PM10 Air Pollution and the Demand for Respiratory Infection Health Services in the Mexico City Metropolitan Area.

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Abstract

Air pollution levels are associated with the demand for hospital appointments due to respiratory illnesses. We performed a time series study of the number of cases seeking attention in primary care units in the Mexico City Metropolitan Area from 1993-1994 to evaluate the increased demand for health services associated with air pollution levels. An additive, generalized Poisson regression model was applied, taking the number of daily appointments and respiratory diagnoses as the dependent, and concentration of suspended particles smaller than 10 microns (PM10) as the independent variables. Controls accounted for the effects of ozone and nitrogen and sulfur oxides. The association was stratified for younger than 5 and older than 65 years of age. We observed a 3% increase in the number of upper respiratory infections at all ages for each 10 g/m3 increase in the average PM10 concentration (RR=1.03 IC 95% 1.007, 1.05). The associated increase was 11% for both the population younger than 5 years of age, (RR=1.11 IC95% 1.07, 1.15); and for the above 65 years age group (RR=1.11 IC95% 1.05, 1.16). Adjusting for the effect of ozone maintained the association for the number of upper respiratory infections with a 12% increase for both the under 5 (RR=1.12 IC95% 1.07, 1.16) and over 65 (RR= 1.12 IC95% 1.06, 1.18) age groups. These results suggest that monitoring the demand for primary level health care services among children and the elderly provides a good parameter for surveillance of the effects of PM10.

Key words: Air pollution, Respiratory infections, Particles < 10 microns, PM10, Elderly

Introduction

Recent epidemiological studies have evaluated the effect of air pollution on human health. The effects have been observed through increased monthly hospitalizations attributed to pneumonia, asthma and bronchitis and related to the monthly average PM-10 in Utah , Buffalo ,New York and southern Ontario . Similarly, an increased demand for emergency services has been reported associated with increasing levels of suspended particles in Steubenville, Ohio , in the metropolitan Pittsburgh and Seattle areas.

Epidemiological studies of the effects of air pollution in Mexico have demonstrated decreased pulmonary function, increased school absenteeism, more medical appointments due to asthma, exacerbations in the symptoms of infantile asthma and increased respiratory symptoms. These studies complement the active environmental epidemiological surveillance of respiratory symptoms carried out by the Secretary of Health which evaluates the effect of the environmental contingency system restricting automobile circulation on days when pollution exceeds established levels.

In order to assess the impact of air pollution due to PM10 on respiratory health, a time series study was carried out estimating the number of appointments in primary care units (Public Health Centers) within the Mexico City Metropolitan Area during 1993 and 1994.

Materials and methods

We examined daily variation in the demand for primary level health care for respiratory symptoms associated with air pollution in the Mexico City Metropolitan Area (MCMA) from January, 1993 through December, 1994. The study initially focussed on five regions of Mexico City, described as Northwest, Northeast, Center, Southwest and Southeast, with the intent of later addressing the entire metropolitan area. Primary health care units were selected in each region, and the data available from each center's files was recorded to evaluate the number and type of appointments for each calendar day.

Air Quality Data

Measurements of air quality and PM10 concentrations were taken from the environmental monitoring station located in the southwestern region of the City (UAM-Xochimilco) since PM10 measurements were unavailable for the entire metropolitan area.. RAMA () air quality measurements were added together for the entire Mexico City area and used to estimate the effect of other pollutants and weather conditions.

Respiratory Morbidity

Information on the number of appointments attended was obtained from the Secretary of Health General Administration of Epidemiology database. Patient files for the study period were reviewed for 26 primary health care units, and 13 of these units having the greatest number of calendar days with morbidity data for the 1993-1994 period were selected for the study. The information collected from the daily morbidity registries summarized the number, motive and diagnoses for all appointments in the care unit. The data were recorded by health-care unit type, clinical diagnosis, patient's sex and age, date of appointment, type of care provided and initial or follow-up visit for all Monday through Friday appointments in the primary care units shown below:

Primary Health Care Units by Region

Region	Health Care Unit
Northwest	C.S. Benito Juárez
	C.S. Tlanepantla
Northeast	C.S. Santa Clara Coatitlán
Center	C.S. Ixnahualtongo
	C.S. Dr. Luis E. Ruiz
	C.S. Morelos
Southwest	C.S. Dr. Heron Proal
	C.S. La Cascada
	C.S. Manuel Escontría
Southeast	C.S. Los Reyes
	C.S. San Andrés Tomatlán
	C.S. Rafael Carrillo
	C.S. Dr. Gastón Melo

Specific diagnoses for daily appointments were categorized to describe the number of cases in each of the 5 age groups (younger than 5 years, 5 to 14, 15 to 19, 50 to 64 and older than 65 years of age). Appointment motive was classified as upper Respiratory Infection (URI) (460-465, 470-478 CIE 9ª), Lower Respiratory Infection (LRI) (466, 480-487, 490-496 CIE 9ª) and other non-respiratory causes (372-374, 680-686, CIE 9ª).

