RELATIONSHIP AMONG PERSONAL, INDOOR AND OUTDOOR FINE PARTICLE CONCENTRATIONS FOR INDIVIDUALS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE LIVING IN THREE AREAS OF MEXICO CITY.

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ABSTRACT
Our study characterized indoor and outdoor exposure to PM$_{10}$ and PM$_{2.5}$ in 39 participants with varying degrees of chronic obstructive pulmonary disease (COPD) from the National Institute of Respiratory Diseases in Mexico. Participants were selected based on the area of residence: from the southeast, downtown and southwest areas of the Mexico City Metropolitan Area, and were followed from February through November 2000. Mini-volt samplers were used to measure indoor and outdoor levels of PM$_{10}$ and PM$_{2.5}$, and personal PM$_{2.5}$ monitoring devices were also used. The highest concentrations of particulates were registered during winter, maximum PM$_{10}$, PM$_{2.5}$ and personal PM$_{2.5}$ levels were 180.6, 160.5, and 126.8 µg /m$^3$, respectively. The highest correlation observed for the study variables, was between personal PM$_{2.5}$ and home indoor PM$_{2.5}$ levels. On average, the southeast area registered the highest levels of PM$_{10}$ and PM$_{2.5}$.

INDEX TERMS
COPD, Personal exposure, PM$_{2.5}$, PM$_{10}$

INTRODUCTION
A significant number of studies have found positive associations between increased daily morbidity and mortality, and suspended particles in air pollution (Lippman et al.,2000, Sarnat et al.,2001, Laden et al.,2000, Sunyer et al,2000, Borja et al., 1998), as well as increased rates of asthma exacerbations, increased respiratory symptoms, reduced lung function, increased hospitalization rates and use of medications(Utell and Frampton, 2000, Anderson et al, 2001, Panella et al, 2000). Indoor air pollution has been related to health effects, particularly in relation to tuberculosis and acute lower respiratory infections (Bruce N. et al., 2000).

In the Mexico City Metropolitan Area (MCMA), suspended particles and ozone constitute the most serious problem regarding air pollution. During 1999 the highest values of PM$_{10}$ were registered in the northeast and southeast, with average concentrations of 222 y 202 µg/m$^3$, respectively, on the following year. The automated network system (RAMA) located in the downtown center area, northeast and southeast had the highest concentrations with peak levels of 166, 160 y 488 µg/m$^3$, respectively (Secretaría del Medio Ambiente, 1999-2000). It was only after July 2000, that RAMA started to routinely monitor PM2.5 in the MCMA.

Recent understanding that indirect exposure assessment may not necessarily reflect individual exposure to air pollutants, has led to an increase need of developing research using direct methods to analyze exposure with a higher degree of certainty and validity (Ott Wr, 1990).

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Health effects attributed to air pollution caused by fine and coarse particulates in susceptible populations living in the MCMA, have not been studied previously. The data presented in this document are part of a study evaluating health effects of particulates in patients with underlying chronic obstructive pulmonary disease (COPD) living in Mexico City. In this study, exposure assessment to PM$_{2.5}$ and PM$_{10}$ was done by indirect and direct methods, using indoor, outdoor and personal monitors. Information about the concentrations of particles in different microenvironments is discussed in this paper.

METHODS

Study Design
Patients with a diagnosis of moderate to severe COPD who were followed at the National Institute of Respiratory Diseases in Mexico were invited to participate in this study. Patients who were active smokers were excluded from the study. A total of 39 patients were followed from February to November. Participants were divided into 6 groups based on their place of residence, in order to study the health effects of particulates in different areas of the MCMA. Each group was monitored continuously in periods of two weeks that were repeated three times at different intervals throughout the year. To determine exposure, indoor and outdoor 24 hour average sampling of PM$_{2.5}$ and PM$_{10}$ were measured in every participant’s home. Personal monitors for particles less than 2.5 µm, were also used in five participants in each group.

