would result if they used all of the pollution control equipment that is standard in U.S. plants.[3] Based on the claims of plant engineers and casual observation, the second scenario is probably more realistic than the first. We know from survey evidence that brick kilns typically employ no pollution control devices whatsoever (Blackman and Bannister 1997).

3.3. Methods

Although the plants in our sample emit a variety of pollutants, we have chosen to focus only on PM10 for several reasons. First, PM10 is generally thought to be responsible for a large proportion of the total noncarcinogenic adverse health impacts of air pollution (Pope et al. 1995). Also, data on the emissions of other types of air pollutants (e.g., toxics) from fixed sources is limited. Finally, the effects of PM10 on human health are relatively well-understood.

We have also chosen to focus only on one category of adverse impacts of PM10: human morbidity and mortality. We do not consider the effects of PM10 on visibility, materials

[3] The "U.S.-level of control scenario" is constructed using U.S. EPA (1995). This document specifies what abatement equipment is typically used to control particulate emissions from different types of intra-plant emissions sources (e.g., boilers and transfer operations) at different types of plants, and also indicates the percent of particulate emissions eliminated. For example, according to U.S. EPA (1995), baghouses are used to control particulate emissions from induction furnaces at iron foundries, and they eliminate 80% of particulate emissions. Baghouses are the relevant control equipment for most of the intra-plant emissions sources at the iron foundry and chemical plant. Note, however, that fluorspar transfer operations are typically controlled by covers and additives to the fluorspar.

damages, or non-use values. Therefore, our estimates of the damages from industrial emissions may be thought of as a lower bound on the total value of the damages.

We use three models to estimate health damages from PM10. First, we use an air dispersion model to estimate each source's contribution to annual average ambient levels of PM10 at several thousand receptor locations in Paso del Norte. Next, we use a health effects model to estimate the number of cases of human mortality and morbidity that result from this pollution each year. Finally, we use a valuation model to calculate the dollar values of these health impacts. This section briefly discusses each of these models. A more detailed discussion is available in Blackman et al. (2000).

Air dispersion model. We use the U.S. EPA's Industrial Source Complex Short Term 3 (ISCST3) air dispersion model to estimate annual average concentrations of PM10 from our sample plants at a rectangular array of 5,546 receptor locations in the study area. ISCST3 uses data on emissions source characteristics (such as smoke stack height, emissions velocity, and emissions temperature) as well as local meteorology and topography to estimate annual concentrations of emissions in a defined study area. Where such data are missing for our sample plants, we use publicly available data from U.S. facilities of the same type (U.S. EPA 2002a).

Health effects model. To estimate exposure to the PM10 produced by our sample plants, we use population data at the survey unit level—that is, at the level of areas geoestadísticas básicas (AGEBs) in Ciudad Juárez and census tracts in El Paso. We assign the inhabitants of each survey unit a distance-weighted average of PM10 concentrations predicted by the ISCST3 model at all model receptor points within 800 meters of the survey unit centroid. Next we estimate the health effects of this exposure using concentration-response (CR) coefficients reported in the epidemiological literature. CR coefficients indicate the expected change in the number of cases of some heath endpoint due to a marginal change in the ambient concentration of an air pollutant. We model the nine different health endpoints: mortalities, respiratory hospital admissions, emergency room visits, adult respiratory symptom days, adult restricted activity days, asthma attacks, child chronic bronchitis, child chronic cough cases, and adult chronic bronchitis cases.

We make the conventional assumption that these health effects are linear functions of PM10 exposure levels (see, e.g., U.S. EPA 1999).

