References

# (1990). Clean Air Act, as amended by Pub. L. No. 101-549. 42 USC.

# (1990). Clean Air Act, as amended by Pub. L. No. 101-549, section 108: Air quality criteria and control techniques, 42 USC § 7408. 42 USC.

# Abbey, D. E., et al. (1999). "Long-term inhalable particles and other air pollutants related to mortality in nonsmokers." American Journal of Respiratory and Critical Care Medicine 159(2): 373-382.

Long-term ambient concentrations of inhalable particles less than 10 mum in diameter (PM10) (1973-1992) and other air pollutants-total suspended sulfates, sulfur dioxide, ozone (O3), and nitrogen dioxide-were related to 1977-1992 mortality in a cohort of 6,338 nonsmoking California Seventh-day Adventists. In both sexes, PM10 showed a strong association with mortality for any mention of nonmalignant respiratory disease on the death certificate, adjusting for a wide range of potentially confounding factors, including occupational and indoor sources of air pollutants. The adjusted relative risk (RR) for this cause of death as associated with an interquartile range (IQR) difference of 43 d/yr when PM10 exceeded 100 mug/m3 was 1.18 (95% confidence interval (CI): 1.02, 1.36). In males, PM10 showed a strong association with lung cancer deaths-RR for an IQR was 2.38 (95% CI: 1.42, 3.97). Ozone showed an even stronger association with lung cancer mortality for males with an RR of 4.19 (95% CI: 1.81, 9.69) for the IQR difference of 551 h/yr when O3 exceeded 100 parts per billion. Sulfur dioxide showed strong associations with lung cancer mortality for both sexes. Other pollutants showed weak or no association with mortality.

# Akinbami, L. J., et al. (2010). "The association between childhood asthma prevalence and monitored air pollutants in metropolitan areas, United States, 2001-2004." Environmental Research 110(3): 294-301.

BACKGROUND: Air pollution exposure has been linked to adverse respiratory health outcomes among children, primarily in studies of acute exposures that are often in limited geographic areas. We sought to assess the association between chronic outdoor air pollution exposure, as measured by 12-month averages by county, and asthma among children in metropolitan areas across the nation. METHODS: Eligible children included those aged 3-17 years residing in US metropolitan areas who were sampled in the 2001-2004 National Health Interview Survey (N=34,073). 12-month average air pollutant levels for sulfur dioxide, nitrogen dioxide, ozone and particulate matter were compiled by county for 2000-2004. Eligible children were linked to pollutant levels for the previous 12 months for their county of residence. Adjusted odds ratios of having current asthma or an asthma attack in the past 12 months were estimated in single pollutant logistic regression models. RESULTS: Children in counties with ozone and, to a less consistent degree, particulate matter levels in the highest quartile were more likely to have current asthma and/or a recent asthma attack than children residing in counties with the lowest pollution levels; the adjusted odds for current asthma for the highest quartile of estimated ozone exposure was 1.56 (95% confidence interval [CI]: 1.15, 2.10) and for recent asthma attack 1.38 (95% CI: 0.99, 1.91). No associations were found with sulfur dioxide or nitrogen dioxide levels. CONCLUSION: Although the current US standard for ozone is based on short-term exposure, this cross-sectional study suggests that chronic (12-month) exposure to ozone and particles is related to asthma outcomes among children in metropolitan areas throughout the US.

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# Alexeeff, S. E., et al. (2015). "Consequences of kriging and land use regression for PM2.5 predictions in epidemiologic analyses: insights into spatial variability using high-resolution satellite data." Journal of Exposure Science and Environmental Epidemiology 25(2): 138-144.

Many epidemiological studies use predicted air pollution exposures as surrogates for true air pollution levels. These predicted exposures contain exposure measurement error, yet simulation studies have typically found negligible bias in resulting health effect estimates. However, previous studies typically assumed a statistical spatial model for air pollution exposure, which may be oversimplified. We address this shortcoming by assuming a realistic, complex exposure surface derived from fine-scale (1 km x 1 km) remote-sensing satellite data. Using simulation, we evaluate the accuracy of epidemiological health effect estimates in linear and logistic regression when using spatial air pollution predictions from kriging and land use regression models. We examined chronic (long-term) and acute (short-term) exposure to air pollution. Results varied substantially across different scenarios. Exposure models with low out-of-sample R(2) yielded severe biases in the health effect estimates of some models, ranging from 60% upward bias to 70% downward bias. One land use regression exposure model with >0.9 out-of-sample R(2) yielded upward biases up to 13% for acute health effect estimates. Almost all models drastically underestimated the SEs. Land use regression models performed better in chronic effect simulations. These results can help researchers when interpreting health effect estimates in these types of studies. Journal of Exposure Science and Environmental Epidemiology advance online publication, 4 June 2014; doi:10.1038/jes.2014.40.

# Allen, R. W., et al. (2011). "The transferability of NO and NO2 land use regression models between cities and pollutants." Atmospheric Environment 45(2): 369-378.

Land use regression (LUR) models are commonly used for exposure assessment in epidemiologic studies of traffic-related air pollution. Models in different cities often contain similar predictors, suggesting that models may be transferable between cities with similar characteristics. LUR models of NO or NO(2) may also be useful for estimating exposure to other pollutants in the traffic pollution mixture. We evaluated the transferability of NO and NO(2) LUR models between Winnipeg, Manitoba and Edmonton. Alberta, and the ability of the Winnipeg NO and NO(2) LUR models to predict concentrations of benzene and toluene. In both cities, LUR models were developed based on measurements with Ogawa passive samplers at 50 locations during two 14-day sampling campaigns, while benzene and toluene concentrations in Winnipeg were measured at 46 independent locations using 3M #3500 passive badges during a single 14-day period. Locally calibrated LUR models explained more variability in NO(2) (R(2): 0.81-0.84) than NO (R(2): 0.55-0.56). Although models transferred to the oosite city did not perform as well as the locally calibrated models for NO(2) (R(2): 0.37-0.52) or NO (R(2): 0.24-0.41), the transferred models explained more variability than simple binary or continuous road proximity metrics (R(2) <= 0.19), which are commonly used in epidemiologic studies. In Winnipeg, the NO(2) LUR model explained 34% and 19% of the variation in benzene and toluene, respectively, while road proximity metrics explained <= 19% of the variation in both pollutants. In conclusion, epidemiologic studies will achieve better exposure assessments by developing LUR models locally and for the pollutant of interest, though transferred LUR models may provide a cost-effective improvement over road proximity metrics for assessing exposure to traffic-related air pollution.

# Altuğ, H., et al. (2013). "Effects of air pollution on lung function and symptoms of asthma, rhinitis and eczema in primary school children." Environmental Science and Pollution Research 20(9): 6455-6467.

Health effects of ambient air pollution were studied in three groups of schoolchildren living in areas (suburban, urban and urban-traffic) with different air pollution levels in Eskişehir, Turkey. This study involved 1,880 students aged between 9 and 13 years from 16 public primary schools. This two-season study was conducted from January 2008 through March 2009. Symptoms of asthma, rhinitis and eczema were determined by the International Study of Asthma and Allergies in Childhood questionnaire in 2008. Two lung function tests were performed by each child for summer and winter seasons with simultaneous ambient air measurements of ozone (O3), nitrogen dioxide (NO2) and sulfur dioxide (SO2) by passive sampling. Effects of air pollution on impaired lung function and symptoms in schoolchildren were estimated by multivariate logistic regression analyses. Girls with impaired lung function (only for the summer season evaluation) were more observed in suburban and urban areas when compared to urban-traffic area ([odds ratio (OR)= 1.49; 95 % confidence interval (CI) 1.04-2.14] and [OR = 1.69 (95 % CI 1.06-2.71)] for suburban vs. urban-traffic and urban vs. urban-traffic, respectively). Significant association between ambient ozone concentrations and impaired lung function (for an increase of 10 μg m(-3)) was found only for girls for the summer season evaluation [OR = 1.11 (95 % CI 1.03-1.19)]. No association was found for boys and for the winter season evaluation. No association was found between any of the measured air pollutants and symptoms of current wheeze, current rhinoconjunctivitis and current itchy rash. The results of this study showed that increasing ozone concentrations may cause a sub-acute impairment in lung function of school aged children.

# Ancona, C., et al. (2015). "Mortality and morbidity in a population exposed to multiple sources of air pollution: A retrospective cohort study using air dispersion models." Environmental Research 137: 467-474.

BACKGROUND AND AIMS: A landfill, an incinerator, and a refinery plant have been operating since the early 1960s in a contaminated site located in the suburb of Rome (Italy). To evaluate their potential health effects, a population-based retrospective cohort study was conducted using dispersion modeling for exposure assessment.

METHODS: A fixed cohort was enrolled in the Rome Longitudinal Study in 2001, mortality and hospitalizations were followed-up until 2010. Exposure assessments to the landfill (H2S), the incinerator (PM10), and the refinery plant (SOX) were performed for each subject using a Lagrangian dispersion model. Individual and small-area variables were available (including exposures levels to NO2 from traffic and diesel trucks). Cox regression analysis was performed (hazard ratios, HRs, 95% CI) using linear terms for the exposures (5th-95th percentiles difference). Single and bi-pollutant models were run.

RESULTS: The cohort included 85,559 individuals. The estimated annual average exposures levels were correlated. H2S from the landfill was associated with cardiovascular hospital admissions in both genders (HR 1.04 95% CI 1.00-1.09 in women); PM10 from the incinerator was associated with pancreatic cancer mortality in both genders (HR 1.40 95% CI 1.03-1.90 in men, HR 1.47 95% CI 1.12-1.93 in women) and with breast morbidity in women (HR 1.13 95% CI 1.00-1.27). SOx from the refinery was associated with laryngeal cancer mortality in women (HR 4.99 95% CI 1.64-15.9) and respiratory hospital admissions (HR 1.13 95% CI 1.01-1.27).

CONCLUSIONS: We found an association of the pollution sources with some cancer forms and cardio-respiratory diseases. Although there was a high correlation between the estimated exposures, an indication of specific effects from the different sources emerged.

# Andersen, Z. J., et al. (2008). "Ambient air pollution triggers wheezing symptoms in infants." Thorax 63(8): 710-716.

Background: There is limited evidence for the role of air pollution in the development and triggering of wheezing symptoms in young children. A study was undertaken to examine the effect of exposure to air pollution on wheezing symptoms in children under the age of 3 years with genetic susceptibility to asthma. Methods: Daily recordings of symptoms were obtained for 205 children participating in the birth cohort study Copenhagen Prospective Study on Asthma in Children and living in Copenhagen for the first 3 years of life. Daily air pollution levels for particulate matter <10 μm in diameter (PM10) and the concentrations of ultrafine particles, nitrogen dioxide (NO2), nitrogen oxide (NOx) and carbon monoxide (CO) were available from a central background monitoring station in Copenhagen. The association between incident wheezing symptoms and air pollution on the concurrent and previous 4 days was estimated by a logistic regression model (generalised estimating equation) controlling for temperature, season, gender, age, exposure to smoking and paternal history of asthma. Results: Significant positive associations were found between concentrations of PM10, NO2, NOx, CO and wheezing symptoms in infants (aged 0-1 year) with a delay of 3-4 days. Only the traffic-related gases (NO2, NOx) showed significant effects throughout the 3 years of life, albeit attenuating after the age of 1 year. Conclusions: Air pollution related to traffic is significantly associated with triggering of wheezing symptoms in the first 3 years of life.

# Andersen, Z. J., et al. (2007). "Ambient particle source apportionment and daily hospital admissions among children and elderly in Copenhagen." Journal of Exposure Science and Environmental Epidemiology 17(7): 625-636.

An association between particulate air pollution and morbidity and mortality is well established. However, little is known about which sources of particulate matter contribute most to the adverse health effects. Identification of responsible sources would merit more efficient control. For a 6-year period (01 January 1999 to 31 December 2004), we examined associations between urban background PM(10) in the presence of gaseous pollutants (CO, NO(2)) and hospital admissions due to cardiovascular and respiratory disease in the elderly (age>/=65), and asthma in children (age 5-18) in Copenhagen, Denmark. We further studied associations between fractions of PM(10) assigned to six sources (biomass, secondary, oil, crustal, sea salt, and vehicle) and admissions during a 1(1/2) -year campaign. We used Poisson generalized additive time-series model adjusted for season, day of the week, public holidays, influenza epidemics, grass pollen, school holidays, and meteorology, with up to 5 days lagged air pollution exposure. We found positive associations between PM(10) and the three health outcomes, with strongest associations for asthma. The PM(10) effect remained robust in the presence of CO and NO(2). We found different PM(10) sources to be variably associated with different outcomes: crustal and secondary sources showed strongest associations with cardiovascular, biomass with respiratory, and vehicle with asthma admissions. These novel results may merit future research of potential mechanism, whereas at present, no single PM(10) source can be attributed to all morbidity.

