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The association of air pollution in respiratory allergy: Its impact in an industrial city

Cindy Elizabeth de Lira-Quezada, MD[a], Sandra Nora González-Díaz, MD, PhD[a]*, Angel Gabriel Cotera-de Lira, BSc[b], Carlos Macouzet-Sánchez, MD, PhD[a], Natalhie Acuña-Ortega, MD[a], Rosa Ivett Guzman-Avilán, MD, PhD[a] and Alejandra Macías-Weinmann, MD[a]

ABSTRACT

Background: Asthma and allergic diseases have increased in recent decades and are more common in industrialized countries. Industrial areas with a considerably high number of inhabitants and vehicles can favor the presence of serious air pollution and therefore the appearance and exacerbation of respiratory allergy symptoms. The objective of this study was to determine the relationship between exposure to environmental pollutants with exacerbation of respiratory allergy.

Methods: A total of 240 subjects above 6 years old who lived in the metropolitan area of Monterrey, Nuevo León, Mexico, with diagnosis of allergic rhinitis and/or asthma, were included. The subject's address was registered in the database and the rhinitis control assessment test (RCAT) and the asthma control test (ACT) were applied. Environmental data were obtained from the Environmental Monitoring System (SIMA) of Nuevo León. Geolocation of industries and avenues in proximity of subject's addresses and SIMA stations were obtained through geographic information systems using ArcGis software.

Results: The relation between pollutants and subjects' RCAT, ACT, and spirometry results in the 14 stations was established. PM10 and forced vital capacity (FVC) had an $r = 0.074$ with $p = 0.005$, PM10 and absolute FEV1/FVC ratio presented an $r = -0.102$ with a $p = 0.000$; The distance found to be associated with a worsening of respiratory symptoms was living 165 m from a main road or 241 m from an industrial establishment.

Conclusions: Exposure to pollutants present in the environment are factors associated with increased symptoms in subjects with respiratory allergies.

Keywords: Airway, Air pollution, Industrial, Northeastern Mexico, Respiratory allergy

[a]Universidad Autónoma de Nuevo León, Faculty of Medicine and Hospital Universitario "Dr. José Eleuterio González", Regional Center of Allergy and Clinical Immunology, Gonzalitos y Madero s/n Colonia Mitras Centro, Monterrey, Nuevo León, CP 64460, Mexico
*Corresponding author. E-mail: sgonzalezdiaz@yahoo.com
Full list of author information is available at the end of the article

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INTRODUCTION

Asthma and allergic diseases have increased in recent decades and are more common in industrialized countries.[1] Currently, there are millions of people in the world with allergies and over 340 million with asthma.[2] Pollution is the leading environmental cause of disease and premature death in the world today.[2] According to the World Health Organization (WHO), 9 out of 10 people breathe air that contains high levels of pollutants.[3]

The most abundant components of air pollution in urban areas are nitrogen dioxide (NO2), ozone (O3) and particulate matter (PM). Sulfur dioxide (SO2) is abundant in industrial areas.[4] PM originates from industrial activities and traffic-related sources, primarily from the combustion of coal and petroleum fuel. Diesel exhaust has been estimated to account for up to 80% of human exposure.[5] Environmental exposures, now considered as "the exposome" have been found to greatly affect the balance of the respiratory mucosae.[6]

Outdoor pollution from traffic, industry, energy production, and heating, etc, influence the respiratory system either directly or through their role as precursors of other polluting particles.[7] Air pollution, diesel exhaust particulates (DEP), traffic related air pollutants (TRAPs), O3, NO2, and SO2 may cause greater permeability, easier penetration of allergens into mucous membranes, and greater interaction with cells of the immune system.[8]

The National Institute of Statistics and Geography (INEGI) in Mexico reported that in 2022 there were 2 627 106 registered vehicles; in addition, there are over 163 000 active units of industries.[9] The Monterrey metropolitan area is surrounded by mountains which constitute a natural physical barrier for the circulation of the wind and, consequently, prevent the elimination of atmospheric pollutants. These characteristics, together with Monterrey being an industrial area with a considerably high number of inhabitants and vehicles, can favor the presence of serious air pollution and therefore the appearance and exacerbation of respiratory allergy symptoms. The objective of this study was to determine the relationship between exposure to environmental pollutants and exacerbation of respiratory allergy.