Valuation model. To estimate the monetary values of health damages, we use a combination of the following: (i) willingness to pay (WTP) figures from the economic literature—i.e., a "benefits transfer" approach, (ii) estimates of the value of [work loss days] based on average daily wages in Ciudad Juárez and El Paso, and (iii) estimates of health care costs based on the value of work loss days. Since over three-quarters of total estimated damages arise from mortality, by far the most important parameter in the valuation model is the value of a statistical life. We use a discrete distribution—$1.9 million (33%), $3.8 million (34%), and $7.5 million (33%)—from Hagler Bailly, Inc. (1991). This distribution is relatively conservative. For example, U.S. EPA used a mean value of $4.8 million per mortality avoided to assess the benefits of the Clean Air Act (see U.S. EPA 1999, Appendix H-8). The parameters used to value respiratory hospital admissions and emergency room visits are estimates of medical costs associated with each endpoint. These estimates are based on work-day-equivalent conversion factors taken from a study for Santiago, Chile (World Bank 1994). We also use conversion factors to estimate the value of child chronic cough.

Unfortunately, to our knowledge, direct estimates of Mexican WTP for reductions in the health endpoints considered in this paper are not yet available. Therefore, we use WTP parameters (for adult respiratory symptom days, adult reduced activity days, asthma attacks, and chronic bronchitis) that are based on U.S. studies. But given that average income adjusted for purchasing power parity is approximately four times as high in the United States as in Mexico, Mexican WTP may be lower than American WTP. Cultural factors may also cause WTP in the two countries to differ. To account for international differences in WTP, we use sensitivity analyses. For each health impact, we use three different values for Mexican WTP based on three different assumptions about the elasticity of WTP with respect to income, a parameter we will call E.[4] We assume alternatively that E = 1, E = 0.33, and E = 0. For example, E = 0.33 implies that if average per capita income adjusted for purchasing power parity is 10% lower in Ciudad Juárez than in El Paso, then WTP is 3.3% lower. An E between 0.2 and 0.5 is supported by some studies that look at differences in WTP across income groups (Alberini et al. 1997, Loehman et al. 1979). Thus, the middle value of the discrete probability distribution we use to value premature mortality in Mexico is $3.80 million assuming E = 0, $2.42 million assuming E = 0.33, and $0.97 million assuming E = 1.

We use Monte Carlo analysis to account for uncertainty associated with the parameterization of our air dispersion, health impacts, and benefits valuation models. That is, where data on probability distributions is available, we treat model parameters as distributions and we use these distributions to generate (95%) confidence intervals for model outputs. To make the tables easier to digest, however, we only report the means of these distributions here.

3.4. Health damages estimates

Tables 3 and 4 present the annual health damages attributable to PM10 emissions from the two sample maquiladoras. The tables present the number of cases for two different emissions control scenarios—absolutely no emissions controls, and U.S.-level controls—as well as the average number of cases for these two scenarios. Table 5 presents the health damages attributable to PM10 emissions from brick kilns, which, as noted above, are completely uncontrolled. Finally, Table 6 gives the annual dollar value of all of these health damages.

[4] The empirical foundations of this second-best approach to estimating international differences in WTP can be legitimately questioned. Evidence on the topic is sparse. Chestnut et al. (1999) find that median WTP to avoid respiratory symptoms is higher in Thailand than one would expect from U.S. studies. See also Alberini et al. (1997).

Table 3. Annual health damages due to estimated PM10 emissions from iron foundry maquiladora (mean value of predicted number of cases)

Health endpoint	No controls			U.S.-level controls			Avg.
	Cd. Juár.	*El Paso*	*Total*	*Cd. Juár.*	*El Paso*	*Total*	*Total*
Mortality	1.44	0.15	1.59	0.09	0.01	0.10	0.85
Resp. hospital admissions	26.69	2.14	28.83	1.58	0.15	1.73	15.28
Emergency room visits	61.70	4.93	66.63	3.66	0.36	4.02	35.33
Adult resp. symptom days	38,970.00	3,520.00	42,490.00	2,319.00	253.10	2,572.10	22,531.05
Work loss days	327.20	26.17	353.37	19.42	1.88	21.30	187.34
Adult rest. activity days	14,320.00	1,145.00	15,465.00	849.90	82.46	932.36	8,198.68
Asthma attacks	4,350.00	347.80	4,697.80	258.10	25.04	283.14	2,490.47
Child chronic bronchitis	165.40	10.63	176.03	9.77	0.77	10.54	93.29
Child chronic cough	191.60	12.32	203.92	11.32	0.89	12.21	108.07
Adult chronic bronchitis	9.70	0.88	10.58	0.58	0.06	0.64	5.61