# Anderson, G. B. and M. L. Bell (2010). "Does one size fit all? The suitability of standard ozone exposure metric conversion ratios and implications for epidemiology." Journal of Exposure Science and Environmental Epidemiology 20(1): 2-11.

Several exposure metrics have been applied in health research and policy settings to represent ozone exposure, such as the 24 h average and daily 8 h maximum. Frequently, results calculated using one exposure metric are converted using a simple ratio to compare or combine findings with results using a different metric. This conversion, however, assumes that such a ratio is constant across locations and time periods. We investigated the appropriateness of this conversion method by examining the relationships among various forms of ozone concentrations (24 h average, daily 1 h maximum, and daily 8 h maximum) within and between communities for 78 US communities from 2000 to 2004 and compared results to commonly used conversion ratios. We explored whether the relationships between ozone exposure metrics differ by region, weather, season, and city-specific characteristics. Analysis revealed variation in the relationship among ozone metrics, both across communities and across time within individual communities, indicating that conversion of ozone exposure metrics with a standard ratio introduces uncertainty. For example, the average ratio of the daily 8 h maximum to the daily concentration ranged from 1.23 to 1.83. Within a community, days with higher ozone levels had lower ratios. Relationships among metrics within a community were associated with daily temperature. The community-average exposure metric ratios were lower for communities with higher long-term ozone levels. Ozone metric ratios differed by season because of the different rate of change of ozone metrics throughout the year. We recommend that health effects studies present results from multiple ozone exposure metrics, if possible. When conversions are necessary, more accurate estimates can be obtained using summaries of data for a given location and time period if available, or by basing conversion ratios on data from a similar city and season, such as the results provided in this study.

# Anderson, H. R., et al. (2001). "Particulate matter and daily mortality and hospital admissions in the West Midlands conurbation of the United Kingdom: associations with fine and coarse particles, black smoke and sulphate." Occupational and Environmental Medicine 58(8): 504-510.

United Kingdom Department of Health. OBJECTIVES: There is considerable evidence linking ambient particles measured as particulate matter with aerodynamic diameter <10 µm (PM(10)) to daily mortality and hospital admissions but it is not clear which physical or chemical components of the particle mixture are responsible. The relative effects of fine particles (PM(2.5)), coarse particles (PM(2.5-10)), black smoke (mainly fine particles of primary origin) and sulphate (mainly fine particles of secondary origin) were investigated, together with ozone, SO(2), NO(2), and CO, on daily mortality and hospital admissions in the west Midlands conurbation of the United Kingdom. METHODS: Time series of health outcome and environmental data were obtained for the period 1994-6. The relative risk of death or hospital admission was estimated with regression techniques, controlling for long term time trends, seasonal patterns, influenza epidemics, effects of day of the week, and temperature and humidity. Models were adjusted for any remaining residual serial correlation and overdispersion. The sensitivities of the estimates for the effects of pollution to the inclusion of a second pollutant and seasonal interactions (warm or cool) were also examined. RESULTS: Daily all cause mortality was not associated with any gaseous or particulate air pollutant in the all year analysis, although all measures of particles apart from PM(2.5-10) showed significant positive effects of the warm season. Neither respiratory nor cardiovascular admissions (all ages) were associated with any air pollutant, and there were no important seasonal interactions. However, analysis of admissions by age found evidence for various associations-notably between PM(10), PM(2.5), black smoke, SO(2,) and ozone (negative) and respiratory admissions in the 0-14 age group. The coarse fraction, PM(2.5-10) differed from PM(2.5) in having smaller and less consistent associations (including several large significant negative associations) and a different lag distribution. The results for black smoke, an indicator of fine primary carbonaceous particles, were very similar to those for PM(2.5), and tended to be more robust in two pollutant models. The effects of sulphate, an indicator of secondary particles, also showed some similarities to those of PM(2.5). CONCLUSIONS: Clear effects of air pollution on mortality and hospital admissions were difficult to discern except in certain age or diagnostic subgroups and seasonal analyses. It was also difficult to distinguish between different measures of particles. Within these limitations the results suggest that the active component of PM(10) resides mostly in the fine fraction and that this is due mainly to primary particles from combustion (mainly vehicle) sources with a contribution from secondary particles. Effects of the coarse fraction cannot be excluded.

# Anderson, S. E., et al. (2007). "Evaluation of the contact and respiratory sensitization potential of volatile organic compounds generated by simulated indoor air chemistry." Toxicological Sciences 97(2): 355-363.

Up to 60 million people working indoors experience symptoms such as eye, nose and throat irritation, headache, and fatigue. Investigations into these complaints have ascribed the effects to volatile organic compounds (VOCs) emitted from building materials, cleaning formulations, or other consumer products. New compounds can result when the VOCs react with hydroxyl or nitrate radicals or ozone present in indoor environments. Several oxygenated organic compounds, such as glyoxal, methylglyoxal, glycolaldehyde, and diacetyl, have been identified as possible reaction products of indoor environment chemistry. Although research has previously identified diacetyl and glyoxal as sensitizers, additional experiments were conducted in these studies to further classify their sensitization potential. Sensitization potential of these four compounds was assessed using quantitative structure-activity relationship (QSAR) programs. Derek for Windows and National Institute for Occupational Safety and Health logistic regression predicted all compounds to be sensitizers, while TOPKAT 6.2 predicted all compounds except for methylglyoxal. All compounds were tested in a combined irritancy and local lymph node assay (LLNA). All compounds except for glyoxal were found to be irritants and all tested positive in the LLNA with EC3 values ranging from 0.42 to 1.9%. Methylglyoxal significantly increased both the B220(+) and IgE(+)B220(+) cell populations in the draining lymph nodes and total serum IgE levels. The four compounds generated by indoor air chemistry were predicted by QSAR and animal modeling to be sensitizers, with the potential for methylglyoxal to induce IgE. The identification of these compounds as sensitizers may help to explain some of the health effects associated with indoor air complaints.

# Aoki, T. and S. Tanabe (2007). "Generation of sub-micron particles and secondary pollutants from building materials by ozone reaction." Atmospheric Environment 41(15): 3139-3150.

This study reports results from two different experiments examining reactions between ozone and common building materials that can lead to the formation of secondary products and particulate-phase materials. Monitored species include sub-micron particles and volatile organic compounds (VOCs). In the first set of experiments, various building materials were placed in a 20 L stainless-steel chamber and exposed to ozone. The materials included expanded polystyrene, a natural rubber adhesive, cedar board, Japanese Cyprus board and silver fir board, as well as d-limonene, which is a known constituent of certain woods and cleaning products. The combination of ozone and either d-limonene, cedar board or cypress board produced sub-micron particles, with most of the increase occurring in the size range of 0.01-0.5 mu m diameter. This was not observed for the other materials. In the case of cedar board, the consequence of ozone exposure over an extended time interval was monitored. As the exposure time elapsed, the concentration of sub-micron particles moderately decreased. In the second set of experiments, unwaxed or waxed plastic tiles were placed in the 20 L chamber and exposed to ozone. Sub-micron particles and organic compounds were measured during the course of the experiments. In the case of the waxed tile, the number of 0.0 1-1.0 mu m size particles grew about 50 x 108 particles m(-3); particle growth was significantly less for the un-waxed tile. For both the waxed and un-waxed tiles, the emission rates of heptane, nonane, nonanal, and decanal increased after ozone was added to the supply air. (However, it is not clear if some or all of this production was due to ozone reacting with the sorbent used for sampling or with compounds captured by the sorbent.) This study provides further evidence that ozone-initiated reactions with building materials can be a significant source of both sub-micron particles and secondary organic compounds in indoor environments. (C) 2006 Published by Elsevier Ltd.

# Arbex, M. A., et al. (2009). "Urban air pollution and chronic obstructive pulmonary disease-related emergency department visits." Journal of Epidemiology and Community Health 63(10): 777-783.

Background: Patients with chronic obstructive pulmonary disease (COPD) can have recurrent disease exacerbations triggered by several factors, including air pollution. Visits to the emergency respiratory department can be a direct result of short-term exposure to air pollution. The aim of this study was to investigate the relationship between the daily number of COPD emergency department visits and the daily environmental air concentrations of PM10, SO2, NO2, CO and O3 in the City of São Paulo, Brazil. Methods: The sample data were collected between 2001 and 2003 and are categorised by gender and age. Generalised linear Poisson regression models were adopted to control for both short- and long-term seasonal changes as well as for temperature and relative humidity. The non-linear dependencies were controlled using a natural cubic spline function. Third-degree polynomial distributed lag models were adopted to estimate both lag structures and the cumulative effects of air pollutants. Results: PM10 and SO2 readings showed both acute and lagged effects on COPD emergency department visits. Interquartile range increases in their concentration (28.3 μg/m3 and 7.8 μg/m3, respectively) were associated with a cumulative 6-day increase of 19% and 16% in COPD admissions, respectively. An effect on women was observed at lag 0, and among the elderly the lag period was noted to be longer. Increases in CO concentration showed impacts in the female and elderly groups. NO2 and O3 presented mild effects on the elderly and in women, respectively. Conclusion: These results indicate that air pollution affects health in a gender- and age-specific manner and should be considered a relevant risk factor that exacerbates COPD in urban environments.

# Arhami, M., et al. (2009). "Associations between personal, indoor, and residential outdoor pollutant concentrations: Implications for exposure assessment to size-fractionated particulate matter." Journal of the Air and Waste Management Association (1990-1992) 59(4): 392-404.

The physical and chemical characteristics of indoor, outdoor, and personal quasi-ultrafine (<0.25 microm)-, accumulation (0.25-2.5 microm)-, and coarse (2.5-10 microm)-mode particles were studied at four different retirement communities in southern California between 2005 and 2007. Linear mixed-effects models and Spearman's correlation coefficients were then used to elucidate the relationships among size-segregated particulate matter (PM) levels, their particle components, and gaseous co-pollutants. Seasonal and spatial differences in the concentrations of all measured species were evaluated at all sites on the basis of P values for product terms. Outdoor quasi-ultrafine (UF) and, to a lesser extent, accumulation-mode particles were the two fractions that best correlated with outdoor concentrations of carbon monoxide (CO), nitrogen dioxide (NO2), nitrogen oxides (NOx; during both phases of the study), and ozone (O3; only during the warmer months). Outdoor and indoor concentrations of CO, NO2, and NOx were more positively correlated to personal quasi-UF particles than larger size fractions. Despite these findings, it seems unlikely that these gaseous co-pollutants could confound epidemiologic associations between quasi-UF particles and adverse health effects. Overall, measured gaseous co-pollutants were weak surrogates of personal exposure to accumulation-mode PM, at least for subjects with similar exposure profiles and living in similar urban locations. Indoor sources were not significant contributors to personal exposure of accumulation and quasi-UF PM, which is predominantly influenced by primary emitted pollutants of outdoor origin. Correlations between personal coarse-mode PM and both outdoor and indoor gaseous co-pollutant concentrations were weak at all sites and during all seasons.

# Armstrong, B. K., et al. (1992). Principles of exposure measurement in epidemiology. New York, NY, Oxford University Press.

# Arnedo-Pena, A., et al. (2009). "Air pollution and recent symptoms of asthma, allergic rhinitis, and atopic eczema in schoolchildren aged between 6 and 7 years." Archivos de Bronconeumología 45(5): 224-229.

OBJECTIVE: The objective of the study was to analyze the relationship between air pollutants and the prevalence of recent symptoms of asthma, allergic rhinitis, and atopic eczema in schoolchildren aged between 6 and 7 years. PATIENTS AND METHODS: The prevalence of recent (previous 12 months) symptoms of allergic diseases was obtained by means of the questionnaire of the International Study of Asthma and Allergies in Childhood (ISAAC), Spain, with the participation of 7 centers (Asturias, Barcelona, Bilbao, Cartagena, La Coruna, Madrid, and Valencia) and 20 455 schoolchildren aged between 6 and 7 years, from 2002 to 2003. The pollutant detection systems of the aforementioned centers provided the mean annual concentrations of sulfur dioxide (SO(2)), nitrogen dioxide (NO(2)), carbon monoxide (CO), and total suspended particulate matter. RESULTS: The annual average concentration of SO(2) showed a significant association with a higher prevalence of recent severe asthma (adjusted odds ratio [aOR] between level-1 and level-3 pollution, 1.32; 95% confidence interval [CI], 1.01-1.73), rhinitis (aOR, 1.56; 95% CI, 1.39-1.75), and rhinoconjunctivitis (aOR, 1.70; 95% CI, 1.45-2.00). The annual average concentration of CO was associated with a higher prevalence of rhinitis (aOR, 1.65; 95% CI, 1.34-2.04), rhinoconjunctivitis (aOR, 1.76; 95% CI, 1.31-2.37), and eczema (aOR, 1.55; 95% CI, 1.17-2.04). The annual average concentration for NO(2) and total suspended particulate matter showed inverse associations with the prevalence of nocturnal dry cough. CONCLUSIONS: Findings suggest that air pollutants such as SO(2) and CO increase the risk of recent symptoms of asthma and allergic rhinitis in schoolchildren aged between 6 and 7 years in Spain.