Statistical Analysis

The relationship between pollution levels and demand for health care was evaluated using a Poisson regression over a time series, with the days as observation units, the number of daily cases as the dependent variable and the concentration of particulate material and other air quality indicators as predictors. The intrinsic periodic variation for morbidity was controlled using a model developed by Samet et al..

We measured results using the number of daily patients, rather than the illness rate, since the influential population for each health center and fluctuations due to population mobility in the areas studied was well defined. To allow nonlinear relationships between morbidity and the prediction variables, such as time and temperature, we used a generalized, additive model. This allowed for replacing the linear prediction factor X in the conventional Poisson regression model with a nonparametric, nonlinear, softened prediction variable function or a combination of linear and nonlinear prediction variables . Since the behavior of morbidity over time is unknown, we used softened, nonparametric functions of prediction variables, in this case the 2-day time and temperature average. 13 .

A basic descriptive model was first developed for the number of daily appointments without considering air pollutants. The relationships with time and temperature were examined using a combination of graphing, Poisson regressions and softened functions for minimum, maximum and average temperatures on the same day, with up to five days lag time, and mobile mean temperatures, with 0 to 2 days and 0 to 5 days lag time.

To consider potential effects of over-dispersed data, the estimated variance of the regression coefficients was multiplied by the square root of the over-dispersion parameter to adjust for the Poisson extra-variation13.

The adjustment allowance and the magnitude of the regression coefficients were evaluated to compare the models, with greater weight given to the greater coefficients in the models to allow the best fit for the data. The adjustment allowance was evaluated using the Akaike Information Criterion (AIC), a measurement of the model16 deviance adjusted for the number of model parameters14. The models were developed for the number of upper respiratory cases and then generalized for the number of appointments attributed to lower respiratory infections and for other non-respiratory causes.

Once the basal model was selected, pollution variables were incorporated emphasizing PM10, although ozone, NO2 and SO2. were also evaluated. The concentrations of the pollutants were evaluated as continuous variables in g/m3 for the particles and ppb for the gases. In the models with multiple pollutants, exposure was characterized using pollutant levels for the same day and, where exposure to pollutants was expressed with lag-times, for each one of the lag period days.

The coefficient expressed per 1000 was used as a best indicator in the percent change per unit contaminant and confidence intervals were 95% for RRs, estimated using normal approximation. The value obtained was similar to that resulting when the coefficient was multiplied by 10 and then expressed as an exponent.. The rate ratios (RR) were expressed for each 10-unit change (μg/m3 or ppb) in the concentration of each pollutant.

We used the statistical packet Stata 5.0 for conventional managing of the Poisson regression and S-Plus 4.0 to carry out adjustments through the Generalized Additive Models.

Results

The average number of daily appointments due to upper respiratory infections (URI) at the health centers was 56 with a range of 4 to 149. The average number of daily appointments for lower respiratory infections (LRI) was 4 with a range of 1 to 21 and for other, non-respiratory causes, average daily appointments were 42 with a range of 5 to 121 (*Figure I*). The average PM10 concentration was 43 μgm3 and the average maximum hourly concentration of ozone was 165 ppb, which over the period of observation exceeded the 110-ppb official Mexican safety limit (NOM-1994). Concentrations of other pollutants were generally low. The average temperature was 16.6 ºC and relative humidity was 53.1%.

Cuadro I Estadísticas descriptivas del Número de casos atendidos diariamente en los Centros de Salud y la Calidad del Aire para el área metropolitana de la ciudad de México 1993-1994

Parámetros	Mínimo	Cuartil Bajo	Mediana	Cuartil Alto	Máximo
Morbilidad					
Número de Consultas diarias por Infecciones Respiratorias Altas	4	6	56	106	149
Número de Consultas diarias por Infecciones Respiratorias Bajas	1	2	4	10	21
Número de Consultas diarias por Otras Causas No Respiratorias	5	10	42	80	143
Calidad del Aire y meteorológicos					
PM_{10} (µg /m³)	10	20	43	74	121
Ozono media (ppb)	4.09	18.04	43.54	70.12	127.07
Ozono máxima (ppb)	12	68	165	263	342
SO_2 media (ppb)	0.62	1.46	4.25	14.42	33.6
NO_2 media (ppb)	12.83	22.83	36.54	60.46	86.83
Temperatura media (ºC)	8.3	12.2	16.6	19.9	35.7
Temperatura mínima (ºC)	-1.2	3.5	9.5	14	14.9
Humedad relativa (%)	19	36.2	53.1	71	86.3

