COMMUTERS' EXPOSURE TO AIR POLLUTION IN MEXICO CITY

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BACKGROUND AND OBJECTIVE

The study describes commuters' exposure levels to PM2.5, CO and benzene during weekdays in two real routes in Mexico City. This research project is a collaboration among Imperial College, and the authorities at national (INE-SEMARNAT) and local (GDF) levels responsible to control and reduce the levels of air pollution. The main objective of the study was to identify the contribution to daily exposure attributable to commuting activities travelling from residential areas located in the north and south of the metropolitan areas towards or via downtown Mexico City.

STUDY DESCRIPTION

The exposure of commuters travelling along real routes in the city was evaluated during morning (6:30-9:30) and evening (17:30-20.30) rush hours in January-March 2003. $PM_{2.5}$, total mass plus chemical components, carbon monoxide (CO) and benzene were evaluated in this campaign. The modes of transport selected for the study were minibus, bus and metro. These three means of transportation provide approximately 75% of daily commuter travel in the city (SETRAVI, 2002). For this study, two routes, 1. La Raza-San Angel and 2. La Villa-Auditorio, were selected from a previous study conducted in 1991 in Mexico City (Fernandez-Bremauntz & Ashmore, 1995).

The pollutants were measured using three sampling techniques; for fine particles, a $PM_{2.5}$ head with a 16.7 l/min pump was used (Adams et al., 2001). An electrochemical Langan monitor was used to evaluate CO (Langan, 1992), benzene was collected by canisters (USEPA, 1999b) and analysed by a gas chromatography flame ionisation detector (GC/FID) and a preconcentration system (DKK Corporation) (Maeda et al., 1998;Maeda et al., 1995). For $PM_{2.5}$, a chemical analysis and a material balance analysis (Chow et al., 2002) was conducted. The species analysed were elemental and organic carbon (Chow et al., 1993), 15 elements (USEPA, 1999a), as well as nitrates and sulphates (CARB, 1992).

A regression model was built using CO commuters' exposure data, CO ambient data, traffic counts, wind speed and road infrastructure. For the ambient data and wind speed, an interpolation technique was applied as input data using the same temporal scale. ARC GIS was used to map commuter's exposure and predicted concentrations along the selected routes.

RESULTS

The levels of $PM_{2.5}$ shows that the higher concentrations in the selected modes of transport were during commuting periods in the morning. From the two selected routes, route 1 showed the highest concentrations in all transport modes. In all the routes and commuting periods, minibuses and buses had similar values of fine particles. However, as a total day of exposure during commuting, for morning and evening rush hours, this study shows that buses (AM=49 $\mu g/m^3$) have a slightly higher concentration than minibuses (AM=44 $\mu g/m^3$) in route 1. For buses, the morning exposure levels were 30% higher in route 1 than in route 2. This difference increased up to 50% in the evening.

The composition of particles shows that carbon was the main species in all the modes of transport. Organic carbon was the species with the highest concentration in all modes of transport and routes. Minibuses and buses show the highest levels of elemental carbon in $PM_{2.5}$. Carbon concentrations were higher in morning rush hours in both routes for every mode of transport than evening commuting periods.

Concentrations of CO were higher for all modes of transport during morning rush hours. Minibuses had the higher CO levels of exposure, whereas the levels in the metro were the lowest with about the same level of CO in both routes. The difference between routes for this pollutant was much less than that for particles.

Benzene showed a similar trend as particles. The difference was that the higher concentrations were found in minibuses rather than buses. As the other pollutants, route 1 was consistently showing the higher concentrations. Higher traffic density and low speed in route 1 may explain the difference of levels of exposure found for benzene and the other pollutants.

For the regression model, the strongest determinant of commuters' exposure was wind speed. High wind speed was observed during commuting periods in the evening therefore the concentration of the selected pollutants decreased in the evening rush hours. The inversion layer effect in the city plays an important role not only to increase ambient concentrations but also commuter's exposure levels in minibuses and buses. An interpolation technique, ordinary kriging, was used only for CO. This shows that the predicted ambient levels could be incorporated in the model to improve the output to predict concentrations of commuters in minibuses and buses. Geographical information was also useful to map and observe the behaviour of CO during commuting periods as well as in ambient levels with the same temporal scale. Other important information included in the regression model and mapped was traffic data and the road network. However, these two determinants were not strong enough and it could be very important to incorporated them in future studies to improve the output of the model.

CONCLUSIONS

The study not only identified the levels of exposure for the selected modes of transport and determinants thereof, but also detected hot spots in street junctions where air pollutants may have health effects on commuters and people doing different daily activities. GIS-based modelling and mapping techniques were useful to indicate air pollution levels commuters may experience. Development with more detailed information about other determinants is recommended to improve the model output obtained. The research supports recommendations that national and local authorities should consider to lessen emissions of air pollution originated mainly from traffic. At the same time, on identifying the determinants over which they may have control.

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REFERENCES

Adams, H. S.; Kenny, L. C.; Nieuwenhuijsen, M. J.; Colvile, R. N.; & Gussman, R. A., 2001. "Design and validation of a high-flow personal sampler for PM2.5", *Journal of Exposure Analysis and Environmental Epidemiology*, vol. 11, no. 1, pp. 5-11.

CARB 1992, *Standard operating procedure for analyzing anions from ambient air particulate samples from the California Acidic Dry Deposition Monitoring Network* California, S.O.P. No. 044.

Chow, J. C.; Watson, J. G.; Pritchett, L. C.; Pierson, W. R.; Frazier, C. A.; & Purcell, R. G., 1993. "The DRI Thermal Optical Reflectance Carbon Analysis System - Description, Evaluation and Aplications in the United States Air Quality Studies", *Atmospheric Environment Part A-General Topics*, vol. 27, no. 8, pp. 1185-1201.

Chow, J. C.; Watson, J. G.; Edgerton, S. A.; & Vega, E., 2002. "Chemical composition of PM2.5 and PM10 in Mexico City during winter 1997", *The Science of The Total Environment*, vol. 287, no. 3, pp. 177-201.

Fernandez-Bremauntz, A. A. & Ashmore, M. R., 1995. "Exposure of commuters to carbon monoxide in Mexico City--I. Measurement of in-vehicle concentrations", *Atmospheric Environment*, vol. 29, no. 4, pp. 525-532.

Langan, L., 1992. "Portability in Measuring Exposure to Carbon Monoxide", Journal of Analysis and Environmental Epidemiology no. Suppl 1, pp. 223-239.

Maeda, T.; Funaki, K.; Yanaguchi, Y.; Ichioka, K.; Suzuki, K.; Yamamoto, N.; & Morita, M., 1998. "On-site monitoring system for hazardous air pollutants using an adsorption thermal desorption capillary GC system equipped with a photoionization detector and an electrolytic conductivity detector", *Hrc-Journal of High Resolution Chromatography*, vol. 21, no. 8, pp. 471-474.

Maeda, T.; Onodera, S.; & Ogino, H., 1995. "On-site monitoring of volatile organic compounds as hazardous air pollutants by gas chromatography", *Journal of Chromatography A*, vol. 710, no. 1, pp. 51-59.

SETRAVI 2002, *Programa Integral de Transporte y Vialidad 2001-2006*, Secretaria de Transporte y Vialidad, Mexico City.

USEPA 1999a, *Determination of Metals in Ambient Particulate Matter Using X-Ray Fluorescence (XRF) Spectroscopy* EPA/625/R-96/010a.

USEPA 1999b, *Determination of Volatile Organic Compounds (VOCs) In Air collected In Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS)* EPA/625/R-96/010b.