# ATSDR (2006). A study of ambient air contaminants and asthma in New York City: Part A and B. Atlanta, GA, U.S. Department of Health and Human Services.

This report compares ambient levels of certain hazardous air pollutants, criteria pollutants, and bioaerosols in two New York City neighborhoods that have different rates of hospital admissions for asthma and different socio-economic status characteristics. Chemical and biological analytes were chosen for this study based on existing information suggesting that exposure to these analytes may be related to acute asthma exacerbations. In addition to data on many commonly measured chemical air pollutants, information was collected on several components of airborne particulate matter that have not previously been assessed for their possible association with asthma exacerbations. The primary goal was to assess whether ambient air quality differed in two New York City locations. It also presents the results of the analysis evaluating the effects of various air contaminants on acute asthma exacerbations.

# Avol, E. L., et al. (1998). "Modeling ozone levels in and around southern California homes." Environmental Science and Technology 32(4): 463-468.

California Air Resources Board. #To investigate residential ozone (O3) concentrations and their relationship to regional monitoring data, we studied 126 southern California homes between February and December 1994. Using a controlled flow sampler, 481 samples were collected over 24 h sampling periods, both inside (n = 241) and immediately outside (n = 240) residences. Indoor O3 levels (13 +- 12 ppb, arithmetic mean) were almost always below observed outdoor measurements (37 +- 19 ppb). Low outdoor concentrations resulted in uniformly low indoor concentrations, but high outdoor levels resulted in a range of indoor levels. Indoor/outdoor ratios (0.37 +- 0.25) were greater during the summer pollution period. Using information collected from interviews performed before and after sampling, we explored relationships between measured indoor O3, home operating characteristics, and ambient O3 reported at the closest regional monitoring station. Indoor O3 levels were largely determined by outdoor O3 levels and the duration of time that windows were kept open. Ozone measured adjacent to study homes predicted indoor levels no better than station ambient values. These data suggest that ambient O3 measured at regional stations, coupled with information about how homes are operated, predict in-home O3 levels moderately well and are potentially useful for future exposure assessment purposes.

# Baldauf, R., et al. (2008). "Traffic and meteorological impacts on near-road air quality: Summary of methods and trends from the Raleigh near-road study." Journal of the Air and Waste Management Association 58(7): 865-878.

A growing number of epidemiological studies conducted worldwide suggest an increase in the occurrence of adverse health effects in populations living, working, or going to school near major roadways. A study was designed to assess traffic emissions impacts on air quality and particle toxicity near a heavily traveled highway. In an attempt to describe the complex mixture of pollutants and atmospheric transport mechanisms affecting pollutant dispersion in this near-highway environment, several real-time and time-integrated sampling devices measured air quality concentrations at multiple distances and heights from the road. Pollutants analyzed included U.S. Environmental Protection Agency (EPA)-regulated gases, particulate matter (coarse, fine, and ultrafine), and air toxics. Pollutant measurements were synchronized with real-time traffic and meteorological monitoring devices to provide continuous and integrated assessments of the variation of near-road air pollutant concentrations and particle toxicity with changing traffic and environmental conditions, as well as distance from the road. Measurement results demonstrated the temporal and spatial impact of traffic emissions on near-road air quality. The distribution of mobile source emitted gas and particulate pollutants under all wind and traffic conditions indicated a higher proportion of elevated concentrations near the road, suggesting elevated exposures for populations spending significant amounts of time in this microenvironment. Diurnal variations in pollutant concentrations also demonstrated the impact of traffic activity and meteorology on near-road air quality. Time-resolved measurements of multiple pollutants demonstrated that traffic emissions produced a complex mixture of criteria and air toxic pollutants in this microenvironment. These results provide a foundation for future assessments of these data to identify the relationship of traffic activity and meteorology on air quality concentrations and population exposures.

# Baldauf, R. W., et al. (2013). "Air quality variability near a highway in a complex urban environment." Atmospheric Environment 64: 169-178.

In response to growing public health concerns regarding elevated air pollutant exposures and adverse human health effects for near-road populations, a study was conducted to assess how complex urban roadway configurations affect local-scale air quality. This study combined fixed-site and mobile air quality measurements with laboratory wind tunnel experiments to examine how the transport and dispersion of traffic-emitted pollutants varies with changing roadway configuration, notably with at-grade and cut section designs. Results of the study indicated that short-term maximum concentrations occurred with measurements made along at-grade locations, however, average concentrations tended to be higher at the top of the cut section compared with the at-grade location, most often occurring during lower air pollutant events. Wind flow and NO2/NOx ratios indicated that the cut section moderated peak concentrations through increased transport and dispersion, as well as reducing the influence of turbulence from vehicle activity near the road. The at-grade locations also experienced a higher impact from primary vehicle emissions than those measurements made at similar distances along a cut section. Mobile monitoring suggested that these peak concentrations quickly conformed to concentration levels measured near cut sections within 50–100 m of the source highway. Wind tunnel simulations of the study site with and without the cut section present indicated that the cut section reduced the concentrations of primary emitted vehicle pollutants by 15-25 percent for receptors located approximately 20 m from the highway. The wind tunnel simulations also revealed that buildings and other urban features influenced local-scale pollutant transport and need to be considered when evaluating near-road air quality.

# Ballester, F., et al. (2006). "Air pollution and cardiovascular admissions association in Spain: Results within the EMECAS project." Journal of Epidemiology and Community Health 60(4): 328-336.

OBJECTIVE: To evaluate the short term effect of air pollution on cardiovascular admissions in 14 Spanish cities METHODS: The period under study was from 1995 to 1999. Daily emergency admissions for all cardiovascular diseases (CVD) and heart diseases (HD) were obtained from hospital records, and the corresponding daily levels of particulates, SO2, NO2, CO, and ozone were recorded. The magnitude of association was estimated using Poisson generalised additive models controlling for confounding and overdispersion. For each cause, lagged effects, up to three days, of each pollutant were examined and combined estimates were obtained. For ozone the analyses were restricted to the warm period. One and two pollutant models were performed. RESULTS: Associations were more consistent in lag 0 (concurrent day) and 1 (lag 0-1), except in the case of ozone where there was a more delayed relation (lag 2-3). For combined estimates an increase of 10 microg/m3 in the PM10 levels in lag 0-1 was associated with an increase of 0.9% (95% CI: 0.4 to 1.5%) in the number of hospital admissions for CVD, and 1.6% (0.8 to 2.3%) for HD. For ozone the corresponding estimates for lag 2-3 were 0.7% (0.3 to 1.0) for CVD, and 0.7% (0.1 to 1.2) for HD. An increase of 1 mg/m3 in CO levels was associated with an increase of 2.1% (0.7 to 3.5%) in CVD admissions, and 4.2% (1.3 to 7.1%) in HD admissions. SO2 and NO2 estimates were more sensitive in two pollutant models CONCLUSIONS: A short term association between increases in daily levels of air pollutants and the number of daily admissions for cardiovascular diseases, with specificity for heart diseases, has been described in Spanish cities.

# Ballester, F., et al. (2001). "Air pollution and emergency hospital admissions for cardiovascular diseases in Valencia, Spain." Journal of Epidemiology and Community Health 55(1): 57-65.

STUDY OBJECTIVE--To estimate the short-term association between air pollution levels and emergency hospital admissions for cardiovascular diseases in Valencia, within 1994-1996 period. DESIGN--Daily levels of air pollution and emergency admissions for cardiovascular diseases were related to using an ecological time series design. The number of admissions was obtained from the hospital records database. Selected groups of causes were all cardiovascular diseases, heart admissions, and admissions for cerebrovascular diseases. The number of admissions for digestive diseases was used as control. Pollutants were black smoke, sulphur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO) and ozone (O3). Magnitude of association was estimated by Poisson autoregresive regression. Estimations were calculated according the hottest (May to October) and the coldest (November to April) periods. SETTING--City of Valencia, Spain, about 750 000 inhabitants. PARTICIPANTS--People being admitted to the two major hospitals in the city, with a catchment area of nearly 400 000 inhabitants. MAIN RESULTS--For the whole period, a significant association for SO2-24 h was found so a rise in its levels of 10 "mu"g/m3 was associated with an increment of 3% (95%CI 0.4 to 5.7%) in the expected number of cardiovascular admissions. A significant association for black smoke, SO2-24 h, SO2-1 h, and CO-1 h was found in the hottest semester. All these associations were verified with a lag of two days. The estimates of the associations for particles, SO2, and CO were affected by the inclusion of the other pollutants in their models. NO2 was independently associated with cerebrovascular admissions. There were no significant associations between air pollution and admissions for digestive diseases. CONCLUSIONS--Current levels of air pollution and emergency cardiovascular admissions are significantly related in Valencia.

# Basagaña, X., et al. (2013). "Measurement error in epidemiologic studies of air pollution based on land-use regression models." American Journal of Epidemiology 178(8): 1342-1346.

Land-use regression (LUR) models are increasingly used to estimate air pollution exposure in epidemiologic studies. These models use air pollution measurements taken at a small set of locations and modeling based on geographical covariates for which data are available at all study participant locations. The process of LUR model development commonly includes a variable selection procedure. When LUR model predictions are used as explanatory variables in a model for a health outcome, measurement error can lead to bias of the regression coefficients and to inflation of their variance. In previous studies dealing with spatial predictions of air pollution, bias was shown to be small while most of the effect of measurement error was on the variance. In this study, we show that in realistic cases where LUR models are applied to health data, bias in health-effect estimates can be substantial. This bias depends on the number of air pollution measurement sites, the number of available predictors for model selection, and the amount of explainable variability in the true exposure. These results should be taken into account when interpreting health effects from studies that used LUR models.

# Bateson, T. F., et al. (2007). "Panel discussion review: Session three - issues involved in interpretation of epidemiologic analyses - statistical modeling." Journal of Exposure Science and Environmental Epidemiology 17: S90-S96.

The Clean Air Act mandates that the US Environmental Protection Agency (EPA) develop National Ambient Air Quality Standards for criteria air pollutants and conduct periodic reviews of the standards based on new scientific evidence. In recent reviews, evidence from epidemiologic studies has played a key role. Epidemiologic studies often provide evidence for effects of several air pollutants. Determining whether there are independent effects of the separate pollutants is a challenge. Among the many issues confronting the interpretation of epidemiologic studies of multi-pollutant exposures and health effects are those specifically related to statistical modeling. The EPA convened a workshop on 13 and 14 December 2006 in Chapel Hill, North Carolina, USA, to discuss these and other issues; Session Three of the workshop was devoted specifically to statistical modeling. Prominent statistical modeling issues in epidemiologic studies of air pollution include (1) measurement error across the co-pollutants; (2) correlation and multi-collinearity among the co-pollutants; (3) the timing of the concentration-response function; (4) confounding; and (5) spatial analyses.

# Baxter, L. K., et al. (2013). "Examining the effects of air pollution composition on within region differences in PM(2.5) mortality risk estimates." Journal of Exposure Science and Environmental Epidemiology 23(5): 457-465.

Multi-city population-based epidemiological studies have observed significant heterogeneity in both the magnitude and direction of city-specific risk estimates, but tended to focus on regional differences in PM(2.5) mortality risk estimates. Interpreting differences in risk estimates is complicated by city-to-city heterogeneity observed within regions due to city-to-city variations in the PM(2.5) composition and the concentration of gaseous pollutants. We evaluate whether variations in PM(2.5) composition and gaseous pollutant concentrations have a role in explaining the heterogeneity in PM(2.5) mortality risk estimates observed in 27 US cities from 1997 to 2002. Within each region, we select the two cities with the largest and smallest mortality risk estimate. We compare for each region the within- and between-city concentrations and correlations of PM(2.5) constituents and gaseous pollutants. We also attempt to identify source factors through principal component analysis (PCA) for each city. The results of this analysis indicate that identifying a PM constituent(s) that explains the differences in the PM(2.5) mortality risk estimates is not straightforward. The difference in risk estimates between cities in the same region may be attributed to a group of pollutants, possibly those related to local sources such as traffic. Journal of Exposure Science and Environmental Epidemiology advance online publication, 19 December 2012; doi:10.1038/jes.2012.114.

# Beelen, R., et al. (2009). "Mapping of background air pollution at a fine spatial scale across the European Union." Science of the Total Environment 407(6): 1852-1867.