METHODS

It is an observational, prospective, longitudinal and descriptive study, carried out from March 2021 to October 2022. The study was submitted and approved by the Ethics Committee of the Faculty of Medicine of the Autonomous University of Nuevo León with registration number AL21-00004. Upon verbal informed consent obtained by subjects or parents/legal guardians, subjects above 6 years old who lived in the metropolitan area of Monterrey with diagnosis of allergic rhinitis and/or asthma, were included. These subjects attended every 2 months the outpatient allergy clinic for control of their respiratory allergy. After inclusion, the subject's address was registered in the database and both the rhinitis control assessment test (RCAT) and the asthma control test (ACT) were applied. Spirometry was performed in every patient, considering a volume exhaled fraction on the first second (FEV1) according to GINA age parameters.

Environmental data were obtained from the Environmental Monitoring System (SIMA) of Nuevo León, including meteorological parameters (temperature, humidity, wind speed, and direction), and air quality measurements (particulate matter less than 10 µm (PM10), particulate matter less than 2.5 µm (PM2.5), O3, SO2, NO2, and carbon monoxide (CO), which are considered the main particle pollutants in the region, according to SIMA through the 14 stations that operate in Monterrey and metropolitan area. Measurements were made using CO with infrared photometry; O3 with UV spectrophotometry; as well as gas phase chemiluminescence for NO2; SO2 with pulsating UV fluorescence; PM10 by beta ray attenuation; and PM2.5 with Beta ray attenuation and white light scattering. The data obtained by the SIMA monitoring network equipment are extracted from each of the stations to carry out an automatic validation process; this allows it to be compared with the requirements established by the Official Mexican Standards as well as WHO standards.

The data were obtained initially by SIMA in comma separated values (CSV) format and loaded into a structured query language (SQL) Server database in master database file (MDF) format due to its extent. SQL language was used to evaluate the information and then the averaged data were exported to Excel; a dynamic table was created and the information was separated by variables.

Geolocation of industries and avenues in proximity of subjects' addresses and SIMA stations as well as dispersion models considering pollutants and climatic factors (precipitation, humidity, wind speed, wind direction, and temperature) were obtained through geographic information systems using ArcGis software. Each subject's address was mapped with the closest environmental monitoring station using spatial union analysis. Spatial join through spatial analysis was applied between layers that allowed the attribute tables of 2 layers to be joined, based on the location of the objects in 1 of them with respect to the other.

Analysis of the correlation between exposure to pollutants and respiratory allergy was performed. For continuous variables, contingency tables were used; for numeric variables, Kruskal-Wallis H-ANOVA and Bonferroni test was applied. Pearson Correlation was used for pollutants and symptoms relation; for categorical variables: chi square or Fisher's exact test was applied, with a value of $p < 0.05$ as statistically significant. Statistical analysis was performed with MegaStat and SPSSv25IBM Corp.

RESULTS

A total of 249 subjects were included; however, 9 were eliminated due to incomplete information: the remaining 240 subjects were evaluated; the majority were female, 128 (53%), and 112 (47%) were male. The subjects age ranged from 6 to 74 years old and they were divided into 3 groups: 42 (17.5%) were 6–11 years old; 36 (15%) were 12–17 years old, and 162 (67.5%) were over 18 years old.

Regarding respiratory allergy, 156 (65%) were diagnosed with allergic rhinitis, 80 (33.3%) with both allergic rhinitis as well as asthma, and 4 (1.6%) had a diagnosis of only asthma. In patients with asthma, the level of control according to ACT was: well controlled 60 (71%) and not well controlled 5 (6%), and poorly controlled corresponded to 19 (23%) subjects. According to RCAT, 170 (71%) reported a score below 21, with nasal congestion being the most commonly reported (213 [89%] of subjects). Regarding subjects' results during the 6 visits completed in the 18-month period, the mean RCAT was 24.80 with a SD of 4.50 and $p = 0.001$; FEV1 had a mean of 87.76, SD: 12.86 and $p = 0.001$; mean of forced vital capacity (FVC) was 88.71, SD: 12.64 and p value of 0.003; absolute FEV1/FVC ratio had a mean of 96.73, SD: 7.72 and p value of 0.096, observing a difference in values throughout the 18-month period. Subjects' addresses belonging to 1 of the municipalities in relation to proximity of SIMA stations, are represented in Fig. 1. The average temperature registered