(Source: RFF model)

Table 4. Annual health damages due to estimated PM10 emissions from chemical plant maquiladora (mean value of predicted number of cases)

Health endpoint	No controls			U.S.-level controls			Avg.
	Cd. Juár.	*El Paso*	*Total*	*Cd. Juár.*	*El Paso*	*Total*	*Total*
Mortality	8.78	2.59	11.37	0.17	0.05	0.22	5.80
Resp. hospital admissions	162.50	35.97	198.47	3.23	0.71	3.94	101.21
Emergency room visits	375.70	83.15	458.85	7.46	1.64	9.10	233.98
Adult resp. symptom days	233,700.0	58,610.0	292,310.0	4,641.00	1,154.0	5,795.0	149,052.5
Work loss days	1,992.00	441.00	2,433.00	39.56	8.68	48.24	1,240.62
Adult rest. activity days	87,210.00	19,300.00	106,510.0	1,732.00	379.80	2,111.80	54,310.90
Asthma attacks	26,480.00	5,862.00	32,342.00	525.90	115.30	641.20	16,491.60
Child chronic bronchitis	1,030.00	183.70	1,213.70	20.45	3.61	24.06	618.88
Child chronic cough	1,194.00	212.90	1,406.90	23.69	4.18	27.87	717.39
Adult chronic bronchitis	58.19	14.59	72.78	1.16	0.29	1.45	37.12

(Source: RFF model)

Table 5. Annual health damages due to estimated PM10 emissions from brick kilns (mean value of predicted number of cases)

Health endpoint	No controls		
	Cd. Juár.	*El Paso*	*Total*
Mortality	14.1	2.6	16.70
Resp. hospital admissions	262	37	299.00
Emergency room visits	607	85	692.00
Adult resp. symptom days	376,600	59,300	435,900
Work loss days	3,216	448	3,664.00
Adult rest. activity days	138,000	19,240	157,240.0
Asthma attacks	42,680	5,950	48,630.00
Child chronic bronchitis	1,637	184	1,821.00
Child chronic cough	1,878	211	2,089.00
Adult chronic bronchitis	93	15	108.00

(Source: RFF model)

Table 6. Annual value of health damages due to PM10 emissions (1999 US $; mean values)

Source	Cd. Juárez			El Paso	Total
	(E = 1.0)	(E = 0.33)	(E = 0)		(E = 0.33)
Iron foundry maquiladora*	1,037,100	2,569,450	4,026,550	422,310	2,991,760
Chemical plant maquiladora*	6,078,300	15,058,150	23,594,350	6,765,600	21,823,750
Brick kilns	19,110,000	47,360,000	74,210,000	13,410,000	60,770,000

*average of "no controls" and "U.S.-level controls" scenarios

E = the elasticity of willingness to pay with respect to income adjusted for purchasing power parity.

We begin with two fairly obvious points. First, not surprisingly, for both of the maquiladoras, the health damages (whether measured in number of cases or in dollars) from uncontrolled emissions are considerably higher than for controlled emissions. For the iron foundry, damages are approximately 17 times as high for uncontrolled emissions as for controlled emissions. For the chemical plant, they are approximately 50 times as high. Thus, it bears emphasis that the magnitude of the health damages from maquiladora emissions depends critically on the level of emissions abatement.

Second, for both plants, health damages in Ciudad Juárez are far greater than in El Paso. For the iron foundry, health damages in Ciudad Juárez are about 10 times those in El Paso. For the chemical plant, health damages in Ciudad Juárez are just over three times those in El Paso. The extent to which each plant's emissions affect Mexicans as opposed to Americans depends on the plant's location, local weather patterns, local topography, and the plant's emissions characteristics.

But these two points are relatively minor. The main question addressed by our health damages modeling is: just how significant are health damages attributable to maquiladora emissions? On the face of it, the damages are quite serious. Even if we assume conservatively that emissions are controlled at U.S. levels, the iron foundry is accountable for four emergency room visits, thousands of adult respiratory symptom days, and hundreds of asthma attacks every year.