Background: There is a need to understand much more about the geographic variation of air pollutants. This requires the ability to extrapolate from monitoring stations to unsampled locations. The aim was to assess methods to develop accurate and high resolution maps of background air pollution across the EU. Methods: We compared the validity of ordinary kriging, universal kriging and regression mapping in developing EU-wide maps of air pollution on a I x 1 km resolution. Predictions were made for the year 2001 for nitrogen dioxide (NO2), fine particles <10 mu m (PM10), ozone (O-3), sulphur dioxide (SO2) and carbon monoxide (CO) using routine monitoring data in Airbase. Predictor variables from EU-wide databases were land use, road traffic, population density, meteorology, altitude, topography and distance to sea. Models were developed for the global, rural and urban scale separately. The best method to model concentrations was selected on the basis of predefined performance measures (R-2, Root Mean Square Error (RMSE)). Results: For NO2, PM10 and O-3 universal kriging performed better than regression mapping and ordinary kriging. Validation of the final universal kriging estimates with results from all validation sites gave e-values and RMSE-values of 0.61 and 6.73 mu g/m(3) for NO2; 0.45 and 5.19 mu g/m(3) for PM10; and 0.70 and 7.69 mu g/m(3) for O-3. For SO2 and CO none of the three methods was able to provide a satisfactory prediction. Conclusion: Reasonable prediction models were developed for NO2, PM10 and O-3 on an EU-wide scale. Our study illustrates that it is possible to develop detailed maps of background air pollution using EU-wide databases. (C) 2008 Elsevier B.V. All rights reserved.

# Bekö, G., et al. (2007). "Further studies of oxidation processes on filter surfaces: Evidence for oxidation products and the influence of time in service." Atmospheric Environment 41(25): 5202-5212.

The sensory pollutants emitted by loaded ventilation filters are assumed to include products formed via oxidation of organics associated with captured particles. In this study, experiments were performed that used either particle production or ozone removal as probes to further improve our understanding of such processes. The measured ratio of downstream to upstream submicron particle concentrations increased when ozone was added to air passing through samples from loaded particle filters. Such an observation is consistent with low volatility oxidation products desorbing from the filter and subsequently partitioning between the gas phase and the surface of particles that have passed through the filter, including particles that were previously too small (&lt; 20 nm) to be detected by the instrument used in these studies. A related set of experiments conducted with unused filters and filters that had been in service from 2 to 16 weeks found that ozone removal efficiencies changed in a manner that indicated at least two different removal mechanisms-reactions with compounds present on the filter media following manufacturing and reactions with compounds associated with captured particles. The contribution from the former varies with the type and manufacturer of the filter, while that of the latter varies with the duration of service and nature of the captured particles. In complimentary experiments, a filter sample protected from ozone during its 9 weeks of service had higher ozone removal efficiencies than an identical filter not protected from ozone during the same 9 weeks of service filtering the same air. This result indicates that a filter's exposure history subsequently influences the quantity of oxidation products generated when ozone-containing air flows through it. (c) 2007 Elsevier Ltd. All rights reserved.

# Bell, M. L. (2006). "The use of ambient air quality modeling to estimate individual and population exposure for human health research: A case study of ozone in the Northern Georgia region of the United States." Environment International 32(5): 586-593.

Ambient monitors are commonly used to estimate exposure for epidemiological studies, and air quality modeling is infrequently applied. However air quality modeling systems have the potential to alleviate some, although not all, of the limitations of monitoring networks. To investigate this application, exposure estimates were generated for a case study high ozone episode in the Northern Georgia Region of the United States based on measurements and concentration estimates from an air quality modeling system. Hourly estimates for 2268 4-km by 4-km gridcells were generated in a domain that includes only eight ozone monitors. Individual and population-based ozone exposures were estimated using multiple approaches, including area-weighted average of modeled estimates, nearest monitor, and spatial interpolation by inverse distance weighting and kriging. Results based on concentration fields from the air quality modeling system revealed spatial heterogeneity that was obscured by approaches based on the monitoring network. With some techniques, such as spatial interpolation, monitoring data alone was insufficient to estimate exposure for certain areas, especially for rural populations. For locations far from ozone monitors, the estimates from the nearest monitor approach tended to overestimate exposure, compared to modeled estimates. Counties in which one or more monitors were present had statistically higher population density and modeled ozone estimates than did counties without monitors (p-value < 0.05). This work demonstrates the use of air quality modeling to generate higher spatial and temporal resolution exposure estimates, and compares the advantages of this approach to traditional methods that use monitoring data alone. The air quality modeling method faces its own limitations, such as the need to thoroughly evaluate concentration estimates and the use of ambient levels rather than personal exposure. (c) 2006 Elsevier Ltd. All rights reserved.

# Bell, M. L., et al. (2004). "Ozone and short-term mortality in 95 US urban communities, 1987-2000." JAMA: Journal of the American Medical Association 292(19): 2372-2378.

CONTEXT: Ozone has been associated with various adverse health effects, including increased rates of hospital admissions and exacerbation of respiratory illnesses. Although numerous time-series studies have estimated associations between day-to-day variation in ozone levels and mortality counts, results have been inconclusive. OBJECTIVE: To investigate whether short-term (daily and weekly) exposure to ambient ozone is associated with mortality in the United States. DESIGN and SETTING: Using analytical methods and databases developed for the National Morbidity, Mortality, and Air Pollution Study, we estimated a national average relative rate of mortality associated with short-term exposure to ambient ozone for 95 large US urban communities from 1987-2000. We used distributed-lag models for estimating community-specific relative rates of mortality adjusted for time-varying confounders (particulate matter, weather, seasonality, and long-term trends) and hierarchical models for combining relative rates across communities to estimate a national average relative rate, taking into account spatial heterogeneity. MAIN OUTCOME MEASURE: Daily counts of total non-injury-related mortality and cardiovascular and respiratory mortality in 95 large US communities during a 14-year period. RESULTS: A 10-ppb increase in the previous week’s ozone was associated with a 0.52% increase in daily mortality (95% posterior interval [PI], 0.27%-0.77%) and a 0.64% increase in cardiovascular and respiratory mortality (95% PI, 0.31%-0.98%). Effect estimates for aggregate ozone during the previous week were larger than for models considering only a single day’s exposure. Results were robust to adjustment for particulate matter, weather, seasonality, and long-term trends. CONCLUSIONS: These results indicate a statistically significant association between short-term changes in ozone and mortality on average for 95 large US urban communities, which include about 40% of the total US population. The findings indicate that this widespread pollutant adversely affects public health.

# Bergen, S., et al. (2013). "A national prediction model for PM2.5 component exposures and measurement error-corrected health effect inference." Environmental Health Perspectives 121(9): 1017-1025.

BACKGROUND: Studies estimating health effects of long-term air pollution exposure often use a two-stage approach, building exposure models to assign individual-level exposures which are then used in regression analyses. This requires accurate exposure modeling and careful treatment of exposure measurement error. OBJECTIVES: To illustrate the importance of accounting for exposure model characteristics in two-stage air pollution studies, we considered a case study based on data from the Multi-Ethnic Study of Atherosclerosis (MESA). METHODS: We built national spatial exposure models that used partial least squares and universal kriging to estimate annual average concentrations of four PM2.5 components: elemental carbon (EC), organic carbon (OC), sulfur (S), and silicon (Si). We predicted PM2.5 component exposures for the MESA cohort and estimated cross-sectional associations with carotid intima-media thickness (CIMT), adjusting for subject-specific covariates. We corrected for measurement error using recently developed methods that account for the spatial structure of predicted exposures. RESULTS: Our models performed well, with cross-validated R(2)s ranging from 0.62 to 0.95. Naïve analyses that did not account for measurement error indicated statistically significant associations between CIMT and exposure to OC, S, and Si. EC and OC exhibited little spatial correlation, and the corrected inference was unchanged from the naïve analysis. The S and Si exposure surfaces displayed notable spatial correlation, resulting in corrected confidence intervals (CIs) that were 50% wider than the naïve CIs, but that were still statistically significant. CONCLUSION: The impact of correcting for measurement error on health effect inference is concordant with the degree of spatial correlation in the exposure surfaces. Exposure model characteristics must be considered when performing two-stage air pollution epidemiology analyses, as naïve health effect inference may be inappropriate.

# Bergen, S. and A. A. Szpiro (2015). "Mitigating the impact of measurement error when using penalized regression to model exposure in two-stage air pollution epidemiology studies." Environmental and Ecological Statistics 22(3): 601-631.

Air pollution epidemiology studies often implement a two-stage approach. Exposure models are built using observed monitoring data to predict exposure at participant locations where the true exposure is unobserved, and the predictions used to estimate the health effect. This induces measurement error which may bias the estimated health effect and affect its standard error. The impact of measurement error depends on assumed data generating mechanisms and the approach used to estimate and predict exposure. A paradigm wherein the exposure surface is fixed and the subject and monitoring locations are random has been previously motivated, but corresponding measurement error methods exist only when modeling exposure with simple, low-rank, unpenalized regression splines. We develop a comprehensive treatment of measurement error when modeling exposure with high-but-fixed-rank penalized regression splines. If sufficiently rich, these models well-approximate full-rank methods such as universal kriging while remaining asymptotically tractable. We describe the implications of penalization for measurement error, motivate choosing the penalty to optimize health effect inference, derive an asymptotic bias correction, and provide a simple non-parametric bootstrap to account for all sources of variability. We find that highly parameterizing the exposure model results in severely biased and inefficient health effect inference if no penalty is used. Choosing the penalty to mitigate measurement error yields much less bias and better efficiency, and can lead to better confidence interval coverage than other common penalty selection methods. Combining the bias correction with the non-parametric bootstrap yields accurate coverage of nominal 95 % confidence intervals.

# Bhaskaran, K., et al. (2011). "The effects of hourly differences in air pollution on the risk of myocardial infarction: case crossover analysis of the MINAP database." B M J 343: d5531.

Objectives To investigate associations between air pollution levels and myocardial infarction (MI) on short timescales, with data at an hourly temporal resolution. Design Time stratified case crossover study linking clinical data from the Myocardial Ischaemia National Audit Project (MINAP) with PM(10), ozone, CO, NO(2), and SO(2) data from the UK National Air Quality Archive. Pollution effects were investigated with delays (lags) of 1-6, 7-12, 13-18, 19-24, and 25-72 hours in both single and multi-pollutant models, adjusted for ambient temperature, relative humidity, circulating levels of influenza and respiratory syncytial virus, day of week, holidays, and residual seasonality within calendar month strata. Setting Population based study in 15 conurbations in England and Wales. Subjects 79 288 diagnoses of myocardial infarction recorded over the period 2003-6. Main outcome measures Excess risk of myocardial infarction per 10 mu g/m(3) increase in pollutant level. Results In single pollutant models, PM(10) and NO(2) levels were associated with a very short term increase in risk of myocardial infarction 1-6 hours later (excess risks 1.2% (95% confidence interval 0.3 to 2.1) and 1.1% (0.3 to 1.8) respectively per 10 mu g/m(3) increase); the effects persisted in multi-pollutant models, though with only weak evidence of an independent PM(10) effect (P=0.05). The immediate risk increases were followed by reductions in risk at longer lags: we found no evidence of any net excess risk associated with the five pollutants studied over a 72 hour period after exposure. Conclusions Higher levels of PM(10) and NO(2), which are typically markers of traffic related pollution, seem to be associated with transiently increased risk of myocardial infarction 1-6 hours after exposure, but later reductions in risk suggest that air pollution may be associated with bringing events forward in time ("short-term displacement") rather than increasing overall risk. The well established effect of air pollution on cardiorespiratory mortality may not be mediated through increasing the acute risk of myocardial infarction, but through another mechanism.

# Blondeau, P., et al. (2005). "Relationship between outdoor and indoor air quality in eight French schools." Indoor Air 15(1): 2-12.

In the frame of the French national research program PRIMEQUAL (inter-ministry program for better air quality in urban environments), measurements of outdoor and indoor pollution have been carried out in eight schools in La Rochelle (France) and its suburbs. The buildings were naturally ventilated by opening the windows, or mechanically ventilated, and showed various air permeabilities. Ozone, nitrogen oxides (NO and NO2), and airborne particle (particle counts within 15 size intervals ranging from 0.3 to 15 m) concentrations were continuously monitored indoors and outdoors for two 2-week periods. The indoor humidity, temperature, CO2 concentration (an indicator of occupancy), window openings and building permeability were also measured. The temporal profiles of indoor and outdoor concentrations show ozone and nitrogen oxides behave differently: NO and NO2 indoor/outdoor concentration ratios (I/O) were found to vary in a range from 0.5 to 1, and from 0.88 to 1, respectively, but no correlation with building permeability was observed. On the contrary, I/O ratios of ozone vary in a range from 0 to 0.45 and seem to be strongly influenced by the building air-tightness: the more airtight the building envelope, the lower the ratio. Occupancy, through re-suspension of previously deposited particles and possible particle generation, strongly influences the indoor concentration level of airborne particles. However, this influence decreases with particle size, reflecting the way deposition velocities vary as a function of size. The influence of particle size on deposition and penetration across the building envelope is also discussed by analyzing the I/O ratios measured when the buildings were unoccupied, by comparing the indoor concentrations measured when the buildings were occupied and when they were not (O/U ratios), and by referring to previously published studies focussing on this topic. Except one case, I/O were found to vary in the range from 0.03 to 1.79. All O/U are greater than one and increase up to 100 with particle size. PRACTICAL IMPLICATIONS: Assessing children's total exposure requires the knowledge of outdoor and indoor air contaminant concentrations. The study presented here provides data on compared outdoor and indoor concentration levels in school buildings, as well as information on the parameters influencing the relationship between outdoor and indoor air quality. It may be used as a basis for estimating indoor concentrations from outdoor concentrations data, or as a first step in designing buildings sheltering children against atmospheric pollution.