An increase of 10 μg/m3 PM10 represented a 3% increase in the number of both URI (RR 1.03 95% C.I. 0.99-1.07) (Figure II) and LRI (RR 1.03 95% C.I. 0.99-1.07) (Figure II). appointments for the entire metropolitan area. For each 10 μg/m3 increment in PM10 , the number of children attended younger than 5 years old increased by 11% for URI. (RR 1.11 95% C.I. 1.070-1.15) and 10.7% for LRI (RR=1.11 95% C.I. 1.05, 1.16) while the number of cases attended for non-respiratory causes in this group increased by 6% (RR=1.06 95% C.I. 1.02-1.10). For adults older than 65 years of age, the increase in the number of cases per 10 μg/m3 increment in PM10 was 11% for URI (IRR=1.10 95% C.I. 1.05-1.16), 13% for LRI (RR=1.13 95% C.I. 1.05-1.22), and 3% for other non-respiratory causes (RR=1.03 95% C.I. 0.98-1.03. (*Figure II*).

Cuadro II. Coeficientes de regresión poisson para los efectos de PM_{10} en el número de casos atendidos en las unidades de primer nivel por grupos de edad en la ZMCM 1993-1994 (Modelo de 1 solo contaminante)

Demanda	Edad	Coeficiente (1000)	t corregida	IRR*	IC95%	
Infecciones Respiratorias Altas						
	Todas las edades	3.01	2.53	1.030	1.007	1.055
	Menores de 5 años	10.45	5.59	1.110	1.070	1.152
	Mayores de 65 años	10.16	4.08	1.107	1.054	1.162
Infecciones Respiratorias Bajas						
	Todas las edades	3.11	1.64	1.031	0.994	1.071
	Menores de 5 años	10.17	4.04	1.107	1.054	1.163
	Mayores de 65 años	12.47	3.25	1.132	1.051	1.221
Otras Causas no Respiratorias						
	Todas las edades	-2.11	-1.76	0.979	0.956	1.002
	Menores de 5 años	6.12	3.05	1.063	1.022	1.106
	Mayores de 65 años	3.44	1.51	1.035	0.990	1.082

- Ajustando por una función suavizada no paramétrica de tiempo, una función suavizada no paramétrica de temperatura promedio de 2 días anteriores y el día de la semana

When more than one pollutant was included in the model, accounting for the effect of ozone, we found a 3% increase in the number of appointments for upper respiratory infections associated with each 10 μg/m3 increase in PM10 (RR=1.03 IC95% 1.002-1.05). The change in lower respiratory infections increased by the same amount of 3.0% (RR=1.03 IC95% 0.99-1.07) (*Figure III*). Including the effect of sulfur dioxide in the model, the number of appointments increased by 3% for both URIs (RR=1.03 95% C.I. 1.006-1.05)and LRIs (RR=1.03 IC95% 0.98-1.06) for each 10 μg/m3 increase in PM10 (*Figure III*).

Cuadro III. Coeficientes de regresión poisson para los efectos de Contaminantes Atmosféricos y el número de casos atendidos en todas las edades por tipo de demanda en las unidades de primer nivel en la ZMCM 1993-1994
(Modelos de más de 2 contaminantes)

Todas las edades	Variables en el modelo **	t. corregida	IRR*	IC95%	
Infecciones Respiratorias Altas					
	PM_{10} ajustado por Ozono	2.12	1.028	1.002	1.055
	Ozono ajustado por PM_{10}	1.09	1.015	0.988	1.043
	PM_{10} ajustado por NO_2	1.01	1.018	0.983	1.055
	NO_2 ajustado por PM_{10}	0.81	1.023	0.968	1.082
	PM_{10} ajustado por SO_2	2.47	1.030	1.006	1.055
	SO_2 ajustado por PM_{10}	1.34	1.066	0.971	1.172
Infecciones Respiratorias Bajas					
	PM_{10} ajustado por Ozono	1.58	1.033	0.992	1.076
	Ozono ajustado por PM_{10}	-0.04	0.999	0.959	1.041
	PM_{10} ajustado por NO_2	0.42	1.012	0.957	1.071
	NO_2 ajustado por PM_{10}	0.79	1.036	0.950	1.131
	PM_{10} ajustado por SO_2	1.39	1.027	0.989	1.068
	SO_2 ajustado por PM_{10}	1.75	1.140	0.985	1.321
Otras causas No Respiratorias					
	PM_{10} ajustado por Ozono	0.09	0.952	0.942	1.002
	Ozono ajustado por PM_{10}	1.00	0.979	0.925	1.033
	PM_{10} ajustado por NO_2	0.93	0.900	0.836	0.964
	NO_2 ajustado por PM_{10}	1.10	1.046	0.927	1.165
	PM_{10} ajustado por SO_2	0.97	0.956	0.929	1.003
	SO_2 ajustado por PM_{10}	0.98	0.900	0.715	1.085

