Determination of the Spatial and Temporal Variation of SO_2, NO_2 and Particulate Matter Using GIS Techniques and Estimation of Concentration Modeling with LUR Method (Case Study: Tehran City)

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Expanded Abstract

Introduction
Studies about the health effects of long-term average exposure to outdoor air pollution have played an important role in the recent health impact assessments. Exposure assessment for epidemiological studies of long-term exposure to ambient air pollution remains a difficult challenge because of substantial small-scale spatial variation. Current approaches for assessing intra-urban air pollution contrasts include the use of exposure indicator variables, interpolation methods, dispersion models and land-use regression (LUR) models. LUR models have been increasingly used in the past few years. Land-use regression combines monitoring of air pollution at typically 20-100 locations, spread over the study area, and development of stochastic models using predictor variables usually obtained through Geographic Information Systems (GIS). Significant predictor variables include various traffic representations, population density, land use, physical geography (e.g. altitude) and climate. Land-use regression methods have generally been applied successfully to model annual mean concentrations of SO_2, NO_2, PM_{10}, $PM_{2.5}$, the soot content of PM and VOCs in different environments, including European and North-American cities. The performance of the method in urban areas is typically better or equivalent to geo-statistical methods, such as kriging, and dispersion models. Further developments of the land-use regression method have more focus on developing models. This can be transferred to other areas and include of additional predictor variables such as wind direction or emission data and further exploration of focal sum methods. Models that include a spatial and a temporal component are of interest for (e.g. birth cohort) the studies that require exposure variables on a finer temporal scale. There is a strong need for validation of LUR models with personal exposure monitoring.

Materials and Methods
This study developed average exposure estimates of one season for Sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and Particulate Matter (PM) in Tehran in 1391. The averages exposures were constructed by first developing land use regression (LUR) models of spatial variation in annual average PM, SO_2 and NO_2. Data were collected from 42 locations in the Tehran City Community Air Survey and emissions source data near monitors. The annual average concentrations from the spatial models were adjusted to account for city-wide temporal trends using the time series derived from regulatory monitors. Models were developed using season 1 data and validated using season 2 data. Average exposures were then estimated for three buffers of maternal address and were averaged into the last four weeks, the trimesters, and the entire period of gestation. We characterized temporal variation of exposure estimates, correlation between PM, NO_2, SO_2 and the correlation of exposures across trimesters.

Results and Discussion
The LUR models of average annual concentrations explained a substantial amount of the spatial variation (R^2 = 0.47 for SO_2), (R^2 = 0.51 for NO_2), (R^2 = 0.71 for PM_{10}) and (R^2 = 0.47 for $PM_{2.5}$). The relative contribution of temporal versus spatial variations in the estimated exposures is varied by time window. The difference in seasonal cycle of these pollutants resulted in different patterns of correlations in the estimated exposures across trimesters. Table 1 shows Spearrman correlation results with wind direction, wind velocity and temperature.

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Table 1. Spearrman's correlation results

Wind direction	Wind velocity	Temperature	Pollutant
-0.085	-0.081	-0.083	SO_2
0.05	0.05	0.05	sig.
-0.98	-0.302	-0.320	NO_2
0.041	0.000	0.000	sig.
-0.008	-0.012	0.055	PM_{10}
0.131	0.000	0.319	sig.
-0.002	-0.05	-0.109	$PM_{2.5}$
0.731	0.361	0.49	sig.

The three levels of spatial buffers did not make a substantive difference in estimated exposures. The combination of spatially resolved monitoring data, LUR models and temporal adjustment using regulatory monitoring data yielded exposure estimates for PM that performed well in validation tests. Table 2 shows RMSE of spline method results. The interaction between seasonality of air pollution and exposure intervals during pregnancy needs to be considered in the future studies.

Table 2. Spline method results

RMSE	Neighbor points	Method RBF	Pollutant	RMSE	Neighbor points	Method RBF	Pollutant
29.51	42	Completely Regularized Spline	NO_2	23.46	42	Completely Regularized Spline	SO_2
29.40	42	Spline with Tension		22.22	42	Spline with Tension	
30.15	42	Multiquadric		33	42	Multiquadric	
29.20	42	Inverse Multiquadric		25.61	42	Inverse Multiquadric	
32	42	Thin Plate Spline		31	42	Thin Plate Spline	
16.50	42	Completely Regularized Spline	$PM_{2.5}$	30.30	42	Completely Regularized Spline	PM_{10}
17.20	42	Spline with Tension		31.25	42	Spline with Tension	
17.90	42	Multiquadric		32.17	42	Multiquadric	
17.50	42	Inverse Multiquadric		32.25	42	Inverse Multiquadric	
16.80	42	Thin Plate Spline		31.89	42	Thin Plate Spline	

Conclusions

Land-use regression methods have generally been applied successfully to model the annual mean concentrations of SO_2, NO_2, PM_{10}, and $PM_{2.5}$. Land-use regression methods can also be benefited from a more systematic selection and description of monitoring locations and monitoring periods. More attention to the precision of geographic data is also important. A model strategy incorporating greater knowledge of the factors related to spatial variation and focusing less on maximizing the percentage of the explained variability would probably result in the models that can more readily be transferred to other areas. Where purpose-designed monitoring is included, the cost of monitoring could probably be reduced if models were transferable. Promising new developments include the use of additional predictor variables such as wind direction data or emission data and the use of the raster GIS environment – for example, to apply focal sum methods. Models that include both a spatial and a temporal component are also of interest for studies that need exposure variables on a more detailed scale. However, it remains to be seen whether these LUR models can outperform dispersion models for shorter averaging periods. Finally, an area of interest for epidemiological research is the need for validation of LUR models with personal monitoring. The combination of spatially resolved monitoring data, LUR models and temporal adjustment using regulatory monitoring data yielded exposure estimates for PM_{10}, $PM_{2.5}$, SO_2 and NO_2. This is performed well in validation tests. The interaction between seasonality of air pollution and exposure intervals during pregnancy needs to be considered in the future studies.

Keywords: air pollution, GIS, land use regression, particulate matter.