If we assume that the level of pollution control is the average between the "no controls" and "U.S.-level of controls" scenarios, health damages are far more serious. In this case, the iron foundry is responsible for one premature mortality, 15 respiratory hospital admission, 35 emergency room visits, tens of thousands of adult respiratory symptom days, and thousands of asthma attacks every year. The value of all such damages is approximately $3 million each year. Assuming a similar level of pollution control, the chemical plant generates $22 million worth of health damages each year.

While these figures may be alarming for those unfamiliar with the devastating health impacts of PM10 pollution, they are not particularly meaningful from a policy perspective. To allocate scarce resources available for pollution control efficiently, policymakers need to understand how health damages from maquiladoras compare to damages attributable to other sources. We have two types of data that allow us to compare the likely magnitude of damages across different types of sources.

First, recall that the SNIFF emissions inventory discussed above clearly indicates that industry is not the leading source of particulate emissions in Ciudad Juárez. Rather, the leading sources are vehicles, unpaved roads, and soil erosion (Table 1). Moreover, even leaving aside vehicles and soils, the single most important industrial subsector in terms of air pollution is brick kilns, not maquiladoras (Table 2). In fact, brick kilns emit more particulate matter than all other industrial plants combined. Given that vehicles and brick kilns emit far more combustion-related fine particulates than maquiladoras, we can be fairly certain that they inflict far more severe health damages.

The health damage modeling confirms that PM10 from brick kilns is more damaging than PM10 from our two sample maquiladoras. Table 5 shows that brick kiln PM10 is responsible for approximately 17 premature mortalities and 300 respiratory hospital admissions each year, while the two maquiladoras combined—assuming the level of pollution control is the average between the "no controls" and "U.S.-level of controls" scenarios—are responsible for seven premature mortalities and 116 respiratory hospital admissions each year. Total monetized health damages from brick kiln PM10 emissions are $61 million, compared to $25 million for combined PM10 emissions from the two maquiladoras (Table 6).

One of the principal reasons that brick kilns inflict such serious health damages is that they lack smoke stacks. Therefore, emissions are not dispersed by wind and dramatically boost PM10 concentrations within a half-kilometer of the kiln. Unfortunately, these areas are densely populated low-income residential neighborhoods (Blackman et al. 2000).

3.5. Environmental justice

Does maquiladora air pollution disproportionately affect the poor? The answer depends principally on whether the pollution the maquiladoras emit concentrates in poor areas. To address this issue, we analyze data on the location of poverty in Ciudad Juárez as well as data from our ISCST3 model on how PM10 from our sample maquiladoras disperses throughout the city. We exclude El Paso from this portion of the analysis because Mexicans are the principal victims of air pollution from the sources in our sample, and because differences in Mexican and U.S. census data greatly complicate the analysis.

Figure 2 presents the spatial distribution of poverty in Ciudad Juárez, measured as the percentage of the labor force in each AGEB earning less than two times the minimum wage. It shows that the poorer sections of Ciudad Juárez are mostly in the southern and western parts of the city. Figures 3 and 4 map concentrations of PM10 attributable to uncontrolled emissions of the two sample maquiladoras. They show that PM10 emissions from the iron foundry are most heavily concentrated in the northwestern portions of the city, while PM10 emissions from the chemical plant are mostly concentrated in southwestern portions of the city. Both are relatively poor areas. These figures suggest that emissions from the two sample maquiladoras affect the poor disproportionately.