# Brauer, M. and J. R. Brook (1997). "Ozone personal exposures and health effects for selected groups residing in the Fraser Valley." Atmospheric Environment 31(14): 2113-2121.

Due to concern regarding poor ambient air quality in the Fraser Valley, a series of exposure and health effects assessments were performed to evaluate the impact of summer photochemical air pollution. In 1992 and 1993, three groups of individuals were selected for personal monitoring of ozone exposure, based on prior expectations of their activity patterns. The first group spent a majority of the work day indoors or commuting, the second group spent more time outdoors and the third group spent the entire personal monitoring period outdoors. Time-activity data were collected for the first two groups and differences in personal ozone exposures were found to be associated with the fraction of time a person spent outdoors. Similarly, differences among groups in the mean ozone exposure were associated with time spent outdoors. These results and other exposure information were used to design a study of the health impacts of summer ambient air pollution that was conducted during the time period of the Pacific'93 field campaign. Aerosol acidity levels in the Fraser Valley were observed to be very low in 1992 so the health study focused on the effects of ozone exposure. The subjects were adult farm workers (26 male, 32 female; mean age 44.4, range 10-69) who spent the entire working day outdoors (a subset of group 3 above). Lung function measurements were made twice daily on each subject, once before and once after their work shift, from 23 June-26 August 1993. Ambient O3 concentrations were measured continuously at several nearby locations. In a regression model including individual lung function level, date, temperature and daily maximum O3, a statistically significant (p < 0.001) negative association was observed between ozone and lung function. This association between ozone and reduced lung function was still apparent the following day, suggesting a persistent ozone effect. These results indicate that exposure to ambient O3 concentrations below either the U.S. NAAQS (120 ppb) or the Canadian Air Quality Objective (82 ppb) may have an adverse effect on the lung function of people engaged in outdoor work for several hours a day.

# Brauer, M., et al. (1991). "Indoor and outdoor concentrations of inorganic acidic aerosols and gases." Journal of the Air and Waste Management Association 41(2): 171-181.

Annular denuder-filter pack sampling systems were used to make indoor and outdoor measurements of aerosol strong H+, SO4(2)-, NH4+, NO3- and NO2-, and the gaseous pollutants SO2, HNO3, HONO and NH3 during summer and winter periods in Boston, Massachusetts. Outdoor levels of SO2, HNO3, H+ and SO4(2-) exceeded their indoor concentrations during both seasons. Winter indoor/outdoor ratios were lower than during the summer, probably due to lower air exchange rates during the winter period. During both monitoring periods, indoor/outdoor ratios of aerosol strong H+ were 40-50 percent of the indoor/outdoor SO4(2-) ratio. Since aerosol strong acidity is typically associated with SO4(2-), this finding is indicative of neutralization of the acidic aerosol by the higher indoor NH3 levels. Geometric mean indoor/outdoor NH3 ratios of 3.5 and 23 respectively were measured for the summer and winter sampling periods. For HONO, NH3, NH4+ and NO2-, indoor concentrations were significantly higher than ambient levels. Indoor levels of NO3- were slightly less than outdoor concentrations.

# Brauer, M., et al. (1989). "Personal exposures to acidic aerosols and gases." Environmental Science and Technology 23(11): 1408-1412.

Exposures to aerosol strong H+, SO:-, NH4+, NO3-,NO;, and the gaseous pollutants SOz, HN03, HN02, and NH3 were monitored in the metropolitan Boston area with a personal annular denuder/filter pack sampling system. The personal exposure measurements were compared to measurements collected at a centrally located ambient monitoring site. Concentrations of acidic aerosols and gases measured by personal monitoring were found to differ significantly from those measured at the fixed outdoor location. Personal exposures to aerosol strong H+ were slightly lower than concentrations measured at the stationary site due to the neutralization of acidic particles and their incomplete penetration into indoor environments. Concentrations of SO:- and NH4+ measured by personal monitoring were similar to those measured by the fixed location ambient monitor. Personal measurements of SOz and HN03 were much lower than those measured outdoors, reflecting deposition of these gases on indoor surfaces. The formation of HN02 via reactions of nitrogen oxides on indoor surfaces resulted in personal exposures to HN02 that were substantially higher than outdoor concentrations. Personal exposures to the basic gas, NH3, were also higher than ambient measurements. To our knowledge, this pilot study represents the first use of annular denuders for personal exposure monitoring and promises to open up a new area of personal exposure sampling techniques. The results of this study support the use of personal monitoring to determine human exposures. By applying the personal monitoring techniques used in this study to representative samples, it will be possible to determine population exposures to acidic aerosols and gases.

# Brauer, M., et al. (2008). "A cohort study of traffic-related air pollution impacts on birth outcomes." Environmental Health Perspectives 116(5): 680-686.

Evidence suggests that air pollution exposure adversely affects pregnancy outcomes. Few studies have examined individual-level intraurban exposure contrasts.

We evaluated the impacts of air pollution on small for gestational age (SGA) birth weight, low full-term birth weight (LBW), and preterm birth using spatiotemporal exposure metrics.

With linked administrative data, we identified 70,249 singleton births (1999-2002) with complete covariate data (sex, ethnicity, parity, birth month and year, income, education) and maternal residential history in Vancouver, British Columbia, Canada. We estimated residential exposures by month of pregnancy using nearest and inverse-distance weighting (IDW) of study area monitors [carbon monoxide, nitrogen dioxide, nitric oxide, ozone, sulfur dioxide, and particulate matter < 2.5 (PM2.5) or < 10 (PM10) microm in aerodynamic diameter], temporally adjusted land use regression (LUR) models (NO, NO2, PM2.5, black carbon), and proximity to major roads. Using logistic regression, we estimated the risk of mean (entire pregnancy, first and last month of pregnancy, first and last 3 months) air pollution concentrations on SGA (< 10th percentile), term LBW (< 2,500 g), and preterm birth.

Residence within 50 m of highways was associated with a 22% (95% CI, 0.81-1.87) [corrected] increase in LBW. Exposure to all air pollutants except O3 was associated with SGA, with similar odds ratios (ORs) for LUR and monitoring estimates (e.g., LUR: OR = 1.02; 95% CI, 1.00-1.04; IDW: OR = 1.05; 95% CI, 1.03-1.08 per 10-microg/m3 increase in NO). For preterm births, associations were observed with PM2.5 for births < 37 weeks gestation (and for other pollutants at < 30 weeks). No consistent patterns suggested exposure windows of greater relevance.

Associations between traffic-related air pollution and birth outcomes were observed in a population-based cohort with relatively low ambient air pollution exposure.

# Brauer, M., et al. (1990). "Measurements of nitrous acid inside two research houses." Environmental Science and Technology 24(10): 1521-1527.

Continuous analyzers for NO, NO2, and HONO were used to study the production and decay of these gases in two indoor air quality research houses, using unvented gas space heaters and ranges as combustion sources. In agreement with previous studies, indoor HONO concentrations were elevated during unvented combustion. Peak (15-min) level up to 100 ppb HONO and 24-h averages as high as 40 ppb were measured. The observed kinetics suggest the secondary formation of HONO, possibly as a result of heterogenous reactions involving NO2, in addition to primary production of HONO during combustion.

# Bresnahan, B. W., et al. (1997). "Averting behavior and urban air pollution." Land Economics 73(3): 34-57.

Unique panel data are used to explain defensive responses to air pollution using determinants predicted by an averting behavior model. Empirical results indicate that persons who experience smog-related symptoms spend significantly less time outdoors as ozone concentrations exceed the national standard. Many people also report making other behavioral changes to avoid smoggy conditions and the propensity to do so appears to increase with schooling or if health symptoms are experienced. Results provide evidence that people adjust daily activities to defend against acute health effects of air pollution, though mitigation appears less closely linked to chronic health impairments.

# Brown, K. W., et al. (2009). "Factors influencing relationships between personal and ambient concentrations of gaseous and particulate pollutants." Science of the Total Environment 407(12): 3754-3765.

Previous exposure studies have shown considerable inter-subject variability in personal-ambient associations. This paper investigates exposure factors that may be responsible for inter-subject variability in these personal-ambient associations. The personal and ambient data used in this paper were collected as part of a personal exposure study conducted in Boston, MA, during 1999–2000. This study was one of a group of personal exposure panel studies funded by the U.S. Environmental Protection Agency's National Exposure Research Laboratory to address areas of exposure assessment warranting further study, particularly associations between personal exposures and ambient concentrations of particulate matter and gaseous co-pollutants. Twenty-four-hour integrated personal, home indoor, home outdoor and ambient sulfate, elemental carbon (EC), PM2.5, ozone (O3), nitrogen dioxide (NO2) and sulfur dioxide were measured simultaneously each day. Fifteen homes in the Boston area were measured for 7 days during winter and summer. A previous paper explored the associations between personal-indoor, personal-outdoor, personal-ambient, indoor-outdoor, indoor-ambient and outdoor-ambient PM2.5, sulfate and EC concentrations. For the current paper, factors that may affect personal exposures were investigated, while controlling for ambient concentrations. The data were analyzed using mixed effects regression models. Overall personal-ambient associations were strong for sulfate during winter (p < 0.0001) and summer (p < 0.0001) and PM2.5 during summer (p < 0.0001). The personal-ambient mixed model slope for PM2.5 during winter but was not significant at p = 0.10. Personal exposures to most pollutants, with the exception of NO2, increased with ventilation and time spent outdoors. An opposite pattern was found for NO2 likely due to gas stoves. Personal exposures to PM2.5 and to traffic-related pollutants, EC and NO2, were higher for those individuals living close to a major road. Both personal and indoor sulfate and PM2.5 concentrations were higher for homes using humidifiers. The impact of outdoor sources on personal and indoor concentrations increased with ventilation, whereas an opposite effect was observed for the impact of indoor sources.

# Brown, K. W., et al. (2009). "Factors influencing relationships between personal and ambient concentrations of gaseous and particulate pollutants." Science of the Total Environment 407(12): 3754-3765.

Previous exposure studies have shown considerable inter-subject variability in personal-ambient associations. This paper investigates exposure factors that may be responsible for inter-subject variability in these personal-ambient associations. The personal and ambient data used in this paper were collected as part of a personal exposure study conducted in Boston, MA, during 1999–2000. This study was one of a group of personal exposure panel studies funded by the U.S. Environmental Protection Agency's National Exposure Research Laboratory to address areas of exposure assessment warranting further study, particularly associations between personal exposures and ambient concentrations of particulate matter and gaseous co-pollutants. Twenty-four-hour integrated personal, home indoor, home outdoor and ambient sulfate, elemental carbon (EC), PM2.5, ozone (O3), nitrogen dioxide (NO2) and sulfur dioxide were measured simultaneously each day. Fifteen homes in the Boston area were measured for 7 days during winter and summer. A previous paper explored the associations between personal-indoor, personal-outdoor, personal-ambient, indoor-outdoor, indoor-ambient and outdoor-ambient PM2.5, sulfate and EC concentrations. For the current paper, factors that may affect personal exposures were investigated, while controlling for ambient concentrations. The data were analyzed using mixed effects regression models. Overall personal-ambient associations were strong for sulfate during winter (p < 0.0001) and summer (p < 0.0001) and PM2.5 during summer (p < 0.0001). The personal-ambient mixed model slope for PM2.5 during winter but was not significant at p = 0.10. Personal exposures to most pollutants, with the exception of NO2, increased with ventilation and time spent outdoors. An opposite pattern was found for NO2 likely due to gas stoves. Personal exposures to PM2.5 and to traffic-related pollutants, EC and NO2, were higher for those individuals living close to a major road. Both personal and indoor sulfate and PM2.5 concentrations were higher for homes using humidifiers. The impact of outdoor sources on personal and indoor concentrations increased with ventilation, whereas an opposite effect was observed for the impact of indoor sources.