Follow-up during the study period included a daily visit from a research nurse and a field technician to fill daily questionnaires on respiratory symptoms, medication use and time-activity patterns. Participants also performed morning and evening peak flow measurements. Technique on peak flow use was reinforced and supervised at every visit.

Particulate Matter Samples
Monitoring of indoor and outdoor PM$_{2.5}$ and PM$_{10}$ was done by using Mini-Volts samplers, which are modified from the standard reference of PM$_{10}$ (40 CFR 50, Appendix J) Samples were collected using impactors at flows of 5 liters/min on 47 mm Teflon filters. Personal monitors for PM$_{2.5}$ used personal pumps (Thomas et al., 1993), with 37 mm Teflon filters using flows of 4 liters/min Participants were instructed on placing the personal impactor in the respiration zone.

Indoor Mini-Volts were placed in the area where the participant spent most of his or her time at home, excluding the kitchen. Care was taken not to place monitors closer than 3 feet from walls and windows or close to plants or trees. In 4 homes, outdoor monitors could not be placed due to a lack of finding a secure place.

Quality Control and Quality Assurance Procedures
Gravimetric analysis of Teflon filters was done under controlled room temperature and humidity (22±3 °C, 40±5% relative humidity). Before weighing the filters, a 48 hour stabilization period was allowed, filter weights were adjusted for the fluctuations of the microbalance (Cahn model 30) 5% of filters were used as blanks and duplicates for PM$_{10}$, PM$_{2.5}$. Filter blanks were handled in the same fashion, but were exposed using the mini-volts without applied flow. Gravimetric results obtained from the blank filters were used to correct for artifacts introduced by filter handling by adjusting the mass of the exposed filters by the average blank filter mass. The detection limit was established as 3 x SD of the mass change in the blank filters divided by the nominal volume of the corresponding exposure time (24 hrs.).
Statistical Analysis Monitoring results were analyzed using the statistical software package STATA. The units of personal exposure and indoor and outdoor concentration are reported in mass per unit of volume (µg/m$^3$). Pearson correlation coefficient was used to explore the association between indoor, outdoor and personal exposure concentrations. These analyses were based on 35 participants who had indoor and outdoor measurements, 13 participants who had personal exposure data and indoor measurements and 15 participants who had personal exposure and outdoor measurements.

RESULTS
A total of 39 adults, 28 males and 11 females participated in the study, 14 completed the three measurement periods, 12 had two measurement periods and 13 only one period. The detection limit for the indoor measurements of PM$_{2.5}$ and PM$_{10}$ ranged from 0.786 to 1.8 and from 0.9 to 1.77, respectively. PM$_{2.5}$ and PM$_{10}$ outdoor measurements detection limit ranged from 0.96 to 4.17 and from 1.56 to 2.8, respectively. For the personal PM$_{2.5}$ measurements, the range was from 3.12 to 5.91 µg/m$^3$.

Geographic and Seasonal Variability
The average concentrations for outdoor PM$_{2.5}$ and PM$_{10}$ were significantly higher during the winter time. Also, during this season, the maximum concentrations of outdoor PM$_{10}$ and PM$_{2.5}$ and personal PM$_{2.5}$ were noted, with maximum values reaching 160.5, 180.6 and 126.8 µg/m$^3$, respectively. Our results are consistent with those obtained from RAMA reports, which also reported the highest number of days with PM$_{10}$ surpassing the established air quality standards. A seasonal variation was also observed in indoor and personal concentrations, however, for indoor PM$_{10}$, the highest values were observed during the spring. (table 1).

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Note: N= no. Observations, x= average concentrations
On average, the Southeast area had the highest levels of PM$_{10}$ and PM$_{2.5}$ (figure 1). Which agrees with previous reports (Chow J. et al, in press).
Relationship between Personal Exposure, Indoor and Outdoor Concentrations.

Throughout the study there were no differences between average indoor and outdoor PM$_{2.5}$ concentrations, however, when the concentrations were individually analyzed by each home, average outdoor PM$_{2.5}$ concentrations were higher than average indoor concentrations 52% of the time. Average outdoor levels of PM10 were higher than indoor levels. Individual analysis revealed higher outdoor levels 71% of the time. The outdoor PM$_{2.5}$ geometric mean was 1.3 (SD 1.7), whereas for PM$_{10}$ it was 0.9 (SD 0.8).