Figure 2. Poverty, maquiladoras and brick kilns in Paso del Norte

Figure 3. Average annual PM10 concentrations due to iron foundry maquiladora emissions (assuming no controls)

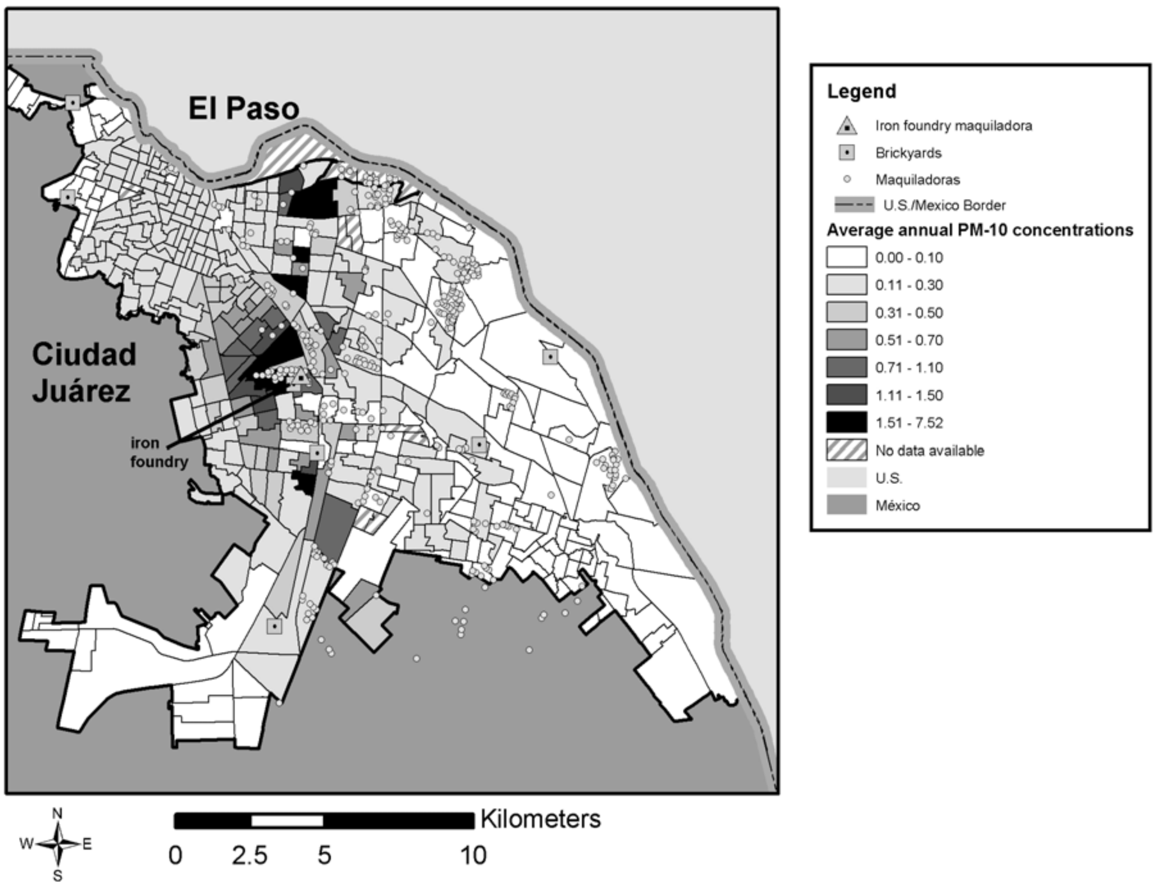
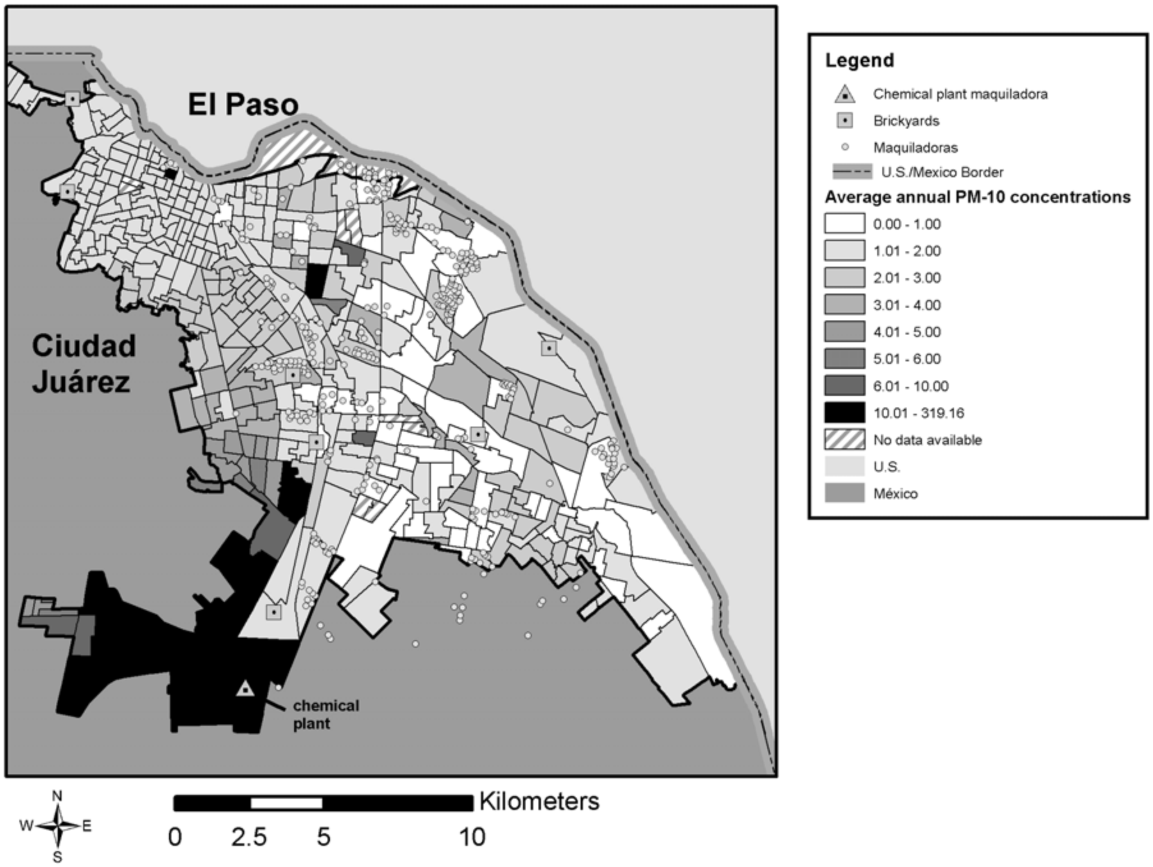