# Bruinen de Bruin, Y., et al. (2004). "Personal carbon monoxide exposure levels: Contribution of local sources to exposures and microenvironment concentrations in Milan." Journal of Exposure Analysis and Environmental Epidemiology 14(4): 312-322.

In the framework of the EXPOLIS study in Milan, Italy, 48-h carbon monoxide (CO) exposures of 50 office workers were monitored over a 1-year period. In this work, the exposures were assessed for different averaging times and were compared with simultaneous ambient fixed-site concentrations. The effect of gas cooking and smoking and different methods of commuting on the microenvironment and exposure levels of CO were investigated. During the sampling the subjects completed a time-microenvironment-activity diary differentiating 11 microenvironments and three exposure influencing activities: gas cooking, smoking and commuting. After sampling, all exposure and time allocation data were stored in a relational database that is used in data analyses. Ambient 48-h and maximum 8-h distributions were similar compared to the respective personal exposures. The maximum 1-h personal exposures were much higher than the maximum 8-h exposures. The maximum 1-h exposures were as well higher than the corresponding ambient distribution. These findings indicate that high short-term exposures were not reflected in ambient monitoring data nor by long-term exposures. When gas cooking or smoking was present, the indoor levels at home and in other indoor microenvironments were higher than without their presence. Compared with ambient data, the latter source was the most affective to increase the indoor levels. Exposure during commuting was higher than in all other microenvironments; the highest daily exposure contribution was found during car/taxi driving. Most of the CO exposure is acquired in indoor microenvironments. For the indoor microenvironments, ambient CO was the weakest predictor for home indoor concentrations, where the subjects spent most of their time, and the strongest for other indoor concentrations, where the smallest fraction of the time was spent. Of the main indoor sources, gas cooking, on average, significantly raised the indoor exposure concentrations for 45 min and tobacco smoking for 30min. The highest exposure levels were experienced in street commuting. Personal exposures were well predicted, but 1-h maximum personal exposures were poorly predicted, by respective ambient air quality data. By the use of time-activity diaries, ETS exposure at the workplaces were probably misclassified due to differences in awareness to tobacco smoke between smokers and nonsmokers.

# Bruinen de Bruin, Y., et al. (2004). "Simulation of working population exposures to carbon monoxide using EXPOLIS-Milan microenvironment concentration and time-activity data." Journal of Exposure Analysis and Environmental Epidemiology 14: 154-163.

Current air pollution levels have been shown to affect human health. Probabilistic modeling can be used to assess exposure distributions in selected target populations. Modeling can and should be used to compare exposures in alternative future scenarios to guide society development. Such models, however, must first be validated using existing data for a past situation. This study applied probabilistic modeling to carbon monoxide (CO) exposures using EXPOLIS-Milan data. In the current work, the model performance was evaluated by comparing modeled exposure distributions to observed ones. Model performance was studied in detail in two dimensions; (i) for different averaging times (1, 8 and 24 h) and (ii) using different detail in defining the microenvironments in the model (two, five and 11 microenvironments). (iii) The number of exposure events leading to 8-h guideline exceedance was estimated. Population time activity was modeled using a fractions-of-time approach assuming that some time is spent in each microenvironment used in the model. This approach is best suited for averaging times from 24 h upwards. In this study, we tested how this approach affects results when used for shorter averaging times, 1 and 8 h. Models for each averaging time were run with two, five and 11 microenvironments. The two-microenvironment models underestimated the means and standard deviations (SDs) slightly for all averaging times. The five- and 11-microenvironment models matched the means quite well but underestimated SDs in several cases. For 1- and 24-h averaging times the simulated SDs are slightly smaller than the corresponding observed values. The 8-h model matched the observed exposure levels best. The results show that for CO (i) the modeling approach can be applied for averaging times from 8 to 24 h and as a screening model even to an averaging time of 1 h; (ii) the number of microenvironments affects only weakly the results and in the studied cases only exposure levels below the 80th percentile; (iii) this kind of model can be used to estimate the number of high-exposure events related to adverse health effects. By extrapolation beyond the observed data, it was shown that Milanese office workers may experience adverse health effects caused by CO.

# Burnett, R. T., et al. (2000). "Association between particulate- and gas-phase components of urban air pollution and daily mortality in eight Canadian cities." Inhalation Toxicology 12(Suppl. 4): 15-39.

Although some consensus has emerged among the scientific and regulatory communities that the urban ambient atmospheric mix of combustion related pollutants is a determinant of population health, the relative toxicity of the chemical and physical components of this complex mixture remains unclear. Daily mortality rates and concurrent data on size-fractionated particulate mass and gaseous pollutants were obtained in eight of Canada’s largest cities from 1986 to 1996 inclusive in order to examine the relative toxicity of the components of the mixture of ambient air pollutants to which Canadians are exposed. Positive and statistically significant associations were observed between daily variations in both gas- and particulate-phase pollution and daily fluctuations in mortality rates. The association between air pollution and mortality could not be explained by temporal variation in either mortality rates or weather factors. Fine particulate mass (less than 2.5 "mu"m in average aerometric diameter) was a stronger predictor of mortality than coarse mass (between 2.5 and 10 "mu"m). Size-fractionated particulate mass explained 28% of the total health effect of the mixture, with the remaining effects accounted for by the gases. Forty-seven elemental concentrations were obtained for the fine and coarse fraction using nondestructive x-ray fluorescence techniques. Sulfate concentrations were obtained by ion chromatography. Sulfate ion, iron, nickel, and zinc from the fine fraction were most strongly associated with mortality. The total effect of these four component was greater than that for fine mass alone, suggesting that the characteristics of the complex chemical mixture in the fine fraction may be a better predictor of mortality than mass alone. However, the variation in the effects of the constituent of the fine fraction between cities was greater than the variation in the mass effect, implying that there are additional toxic components of fine particulate matter not examined in this study whose concentrations and effect vary between locations. One of these component, carbon, represent half the mass of fine particulate matter. We recommend that measurements of elemental and organic carbon be undertaken in Canadian urban environment to examine their potential effect on human health.

# Burnett, R. T., et al. (1997). "The role of particulate size and chemistry in the association between summertime ambient air pollution and hospitalization for cardiorespiratory diseases." Environmental Health Perspectives 105(6): 614-620.

In order to address the role that the ambient air pollution mix, comprised of gaseous pollutants and various physical and chemical measures of particulate matter, plays in exacerbating cardiorespiratory disease, daily measures of fine and coarse particulate mass, aerosol chemistry (sulfates and acidity), and gaseous pollution (ozone, nitrogen dioxide, sulfur dioxide, and carbon monoxide) were collected in Toronto, Ontario, Canada, in the summers of 1992, 1993, and 1994. These time series were then compared with concurrent data on the number of daily admissions to hospitals for either cardiac diseases (ischemic heart disease, heart failure, and dysrhythmias) or respiratory diseases (tracheobronchitis, chronic obstructive lung disease, asthma, and pneumonia). After adjusting the admission time series for long-term temporal trends, seasonal variations, the effects of short-term epidemics, day of the week effects, and ambient temperature and dew point temperature, positive associations were observed for all ambient air pollutants for both respiratory and cardiac diseases. Ozone was least sensitive to adjustment for the gaseous and particulate pollution measures. However, the association between the health outcomes and carbon monoxide, fine and coarse mass, sulfate levels and aerosol acidity could be explained by adjustment for exposure to gaseous pollutants. Increases in ozone, nitrogen dioxide, and sulfur dioxide equivalent to their interquartile ranges corresponded to an 11% and 13% increase in daily hospitalizations for respiratory and cardiac diseases, respectively. The inclusion of any one of the particulate air pollutants in multiple regression models did not increase these percentages. Particle mass and chemistry could not be identified as an independent risk factor for the exacerbation of cardiorespiratory diseases in this study beyond that attributable to climate and gaseous air pollution. We recommend that effects of particulate matter on health be assessed in conjunction with temporally covarying gaseous air pollutants.

# Butland, B. K., et al. (2013). "Measurement error in time-series analysis: a simulation study comparing modelled and monitored data." BMC Medical Research Methodology 13: 136.

BACKGROUND: Assessing health effects from background exposure to air pollution is often hampered by the sparseness of pollution monitoring networks. However, regional atmospheric chemistry-transport models (CTMs) can provide pollution data with national coverage at fine geographical and temporal resolution. We used statistical simulation to compare the impact on epidemiological time-series analysis of additive measurement error in sparse monitor data as opposed to geographically and temporally complete model data.

METHODS: Statistical simulations were based on a theoretical area of 4 regions each consisting of twenty-five 5 km × 5 km grid-squares. In the context of a 3-year Poisson regression time-series analysis of the association between mortality and a single pollutant, we compared the error impact of using daily grid-specific model data as opposed to daily regional average monitor data. We investigated how this comparison was affected if we changed the number of grids per region containing a monitor. To inform simulations, estimates (e.g. of pollutant means) were obtained from observed monitor data for 2003-2006 for national network sites across the UK and corresponding model data that were generated by the EMEP-WRF CTM. Average within-site correlations between observed monitor and model data were 0.73 and 0.76 for rural and urban daily maximum 8-hour ozone respectively, and 0.67 and 0.61 for rural and urban loge(daily 1-hour maximum NO2).

RESULTS: When regional averages were based on 5 or 10 monitors per region, health effect estimates exhibited little bias. However, with only 1 monitor per region, the regression coefficient in our time-series analysis was attenuated by an estimated 6% for urban background ozone, 13% for rural ozone, 29% for urban background loge(NO2) and 38% for rural loge(NO2). For grid-specific model data the corresponding figures were 19%, 22%, 54% and 44% respectively, i.e. similar for rural loge(NO2) but more marked for urban loge(NO2).

CONCLUSION: Even if correlations between model and monitor data appear reasonably strong, additive classical measurement error in model data may lead to appreciable bias in health effect estimates. As process-based air pollution models become more widely used in epidemiological time-series analysis, assessments of error impact that include statistical simulation may be useful.

# Carey, I. M., et al. (2013). "Mortality associations with long-term exposure to outdoor air pollution in a national English cohort." American Journal of Respiratory and Critical Care Medicine 187(11): 1226-1233.

Rationale: Cohort evidence linking long-term exposure to outdoor particulate air pollution and mortality has come largely from the United States. There is relatively little evidence from nationally representative cohorts in other countries. Objectives: To investigate the relationship between long-term exposure to a range of pollutants and causes of death in a national English cohort. Methods: A total of 835,607 patients aged 40-89 years registered with 205 general practices were followed from 2003-2007. Annual average concentrations in 2002 for particulate matter with a median aerodynamic diameter less than 10 (PM10) and less than 2.5 μm (PM2.5), nitrogen dioxide (NO2), ozone, and sulfur dioxide (SO2) at 1 km(2) resolution, estimated from emission-based models, were linked to residential postcode. Deaths (n = 83,103) were ascertained from linkage to death certificates, and hazard ratios (HRs) for all- and cause-specific mortality for pollutants were estimated for interquartile pollutant changes from Cox models adjusting for age, sex, smoking, body mass index, and area-level socioeconomic status markers. Measurements and Main Results: Residential concentrations of all pollutants except ozone were positively associated with all-cause mortality (HR, 1.02, 1.03, and 1.04 for PM2.5, NO2, and SO2, respectively). Associations for PM2.5, NO2, and SO2 were larger for respiratory deaths (HR, 1.09 each) and lung cancer (HR, 1.02, 1.06, and 1.05) but nearer unity for cardiovascular deaths (1.00, 1.00, and 1.04). Conclusions: These results strengthen the evidence linking long-term ambient air pollution exposure to increased all-cause mortality. However, the stronger associations with respiratory mortality are not consistent with most US studies in which associations with cardiovascular causes of death tend to predominate.

# Cendon, S., et al. (2006). "Air pollution effects on myocardial infarction." Revista de Saude Publica 40(3): 414-419.

OBJECTIVE: Myocardial infarction is an acute and severe cardiovascular disease that generally leads to patient admissions to intensive care units and few cases are initially admitted to infirmaries. The objective of the study was to assess whether estimates of air pollution effects on myocardial infarction morbidity are modified by the source of health information.

METHODS: The study was carried out in hospitals of the Brazilian Health System in the city of São Paulo, Southern Brazil. A time series study (1998-1999) was performed using two outcomes: infarction admissions to infirmaries and to intensive care units, both for people older than 64 years of age. Generalized linear models controlling for seasonality (long and short-term trends) and weather were used. The eight-day cumulative effects of air pollutants were assessed using third degree polynomial distributed lag models.

RESULTS: Almost 70% of daily hospital admissions due to myocardial infarction were to infirmaries. Despite that, the effects of air pollutants on infarction were higher for intensive care units admissions. All pollutants were positively associated with the study outcomes but SO2 presented the strongest statistically significant association. An interquartile range increase on SO2 concentration was associated with increases of 13% (95% CI: 6-19) and 8% (95% CI: 2-13) of intensive care units and infirmary infarction admissions, respectively.