The average correlation between indoor and outdoor PM$_{2.5}$ was 0.40, and it was statistically significant in 22/35 houses sampled. For those houses with significant correlation coefficients, the variability of indoor concentrations could be explained between 19 and 86% by the concentration of particles in the outdoor. Intra-home variability could be secondary to variations in house ventilation system and indoor sources of PM$_{2.5}$. Indoor levels of PM$_{2.5}$ were higher than personal exposure levels in 66% of the measurements, whereas outdoor levels were higher in 61%. The geometric mean for the ratio personal/interior was 1.5 (S.D. 1.5) and for the personal/exterior, 1.4 (S.D. 1.1).

Indoor PM$_{2.5}$ concentrations explained 50% of the variability of the personal concentration (p<0.0001) (figure 2), this association differs from other studies in which outdoor levels...
explain most of the personal exposure variability (Nicole et al, 1998), however, other studies have found similar results (Spengler et al, 1981). The correlation coefficients for indoor and outdoor levels of both PM$_{2.5}$ and PM$_{10}$ (0.41 , 0.28), were significant.

**Relationship Between PM$_{2.5}$ and PM$_{10}$**
The average concentration of indoor and outdoor particles less than 10 µm were higher than indoor, outdoor and personal PM$_{2.5}$ (figure 3). The correlation between PM$_{2.5}$ duplicates was highly significant (R=0.93, p>0.001). Correlations between indoors PM$_{10}$ Vs. PM$_{2.5}$ was R= 0.76 (p<0.0001), and between outdoors PM$_{10}$ Vs. PM$_{2.5}$ R=0.63 (p<0.0001).

**DISCUSSION AND CONCLUSIONS**
Our study found a significant correlation between personal exposure to PM$_{2.5}$ and indoor PM$_{2}$ concentrations. Indoor sources of PM$_{2.5}$ affect personal exposure probably due to their low sedimentation rate which enhances a more homogeneous and uniform indoor PM$_{2.5}$ concentration. This spatial uniformity along with the fact that participants spent most of their time indoors (86%), explains the strong association between indoor PM$_{2.5}$ and personal PM$_{2.5}$. Time spent indoors is similar to other reports showing that in urban populations, an average 80% of time is spent indoors, either at work or home (Clayton et al, 1993; Dockery et al, 1981; Hosein et al, 1991; Ott. W, 1990).

Spatial and temporal variations of outdoor PM$_{2.5}$ and PM$_{10}$ were also observed in the different regions studied in the MCMA. The highest levels were recorded in the southeast area which includes the Iztapalapa and Nezahualcóyotl, municipalities with the highest population densities in the MCMA. Furthermore, this area also suffers from erosion and a polluted atmosphere from industrial and heavy vehicle emissions. In our study we found that PM$_{2.5}$ measurements were characterized by: personal exposure > outdoor levels > indoor levels, which is consistent with other studies in the MCMA and other countries, this consistency applies for the personal > indoor level; however, other studies have found different results: indoor level>outdoor level ratio (Rojas, 1994; Olaiz, 1998; sexton et al, 1982; Spengler et al, 1981). Due to this inconsistencies it is important to recognize that fixed measurements or measurements limited to indoor sources may not fully reflect the best exposure assessment needed to evaluate the health effects of particulates. Our measurements of PM$_{10}$ also found a ratio of outdoor > indoor, which is indicative of important point source emissions near to the place of residence. It is therefore important to evaluate filter composition analyses to expand our knowledge of particle speciation and how it affects indoor and outdoor pollution. Further research is also needed to analyze the characteristics of the homes, including a detailed analyses of indoor emission sources and careful evaluation of time activity pattern of each household. The results of peak flow measurements, questionnaires on respiratory symptoms and time-activity patterns will reported in other paper.

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