Figure 4. Average annual PM10 concentrations due to chemical plant maquiladora emissions (assuming no controls)



We use regression analysis to test this hypothesis. Taking AGEBs as our unit of analysis, we regress CONCENTRATION, the average annual PM10 concentration (in micrograms per cubic meter per year) attributable to an emissions source onto POVERTY, the percentage of the labor force in each AGEB earning less than two times the minimum wage. We conduct this analysis assuming alternatively that emissions from the two sample maquiladoras are controlled and uncontrolled.

Table 7 presents the regression results.

Table 7. Ordinary least squares regression results

Dependent variable = CONCENTRATION [ug PM10/m^3/year]

Source	Controlled?	Constant	POVERTY
Iron foundry maquiladora	no	0.6379**	-0.5712†
		(0.1947)	(0.3289)
	yes	0.0195**	-0.0018
		(0.0074)	(0.0125)
Chemical plant maquiladora	no	12.2139*	-14.8264
		(5.5829)	(9.4306)
	yes	0.1602	-0.1642
		(0.0787)*	(0.1329)
Brick kilns	no	658.2924	2919.1870**
		(649.2084)	(1096.6330)

Standard errors in parentheses
** significant at 1% level two tailed test
* significant at 5% level two tailed test
† significant at 10% level two tailed test

The regression results do not support the hypothesis that emissions from the two maquiladoras disproportionately affect the poor. The coefficients for CONCENTRATION is only significantly different from zero in one of the four models—that for uncontrolled emissions from the iron foundry. However, the sign is negative. This implies that higher PM10 concentrations are typically found in wealthier AGEBs, not in poorer ones. Thus, overall, we find no evidence that emissions from the two maquiladoras in our sample disproportionately affect the poor.