Subjects	SIMA station
45	San Nicolas
34	San Bernabe
31	La Pastora
27	Obispado
22	Apodaca
20	Escobedo
18	Juarez
13	Universidad
10	Pueblo Serena
8	Santa Catarina
5	García
4	San Pedro
2	Cadereyta
1	Pesquería
Total:240	

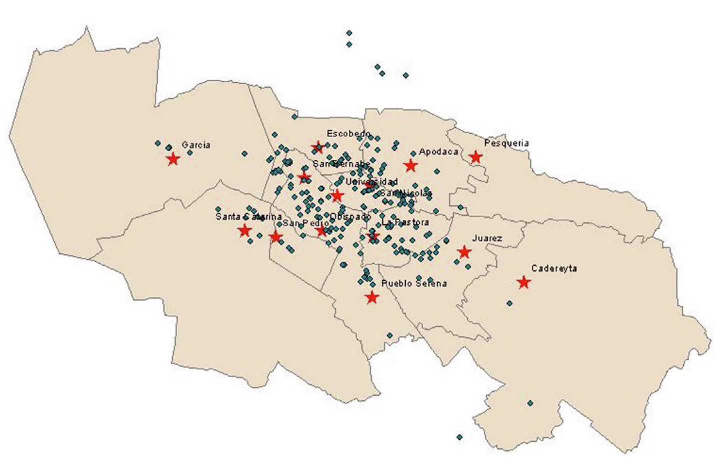
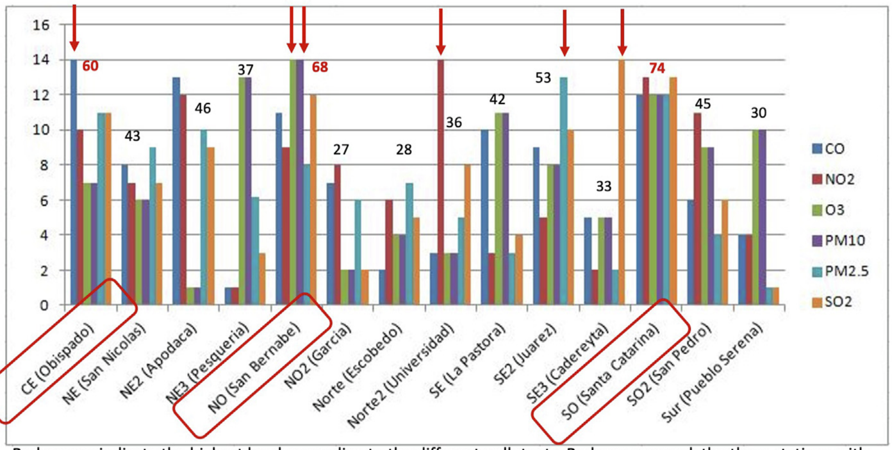


Fig. 1 Proximity of subject's addresses to stations obtained by ArcGIS based on spatial union



Red arrows indicate the highest levels according to the different pollutants. Red squares mark the three stations with the highest pollutants.

Fig. 2 Highest pollutant stations detected. Red arrows indicate the highest levels according to the different pollutants. Red squares mark the three stations with the highest pollutants

throughout the area in the period studied ranged from 23.14 to 24.14°C; relative humidity ranged from 54.74 to 56.08%; wind direction was 127.09–139.83°, corresponding to a southeast direction, and wind speed mean range was 9.06–9.72 km/h. SIMA stations were ordered according to the highest level of pollutant, being Santa Catarina, San Bernabe, and Obispado, the highest results (Fig. 2).