CONCLUSIONS: It may be assumed there is a misclassification of myocardial infarction admissions to infirmaries leading to overestimation. Also, despite the absolute number of events, admissions to intensive care units data provides a more adequate estimate of the magnitude of air pollution effects on infarction admissions.

# Chang, L. T., et al. (2000). "Hourly personal exposures to fine particles and gaseous pollutants--Results from Baltimore, Maryland." Journal of the Air and Waste Management Association 50(7): 1223-1235.

Electric Power Research Institute; American Petroleum Institute. A study to characterize 1-hr multi-pollutant exposures was performed in Baltimore, MD, during the summer of 1998 and the winter of 1999, and was conducted over a 15-day period in each of the two seasons. Personal exposures were measured by a trained field technician, who wore a newly developed Roll-Around System (RAS) to measure 1-hr PM2.5 and gaseous (CO, O3, NO2, SO2, volatile organic compounds [VOCs]) exposures. One-hour O3, NO2, and SO2 personal exposures were measured using samplers developed in our laboratory, while short-term PM2.5, CO, and VOCs exposures were measured using currently available monitors. All 1-hr multi-pollutant exposures were measured while the technician performed pre-determined activities, beginning at 7:00 a.m. and ending at 7:00 p.m. of the same day. Activities were scripted to simulate activities performed by older adults (65+ years of age). Corresponding 1-hr ambient pollutant concentrations were obtained from federal or state monitoring networks. In this paper, we discuss the results from our study and present our descriptive analysis of the 1-hr personal particulate and gaseous exposure data. Personal PM2.5, O3, CO, and VOCs exposures showed substantial variability over the 12-hr sampling periods. Multiple pairwise comparison tests showed that 1-hr personal O3 exposures were significantly lower in indoor microenvironments as compared with outdoor microenvironments. One-hour personal CO exposures measured in vehicles were significantly higher than those measured in other microenvironments. The associations between 1-hr personal exposures and corresponding ambient concentrations differed by pollutant and by microenvironment. For example, the correlation between personal PM2.5 exposures and ambient concentrations was lowest (r s = 0.36, p < 0.05) in the winter for in-door non-residential microenvironments, and was highest (r s = 0.90, p < 0.05) in the winter for in-vehicle microenvironments. For O3, the correlation between personal exposures and ambient levels was weakest in the winter for residential microenvironments (r s = 0.05, p > 0.05), and was strongest in the summer for outdoor near-roadway microenvironments (r s = 0.91, p < 0.05). Implications: Several recent studies have demonstrated associations between short-term ambient air pollutant concentrations and a variety of adverse respiratory and cardiovascular effects. Despite this, few studies have characterized short-term air pollutant exposures, and none of these studies have examined the relationship among short-term personal particulate and gaseous exposures. This paper describes a new personal "roll-around" monitor, which was used to measure 1-hr personal PM2.5, CO, O3, and VOCs exposures simultaneously. In addition, this paper characterizes the magnitude and variability in 1-hr personal particulate and gaseous exposures and examines associations between these exposures and corresponding ambient levels. Results from this study could help to interpret results from epidemiologic studies and to better assess the health impacts of complex mixtures of air pollutant exposures.

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# Chen, G., et al. (2008). "Short-term effects of ambient gaseous pollutants and particulate matter on daily mortality in Shanghai, China." Journal of Occupational Health 50(1): 41-47.

Identification of the specific pollutants contributing most to the health hazard of the air pollution mixture may have important implications for environmental and social policies. In the current study, we conducted a time-series analysis to examine the specific effects of major air pollutants [particulate matter less than 10 microns in diameter (PM(10)), sulfur dioxide (SO(2)), and nitrogen dioxides (NO(2))] on daily mortality in Shanghai, China, using both single-pollutant and multiple-pollutant models. In the single-pollutant models, PM(10), SO(2), and NO(2) were found to be associated with mortality from both all non-accidental causes and from cardiopulmonary diseases. Unlike some prior studies in North America, we found a significant effect of gaseous pollutants (SO(2) and NO(2)) on daily mortality even after adjustment for PM(10) in the multiple-pollutant models. Our findings, combined with previous Chinese studies showing a consistent, significant effect of gaseous pollutants on mortality, suggest that the role of outdoor exposure to SO(2) and NO(2) should be investigated further in China.

# Chen, L., et al. (2014). "The Air Quality Health Index as a predictor of emergency department visits for ischemic stroke in Edmonton, Canada." Journal of Exposure Science and Environmental Epidemiology 24(4): 358-364.

The Air Quality Health Index (AQHI) is an aggregate measure of outdoor air quality. We investigated associations between the AQHI and emergency department (ED) visits for acute ischemic stroke to validate the AQHI as a predictor of risk of morbidity from stroke. ED visits in Edmonton, Canada between 1998 and 2002 were linked to hourly AQHI values and concentrations of carbon monoxide (CO), nitrogen dioxide (NO2), ozone, particulate matter with aerodynamic diameter less than 2.5 and 10 μm, and sulfur dioxide. A time-stratified case-crossover analysis was employed, and measures of association were adjusted for temperature and relative humidity. The AQHI, NO2 and CO were positively associated with the number of ED visits for ischemic stroke during April-September, and associations were strongest for persons 75 years of age and older. In this age range, the odds ratios (95% confidence intervals) for an interquartile range increase of AQHI in 1-24 h, 25-48 h, and 1-72 h lag periods were 1.23 (1.08-1.40), 1.15 (1.01-1.31), and 1.30 (1.10-1.54), respectively. Significant positive associations were also observed for NO2 and CO. Our finding that ED visits for stroke were significantly associated with the AQHI suggests that the AQHI may be a valid communication tool for air pollution morbidity effects related to stroke. Journal of Exposure Science and Environmental Epidemiology advance online publication, 4 December 2013; doi:10.1038/jes.2013.82.

# Chen, R., et al. (2010). "Ambient air pollution and hospital admission in Shanghai, China." Journal of Hazardous Materials 181(1-3): 234-240.

No prior studies exist in Mainland China examining the association of outdoor air pollution with hospital admissions. In this study, we conducted a time-series analysis to examine the association of outdoor air pollutants (PM(10), SO(2), and NO(2)) with both total and cause-specific hospital admission in Shanghai, using three years of daily data (2005-2007). Hospital admission and air pollution data were collected from the Shanghai Health Insurance Bureau and Shanghai Environmental Monitoring Center. Natural spline model was used to analyze the data. We found outdoor air pollution was associated with increased risk of total and cardiovascular hospital admission in Shanghai. The effect estimates of air pollutants varied by lag (L) structures of pollutants' concentrations. For lag 5, a 10 microg/m(3) increase in concentration of PM(10), SO(2) and NO(2) corresponded to 0.18% (95% CI: -0.15%, 0.52%), 0.63% (95% CI: 0.03%, 1.23%), and 0.99% (95% CI: 0.10%, 1.88%) increase of total hospital admission; and 0.23% (95% CI: -0.03%, 0.48%), 0.65% (95% CI: 0.19%, 1.12%), and 0.80% (95% CI: 0.10%, 1.49%) increase of cardiovascular hospital admission. The associations appeared to be more evident in the cool season (from November to April) than in the warm season (from May to October). We found significant effects of gaseous pollutants (SO(2) and NO(2)) after adjustment for PM(10). Our analyses provide the first evidence in China that the current air pollution level has an effect on hospital admission and strengthen the rationale for further limiting air pollution levels in Shanghai.

# Cheng, M. F., et al. (2009). "Air pollution and hospital admissions for myocardial infarction in a tropical city: Kaohsiung, Taiwan." Journal of Toxicology and Environmental Health, Part A: Current Issues 72(19): 1135-1140.

This study was undertaken to determine whether there was an association between air pollutant levels and increased hospital admissions for myocardial infarction (MI) in Kaohsiung, Taiwan. Hospital admissions for MI and ambient air pollution data for Kaohsiung were obtained for the period 1996-2006. The relative risk of hospital admissions was estimated using a case-crossover approach, controlling for weather variables, day of the week, seasonality, and long-term time trends. In the single-pollutant models, on warm days (>25 °C), statistically significant positive associations were found in all pollutants except particulate matter (PM10) and sulfur dioxide (SO2). On cool days (<25 °C), all pollutants were significantly associated with MI admissions except for ozone (O3). For the two-pollutant model, O3 and carbon monoxide (CO) were significant in combination with each of the other four pollutants on warm days. On cool days, nitrogen dioxide (NO2) remained statistically significant in all the two-pollutant models. This study provides evidence that higher levels of ambient air pollutants increase the risk of higher frequency of hospital admissions for MI.

# Christakos, G. and V. M. Vyas (1998). "A composite space/time approach to studying ozone distribution over eastern United States." Atmospheric Environment 32(16): 2845-2857.

National Institute of Environmental Health Sciences; U.S. Army. #This work is concerned with the composite space/time analysis of ozone concentrations over Eastern U.S. A novel method is used, which introduces a mode of reasoning that is a fundamental combination of inductive and deductive processes. The method is based on a spatiotemporal random field that organizes information concerning ozone distribution by reference to a space/time continuum. Randomness manifests itself as an ensemble of realizations (possibilities, potentialities) regarding the ozone distribution. Random field representations can take several forms which can embody physical characteristics of the ozone distribution or transform the data into a form that has certain desirable features. Numerical applications of the composite space/time method show that it generates ozone estimates that are more accurate than the estimates obtained from purely spatial mapping methods; and it also leads to a technique of space/time ozone trend determination that performs better than mean filtering. Composite space/time ozone maps offer a means of gaining understanding and insight into the variation of ozone concentrations over the Eastern U.S. and are important tools in ascertaining compliance with ambient air quality standards. Theses maps are also the necessary inputs to ozone reliability studies and to ozone exposure-health damage analysis.

# Christakos, G. and V. M. Vyas (1998). "A novel method for studying population health impacts of spatiotemporal ozone distribution." Social Science & Medicine 47(8): 1051-1066.

This work is concerned with the development of a method to study the impact of ozone exposure on human health. The analysis is based on random field representations of exposure variation and health damage uncertainty in a composite space/time continuum, which previous studies did not allow. Ozone exposure-health damage is considered as a spatiotemporal holistic system, by looking at the whole picture, not just certain isolated parts. Ozone maps over the eastern United States provide the basic Framework for studying exposure-health relationships, that focus on a community wise basis. Composite space/time maps of health damage indicators associated with the ozone exposure levels are obtained. These maps constitute an important part of many health studies, offering a valuable description of the data and an important basis for further analysis. Health damage maps can identify, for example, regions over the eastern United States that will respond in certain ways to variation of ozone levels or the application of health management practices. Application areas are identified for future study.

# Chuang, K. J., et al. (2008). "Particulate air pollution as a risk factor for ST-segment depression in patients with coronary artery disease." Circulation 118(13): 1314-1320.

BACKGROUND: The association of particulate matter (PM) with cardiovascular morbidity and mortality is well documented. PM-induced ischemia is considered a potential mechanism linking PM to adverse cardiovascular outcomes. METHODS AND RESULTS: In a repeated-measures study including 5979 observations on 48 patients 43 to 75 years of age, we investigated associations of ambient pollution with ST-segment level changes averaged over half-hour periods measured in the modified V(5) position by 24-hour Holter ECG monitoring. Each patient was observed up to 4 times within 1 year after a percutaneous intervention for myocardial infarction, acute coronary syndrome without infarction, or stable coronary artery disease without acute coronary syndrome. Elevation in fine particles (PM(2.5)) and black carbon levels predicted depression of half-hour-averaged ST-segment levels. An interquartile increase in the previous 24-hour mean black carbon level was associated with a 1.50-fold increased risk of ST-segment depression > or =0.1 mm (95% CI, 1.19 to 1.89) and a -0.031-mm (95% CI, -0.042 to -0.019) decrease in half-hour-averaged ST-segment level (continuous outcome). Effects were greatest within the first month after hospitalization and for patients with myocardial infarction during hospitalization or with diabetes. CONCLUSIONS: ST-segment depression is associated with increased exposure to PM(2.5) and black carbon in cardiac patients. The risk of pollution-associated ST-segment depression may be greatest in those with myocardial injury in the first month after the cardiac event.

# Clougherty, J. E., et al. (2013). "Intra-urban spatial variability in wintertime street-level concentrations of multiple combustion-related air pollutants: The New York City Community Air Survey (NYCCAS)." Journal of Exposure Science and Environmental Epidemiology 23(3): 232-240.