By contrast, for brick kilns, the coefficient on CONCETRATION is significant and positive, suggesting that brick kiln emissions do disproportionately affect the poor: higher PM10 concentrations are generally found in poorer AGEBs. This is undoubtedly because, as noted above, PM10 emissions from brick kilns mostly concentrate within a half-kilometer of the brickyards, which tend to be located in low-income residential neighborhoods (Figure 2).

Note that the finding that the poor do not suffer disproportionately from maquiladora emissions does not appear to be driven by the idiosyncratic nature of our sample. As Figure 1 illustrates, there is no obvious spatial correlation between the location of maquiladoras and the location of poverty in Ciudad Juárez.

4. Conclusion

We have used a limited data set—comprised of a sector-level emissions inventory and original emissions estimates for a small sample of industrial facilities—to shed light on the links between maquiladoras, air pollution, and human health in Paso del Norte. We found that particulate emissions from maquiladoras undoubtedly have significant impacts on human health—collectively, these plants are probably responsible for dozens of cases of premature mortality and thousands of cases of respiratory disease each year.

However, particulate emissions generate health damages of similar magnitudes regardless of the source, and maquiladoras are clearly *not* the region's leading sources of particulates. That dubious distinction belongs to unpaved roads, vehicles, and brick kilns. Given that vehicles and brick kilns emit far more combustion-related fine particulates than maquiladoras, we can be fairly certain that they inflict more health damages. Finally, we found no evidence that health damages attributable to maquiladoras disproportionately affect the poor.

Do these results imply that policymakers and environmental advocates should not pressure maquiladoras to further control air pollution? Probably not. To use scarce resources available for pollution control most efficiently, policymakers need to examine both the benefits and costs of pollution control. The evidence we have examined only suggests that the benefits of controlling emissions from maquiladoras are low relative to other sources. However, we have said nothing about the costs of pollution control.

Although an analysis of pollution control costs is outside the scope of this study—data on such costs is even more difficult to generate than data on emissions—on the face of it, there is good reason to suspect that control costs for maquiladoras are relatively modest compared to other leading sources of fine particulate pollution—vehicles and brick kilns. Control costs for brick kilns and vehicles are quite substantial when transactions and political costs are counted along with pecuniary costs. Complementary research has shown that the pecuniary costs of controlling emissions from all of the region's 350 brick kilns are reasonably low, on the order of $20,000 to $200,000 per year (Blackman et al. 2000). However, the transactions costs would probably be significant given that regulators would have to monitor hundreds of firms, most of which are informal. Also, brickmakers are among the most impoverished entrepreneurs in Paso del Norte—typically operating on profit margins of less than $100 per month—and, as a result, it has historically been difficult to muster political support for stringent pollution control measures (Blackman and Bannister 1997). Put slightly differently, political costs of enforcing the "polluter pays" principle in the brickmaking sector may be substantial.

For similar reasons, the transactions and political costs of attempting to control emissions from mobile sources are likely to be quite high. Such sources are exceptionally numerous, and those that are the most polluting are typically owned by the poorest households. Also, as car owners, most of the region's residents have built-in incentives to oppose drastic measures to control vehicle emissions.

Controlling air pollution from maquiladoras is likely to be straightforward by comparison. These sources are relatively large, limited in number, and formal. In addition, the owners' financial resources are relatively plentiful. Thus, transactions costs may be relatively low, and there is some hope that political costs may be low. The pecuniary costs of control will depend critically on whether the maquiladoras have already undertaken the pollution control investments required by law: the greater the investments already made, the more expensive it will be to further control emissions. Thus, a key consideration in determining whether or not maquiladoras are an appropriate target for pollution control efforts is the extent to which they are complying with existing regulations.

Finally, it is worth noting that further research on the benefits and costs of controlling emissions from a larger sample of emissions sources is needed to fully understand the link between Paso del Norte's air pollution and its maquiladoras. Such research would be greatly facilitated by the development and dissemination of a complete plant-level emissions inventory for the Paso del Norte air basin, along with plant-level data on abatement costs.

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