The relation between pollutants and subjects' RCAT, ACT, and spirometry results in the 14 stations was established. Pollutants analyzed were matched to the days of the subjects' visits. PM10 and FVC had an $r = 0.074$ with $p = 0.005$, PM10 and absolute FEV1/FVC ratio presented an $r = -0.102$ with a $p = 0.000$; PM2.5 and absolute FEV1/FVC ratio presented an $r = -0.93$ with a $p = 0.004$. The r value of O3 and RCAT score was of -0.081 and a $p = 0.002$; O3 and FEV1 showed a $r = 0.112$ and $p = 0.005$ (Table 1). The subjects of the San Bernabe station perimeter, presented a positive correlation with the pollutants SO2 and O3 with RCAT ($r = 0.415$, $p = 0.014$) ($r = 0.430$, $p = 0.012$), NO2 with FEV1 value ($r = -0.404$, $p = 0.018$) and FVC ($r = -0.506$, $p = 0.002$); PM10 with FVC ($r = 0.372$, $p = 0.030$).

Proximity analysis was performed to determine the mean distance between subjects homes and avenues as well as industrial establishments related to worse or uncontrolled respiratory symptoms (Figs. 3 and 4).

DISCUSSION

It is now recognized that the prevalence of allergic diseases has increased in recent decades throughout industrialized countries, and our results confirm a significant correlation between exposure to pollutants and less controlled symptoms.[10] Climate change and pollutants may influence aeroallergens, altering pollen into highly allergenic particles.[11] Increases in air pollution related to climate change can affect plant physiology resulting in more allergenic pollen. All these factors directly impact the symptoms of allergy sufferers or can lead to increased sensitization rates.[12]

Pollutants may disrupt pollen, causing the release of pauci-micronic molecules, being delivered to upper and lower airway.[13,14] An oxidant overload generated by pollutants will result in the accumulation of reactive oxygen species (ROS) and nitrogen that will ultimately lead to tissue inflammation and cell apoptosis; this has been established in the oxidative stress hypothesis. These factors therefore lead to an increase in respiratory symptoms.[15] The results of the highest pollutants detected by the SIMA stations each portray specific characteristics regarding their location. Santa Catarina, with levels of NO2 far above WHO standards, is surrounded by a condensed industrial area, as well as avenues and highways leading out of state with an increased circulation of large diesel vehicles. San Bernabe, with high levels of

	RCAT	ACT	FEV1 value	FVC value	Absolute FEV1/FVC ratio
			r value		
PM10	0.011, $p = 0.664$	0.032, $p = 0.227$	0.025, $p = 0.343$	0.074, $p = 0.005$	−0.102, $p = 0.000$
PM2.5	0.021, $p = 0.428$	0.013, p = 0.627	−0.003, $p = 0.897$	0.036, p = 0.167	−0.093, $p = 0.004$
SO2	−0.033, $p = 0.207$	0.004, p = 0.868	−0.020, $p = 0.448$	0.007, $p = 0.801$	−0.019, $p = 0.462$
O3	−0.081, $p = 0.002$	−0.004, $p = 0.867$	0.112, p = 0.005	0.122, p = 0.003	−0.016, $p = 0.552$
NO2	0.050, $p = 0.059$	0.000, $p = 0.992$	−0.094, $p = 0.000$	−0.084, p = 0.001	−0.069, $p = 0.008$
CO	0.017, $p = 0.517$	−0.025, p = 0.348	−0.148, $p = 0.003$	−0.150, $p = 0.001$	0.003, $p = 0.894$

Table 1. Correlation of pollutants from the 14 stations with respiratory assessment