* ajustando por una función suavizada no paramétrica de tiempo, una función suavizada no paramétrica de temperatura promedio de 2 días anteriores y el día de la semana
** PM_{10} media, Ozono rezago 3 días, NO_2 media, SO_2 rezago de 5 días

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Discussion

The study suggests the that exposure to high levels of de PM10 has a significant effect on the number of primary level health care appointments due to URI and LRI, especially for the groups younger than 5 and older than 65 years of age. The study is unique in that it assesses the impact of pollution on the respiratory health of a population which seeks health care from primary level care facilities (public health clinics) and which does not have access to medical service through the Mexican Social Security system. Previous reports carried out in the Mexico City Metropolitan Area have mostly surveyed the population insured through the Mexican Social Security system, who have access to emergency hospital service in second level care facilities and these reports have focussed on pollution's impact on asthmatic individuals.8

Similar studies carried out in other cities document health effects due to PM10 exposure. In Denver, Colorado and Pope's studies demonstrated changes in pulmonary function and increased acute respiratory symptoms on a panel of subjects in Utah Valley, Utah correlated with exposure to PM10 . . Symptoms compatible with URI and LRIs resulting from exposure to PM10 and ozone have been demonstrated in studies using human volunteers and others documenting epithelial cell alterations of the respiratory tract. The mechanisms by which these pollutants predispose subjects to respiratory infections suggest that exposure alters the immune system.

The association between NO2 concentrations and the demand for health care for non-respiratory causes for the younger than 5 and older than 65 years of age groups is interesting. It is possible that short-term exposure to this contaminant is less damaging than exposure to particles, particularly for these age groups.

Interpretation of the results in any epidemiological study demands establishing limitations and potentials of the study, itself. A study concerning over time, such as this one, one avoids confusion by factors such as occupation, smoking habits and socio-economic status since these factors are not expected to vary with changes in pollutant concentrations over time. The general population attending the Secretary of Health public health clinics and used in this study is a fairly homogeneous socioeconomic group. However, a direct estimation cannot be made without considering factors correlated with air pollution concentration over time, and the model used must take into account weather conditions (temperature and humidity) as well as other variables such as day of the week and season.

Since the data used were air quality and medical attention records created for purposes other than this study, it was impossible to evaluate their validity, so that measurement errors could be inherent in the results. Nonetheless, we consider the risk estimators obtained to be conservative.

The primary care registry for appointments contained some problems as far as consistency and quality of the data. We minimized these problems by excluding those health care units with severe inconsistencies in the original analysis. We still do not know the level of uncertainty associated with the initial patient registry. However, inaccuracies in the registries would be expected to be independent from air quality and thus would incur non-differential errors, which would result in underestimating the observed effects.

The decision to use atmospheric monitoring data from the Pedregal area of Mexico City as representative of particulate matter (PM10) behavior for the rest of the Mexico City metropolitan area (MCMA) was based on the high correlations shown to exist among monitoring sites in different regions of the city. Data from one monitoring site has been documented in other studies to extrapolate levels for the entire MCMA .

Using existing data for the study period was appropriate since we were merely modeling the behaviors of the demand for primary level medical services and its association with the levels of air pollution due to PM10 over the same time frame. If it is true that PM10 pollution in the southeast of the MCMA is lower than in the northeast region, the behavior over the two years of the study was similar in its temporal distribution. ??

Primary level health care units could be appropriate sites to maintain a Passive Epidemiological Surveillance System evaluating acute effects of PM10 air pollution on health. The results on this study show an association between PM10 exposure and the number of cases attended due to respiratory afflictions in the Mexico City Metropolitan Area. These results should be confirmed with more detailed, follow up studies of air pollution exposure effects.

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