PM10, includes the city's quarries and dense traffic zones. The area of Obispado, with elevated levels of CO, is the crossing point of some of Monterrey's main avenues (Gonzalitos, Constitución, and Morones Prieto) which carry heavy traffic from vehicles coming from every cardinal direction. In Cadereyta, an oil refinery has been part of the local scenery for years, with regular emissions of SO2 into the air. The region's southeast wind direction was an important factor in the transport of SO2 originating from the refinery and into the city and its neighboring suburbs. However, once pollutants are in the city's atmosphere, decreased wind velocity generally translated to a lower dispersion of air pollutants – a factor seen throughout the period studied. Ottaviano et al reported a causal relationship between aeroallergen concentration and ears, nose and throat (ENT) admissions. They found that the levels of PM10 at specific days preceding emergency room admissions correlated with certain upper airway disorders.[16] In our study, PM10 was correlated particularly in lung function values such as FVC. According to Lee S et al outdoor air pollutants (PM10, NO2, O3, CO, and SO2) had significant short-term effects in all age groups (except for CO and SO2 in infants).[17] Traffic pollution is a major source of exposure in homes close to a major road. People living near traffic sites are exposed to high concentrations of air pollutants including PM2.5 and NO2. Garcia et al established that the evidence for adverse NO2 effects is stronger for FEV1, representing airway mechanical properties and/or airway caliber, compared with that for FVC, representing lung volume.[18,19] Eckel et al related FeNO measured on 2143 children to 5 classes of metrics of residential TRP: distances to freeways and major roads. In children with asthma, length of roads was positively associated with FeNO, with stronger associations and higher FeNO for 100-, 300-, and 1000-m increases in the length of all roads in 50-, 100-, and 200-m buffers, respectively. In our study FeNO was not measured in the subjects included, however it could be considered as a variable for future follow-up studies.[20]

Ierodiakonou et al reported in children from 8 cities in North America (Albuquerque, New Mexico; Baltimore, Maryland; Boston,

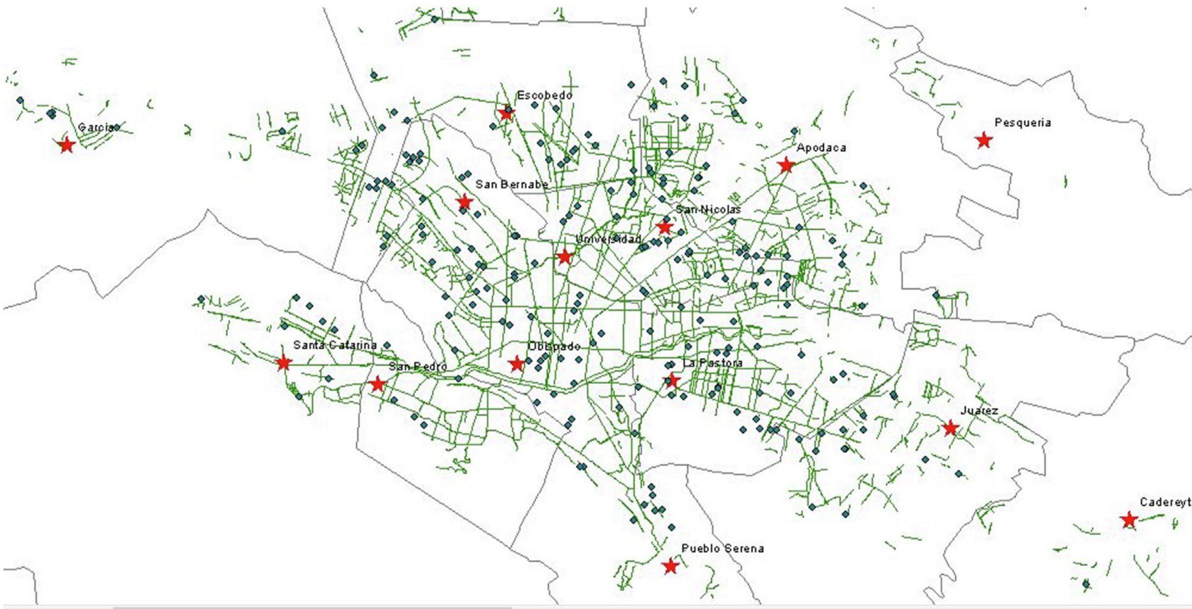


Fig. 3 Mean distance of 165 m from subjects' addresses to avenues was observed as having the highest association between pollutants and respiratory symptoms. The red stars indicate the SIMA stations and the teal squares represent the subjects included

Massachusetts; Denver, Colorado; San Diego, California; Seattle, Washington; St. Louis, Missouri; and Toronto-Ontario, Canada) that longer-term 4-month averages of CO were negatively associated with prebronchodilator % predicted FEV1 and FVC. Increased 4-month average NO2 levels were associated with reduced post-bronchodilator FEV1 and FVC % predicted.[21]

Bronner et al reported that living 50–200 m from a main road has been associated with increased risk of respiratory allergy.[22] Schulz et al reported that people living within 800 m of an industrial

Fig. 4 Proximity analysis with an average of 241 m between the homes of subjects with uncontrolled respiratory symptoms and industrial establishments. The red stars indicate the SIMA stations, teal circles represent the subjects included, and the green circles belong to the industrial establishments

site are 47% more likely to have asthma.[23] In our research, the distance we found to be associated with a worsening of respiratory symptoms was living 165 m from a main road or 241 m from an industrial establishment. Rice et al published that proximity of the home to a major roadway at time of assessment, but not birth, was associated with mid-childhood (age 7–10) asthma overall and in sensitivity analyses confined only to those who moved (62%).[24,25]

Outdoor pollutants such as nitrogen oxides increase the amount of pollen grains produced by plants and are able to chemically modify them. According to Ščevková et al, among the atmospheric pollutants, NO2 and CO were significantly and positively interrelated with pollen and allergen levels, respectively. They also observed a significant negative association between PM10 and allergen concentration.[26]

A limitation to be considered in this research is that although it was performed in 1 of the most polluted and industrial areas in Mexico, it remains a single-center study and a comparison with other urban areas would aid in establishing a greater association with subject's response.

A relationship was found between subjects with greater exposure to pollutants and worsening of nasal symptoms, being nasal congestion the most frequently reported in RCAT, as well as differences in lung function values. As population that lives in Monterrey and the metropolitan area, we find ourselves immersed between avenues and industrial establishments, which are associated with worsening respiratory symptoms. Actions are required among all government orders to establish concrete measures to reduce the pollution rates that affect the population. Measures to combat the effects of climate change is an approach that has to be taken at the national and international levels.

Abbreviations

ACT, asthma control test; CO, carbon monoxide; DEP, diesel exhaust particulates; FEV1, volume exhaled fraction on the first second; FEV1/FVC ratio, volume exhaled fraction on the first second/*f*orced vital capacity ratio; INEGI, National Institute of Statistics and Geography; NO2, nitrogen dioxide; PM, particulate matter; PM2.5, particulate matter less than 2.5 micrometers; PM 10, particulate matter less than 10 micrometers; O3, ozone; RCAT, rhinitis control assessment test; ROS, reactive oxygen species; SIMA, Environmental Monitoring System; SO2, sulfur dioxide; TRAPs, traffic related air pollutants; UV, ultraviolet; WHO, World Health Organisation

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Data availability statement

Any additional data is available upon request to the authors.

Author contributions

Cindy de Lira-Quezada contributed to design of the study, data collection, interpretation of the results, and manuscript writing. Sandra Nora Gonzalez-Diaz: Design of the study, manuscript elaboration, and revision. Angel Gabriel Cotera-de Lira contributed to data collection and analysis. Natalhie Acuña-Ortega, Alejandra Macias-Weinmann, Rosa Ivett Guzman-Avilan, and Carlos Macouzet-Sánchez contributed to manuscript writing.
All authors give consent for publication.

Ethics statement

The study was submitted and approved by the Ethics Committee of the Faculty of Medicine of the Autonomous University of Nuevo León, with registration number AL21-00004. Upon verbal informed consent obtained by subjects or parents/legal guardians (previously authorized by Faculty of Medicine Ethics Committee), subjects above 6 years old who lived in the metropolitan area of Monterrey with diagnosis of allergic rhinitis and/or asthma, were included.

Declaration of competing interest

The authors have no conflicts of interest to declare.

Author details

[a]Universidad Autónoma de Nuevo León, Faculty of Medicine and Hospital Universitario "Dr. José Eleuterio González", Regional Center of Allergy and Clinical Immunology, Gonzalitos y Madero s/n Colonia Mitras Centro, Monterrey, Nuevo León, CP 64460, Mexico. [b]Monterrey, Nuevo León, Mexico.

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