Although intra-urban air pollution differs by season, few monitoring networks provide adequate geographic density and year-round coverage to fully characterize seasonal patterns. Here, we report winter intra-urban monitoring and land-use regression (LUR) results from the New York City Community Air Survey (NYCCAS). Two-week integrated samples of fine particles (PM(2.5)), black carbon (BC), nitrogen oxides (NO(x)) and sulfur dioxide (SO(2)) were collected at 155 city-wide street-level locations during winter 2008-2009. Sites were selected using stratified random sampling, randomized across sampling sessions to minimize spatio-temporal confounding. LUR was used to identify GIS-based source indicators associated with higher concentrations. Prediction surfaces were produced using kriging with external drift. Each pollutant varied twofold or more across sites, with higher concentrations near midtown Manhattan. All pollutants were positively correlated, particularly PM(2.5) and BC (Spearman's r=0.84). Density of oil-burning boilers, total and truck traffic density, and temporality explained 84% of PM(2.5) variation. Densities of total traffic, truck traffic, oil-burning boilers and industrial space, with temporality, explained 65% of BC variation. Temporality, built space, bus route location, and traffic density described 67% of nitrogen dioxide variation. Residual oil-burning units, nighttime population and temporality explained 77% of SO(2) variation. Spatial variation in combustion-related pollutants in New York City was strongly associated with oil-burning and traffic density. Chronic exposure disparities and unique local sources can be identified through year-round saturation monitoring. Journal of Exposure Science and Environmental Epidemiology advance online publication, 30 January 2013; doi:10.1038/jes.2012.125.

# Connell, D. P., et al. (2005). "The Steubenville Comprehensive Air Monitoring Program (SCAMP): Associations among fine particulate matter, co-pollutants, and meteorological conditions." Journal of the Air and Waste Management Association 55(4): 481-496.

We determined 24-hr average ambient concentrations of PM2.5 and its ionic and carbonaceous components in Steubenville, OH, between May 2000 and May 2002. We also determined daily average gaseous co-pollutant concentrations, meteorological conditions, and pollen and mold spore counts. Data were analyzed graphically and by linear regression and time series models. Multiple-day episodes of elevated fine particulate matter (PM2.5) concentrations often occurred during periods of locally high temperature (especially during summer), high pressure, or low wind speed (especially during winter) and generally ended with the passage of a frontal system. After removing autocorrelation, we observed statistically significant positive associations between concentrations of PM2.5 and concentrations of CO, NOx, and SO2. Associations with NOx and CO exhibited significant seasonal dependencies, with the strongest correlations during fall and winter. NOx, CO, SO2, O3, temperature, relative humidity, and wind speed were all significant predictors of PM2.5 concentration in a time-series model with external regressors, which successfully accounted for 79% of the variance in log-transformed daily PM2.5 concentrations. Coefficient estimates for NOx and temperature varied significantly by season. The results provide insight that may be useful in the development of future PM2.5 reduction strategies for Steubenville. Additionally, they demonstrate the need for PM epidemiology studies in Steubenville (and elsewhere) to carefully consider the potential confounding effects of gaseous co-pollutants, such as CO and NOx, and their seasonally dependent associations with PM2.5.

# Costa Nascimento, L. F., et al. (2012). "Environmental pollutants and stroke-related hospital admissions." Cadernos de Saúde Pública 28(7): 1319-1324.

Some effects of environmental pollution on human health are known, especially those affecting the respiratory and cardiovascular systems. The current study aimed to estimate these effects on the production of hospital admissions for stroke. This was an ecological study using hospital admissions data in Sao Jose dos Campos, Sao Paulo State, Brazil, with diagnosis of stroke, from January 1, 2007, to April 30, 2008. The target pollutants were particulate matter, sulfur dioxide, and ozone. Use of a Poisson linear regression model showed that same-day exposure to particulate matter was associated with hospitalization for stroke (RR = 1.013; 95%CI: 1.001-1.025). An increase of 10 mu g/m(3) in this pollutant increased the risk of hospitalization by 12% (RR = 1.137; 95%CI: 1.014-1.276). In the multi-pollutant model, it was thus possible to identify particulate matter as associated with hospitalization for stroke in a medium-sized city like Sao Jose dos Campos.

# Crosley, D. R. (1996). "NOy blue ribbon panel." Journal of Geophysical Research 101(D1): 2049-2052.

Total NOy was determined on the Pacific Exploratory Mission-West A using two separate instruments, one operated by Georgia Institute of Technology and one by Nagoya University. The two data sets exhibited significant disagreement, with no systematic correlation, and differences often a factor of 2 or more. Additionally, regardless of data set chosen, the total NOy was much greater than the sum of its components measured separately. A panel was convened by NASA in July 1993 to examine these conflicting data sets and the question of 'missing NOy' on this mission. This paper reports the conclusions and recommendations from the panel.

# Dadvand, P., et al. (2014). "Residential proximity to major roads and term low birth weight: The roles of air pollution, heat, noise, and road-adjacent trees." Epidemiology 25(4): 518-525.

Background: Maternal residential proximity to roads has been associated with adverse pregnancy outcomes. However, there is no study investigating mediators or buffering effects of road-adjacent trees on this association. We investigated the association between mothers' residential proximity to major roads and term low birth weight (LBW), while exploring possible mediating roles of air pollution (PM2.5, PM2.5-10, PM10, PM2.5 absorbance, nitrogen dioxide, and nitrogen oxides), heat, and noise and buffering effect of road-adjacent trees on this association. Methods: This cohort study was based on 6438 singleton term births in Barcelona, Spain (2001-2005). Road proximity was measured as both continuous distance to and living within 200 m from a major road. We assessed individual exposures to air pollution, noise, and heat using, respectively, temporally adjusted land-use regression models, annual averages of 24-hour noise levels across 50 m and 250 m, and average of satellite-derived land-surface temperature in a 50-m buffer around each residential address. We used vegetation continuous fields to abstract tree coverage in a 200-m buffer around major roads. Results: Living within 200 m of major roads was associated with a 46% increase in term LBW risk; an interquartile range increase in heat exposure with an 18% increase; and third-trimester exposure to PM2.5, PM2.5-10, and PM10 with 24%, 25%, and 26% increases, respectively. Air pollution and heat exposures together explained about one-third of the association between residential proximity to major roads and term LBW. Our observations on the buffering of this association by road-adjacent trees were not consistent between our 2 measures of proximity to major roads. Conclusion: An increased risk of term LBW associated with proximity to major roads was partly mediated by air pollution and heat exposures.

# Dales, R., et al. (2008). "The influence of living near roadways on spirometry and exhaled nitric oxide in elementary schoolchildren." Environmental Health Perspectives 116(10): 1423-1427.

Background: Living near major roadways has been associated with an increase in respiratory symptoms, but little is known about how this relates to airway inflammation. Objective: We assessed the effects of living near local residential roadways based on objective indicators of ventilatory function and airway inflammation. Methods: We estimated ambient air pollution, resolved to the level of the child’s neighborhood, using a land-use regression model for children 9-11 years of age. We also summed the length of roadways found within a 200-m radius of each child’s neighborhood. We had measurements of both air pollution exposure and spirometry for 2,328 children, and also had measurements of exhaled nitric oxide (eNO) for 1,613 of these children. Results: Each kilometer of local roadway within a 200-m radius of the home was associated with a 6.8% increase in eNO (p = 0.045). Each kilometer of any type of roadway (local, major, highway) was also associated with an increase in eNO of 10.1% (p = 0.002). Each microgram per cubic meter increase in PM2.5 was associated with a 3.9% increase in eNO (p = 0.058) and 0.70% decrease in forced vital capacity (FVC) expressed as a percentage of predicted (p = 0.39). Associations between roadway density and both forced expired volume in 1 sec and FVC were negative but not statistically significant at p < 0.05. Conclusion: Traffic from local neighborhood roadways may cause airway inflammation as indicated by eNO. This may be a more sensitive indicator of adverse air pollution effects than traditional measures of ventilatory function.

# Darrow, L. A., et al. (2009). "Ambient air pollution and preterm birth: A time-series analysis." Epidemiology 20(5): 689-698.

BACKGROUND: An emerging body of evidence suggests that ambient levels of air pollution during pregnancy are associated with preterm birth. METHODS: To further investigate these relationships we used vital record data to construct a retrospective cohort of 476,489 births occurring between 1994 and 2004 in 5 central counties of metropolitan Atlanta. Using a time-series approach, we examined aggregated daily counts of preterm birth in relation to ambient levels of carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, particulate matter <10 microm in diameter (PM10), particulate matter <2.5 microm in diameter (PM2.5), and speciated PM measurements. Daily pollutant levels in 5-county Atlanta were characterized using a population-weighted spatial average of air quality monitors in the study area. We also examined ambient concentrations at individual monitors in analyses limited to mothers with residential geocodes within 4 miles of each monitor. Relationships between average pollution levels during 3 gestational windows of interest were modeled using Poisson generalized linear models. Results were adjusted for seasonal and long-term time trends. RESULTS: Although most results were null, there were 3 positive associations between ambient pollution levels and preterm birth in the 4-mile capture-area analyses. Daily preterm birth rates were associated with average NO2 concentrations in the preceding 6 weeks and with average PM2.5 sulfate and PM2.5 water-soluble metal concentrations in the preceding week. CONCLUSIONS: Results provide limited support for late-pregnancy effects of ambient air pollution on preterm birth.

# Darrow, L. A., et al. (2011). "The use of alternative pollutant metrics in time-series studies of ambient air pollution and respiratory emergency department visits." Journal of Exposure Science and Environmental Epidemiology 21(1): 10-19.

Various temporal metrics of daily pollution levels have been used to examine the relationships between air pollutants and acute health outcomes. However, daily metrics of the same pollutant have rarely been systematically compared within a study. In this analysis, we describe the variability of effect estimates attributable to the use of different temporal metrics of daily pollution levels. We obtained hourly measurements of ambient particulate matter (PM2.5), carbon monoxide (CO), nitrogen dioxide (NO2), and ozone (O3) from air monitoring networks in 20-county Atlanta for the time period 1993–2004. For each pollutant, we created (1) a daily 1-h maximum; (2) a 24-h average; (3) a commute average; (4) a daytime average; (5) a nighttime average; and (6) a daily 8-h maximum (only for O3). Using Poisson generalized linear models, we examined associations between daily counts of respiratory emergency department visits and the previous day's pollutant metrics. Variability was greatest across O3 metrics, with the 8-h maximum, 1-h maximum, and daytime metrics yielding strong positive associations and the nighttime O3 metric yielding a negative association (likely reflecting confounding by air pollutants oxidized by O3). With the exception of daytime metric, all of the CO and NO2 metrics were positively associated with respiratory emergency department visits. Differences in observed associations with respiratory emergency room visits among temporal metrics of the same pollutant were influenced by the diurnal patterns of the pollutant, spatial representativeness of the metrics, and correlation between each metric and copollutant concentrations. Overall, the use of metrics based on the US National Ambient Air Quality Standards (for example, the use of a daily 8-h maximum O3 as opposed to a 24-h average metric) was supported by this analysis. Comparative analysis of temporal metrics also provided insight into underlying relationships between specific air pollutants and respiratory health.

# Darrow, L. A., et al. (2011). "Ambient air pollution and birth weight in full-term infants in Atlanta, 1994-2004." Environmental Health Perspectives 119(5): 731-737.

Background: An emerging body of evidence suggests that ambient levels of air pollution during pregnancy are associated with fetal growth. Objectives: We examined relationships between birth weight and temporal variation in ambient levels of carbon monoxide, nitrogen dioxide (NO2), sulfur dioxide (SO2), ozone, particulate matter ≤ 10 μm in diameter (PM10), ≤ 2.5 μm (PM2.5), 2.5 to 10 µm (PM2.5-10), and PM2.5 chemical component measurements for 406,627 full-term births occurring between 1994 and 2004 in five central counties of metropolitan Atlanta. Methods: We assessed relationships between birth weight and pollutant concentrations during each infant's first month of gestation and third trimester, as well as in each month of pregnancy using distributed lag models. We also conducted capture-area analyses limited to mothers residing within 4 miles (6.4 km) of each air quality monitoring station. Results: In the five-county analysis, ambient levels of NO2, SO2, PM2.5 elemental carbon, and PM2.5 water-soluble metals during the third trimester were significantly associated with small reductions in birth weight (-4 to -16 g per interquartile range increase in pollutant concentrations). Third-trimester estimates were generally higher in Hispanic and non-Hispanic black infants relative to non-Hispanic white infants. Distributed lag models were also suggestive of associations between air pollutant concentrations in late pregnancy and reduced birth weight. The capture-area analyses provided little support for the associations observed in the five-county analysis. Conclusions: Results provide some support for an effect of ambient air pollution in late pregnancy on birth weight in full-term infants.

# Delfino, R. J., et al. (1996). "Daily asthma severity in relation to personal ozone exposure and outdoor fungal spores." American Journal of Respiratory and Critical Care Medicine 154(3 Pt 1): 633-641.

U.S. National Institute of Health, National Institute of Environmental Health Sciences Grant No. ES06214. #Epidemiologic investigations of ambient ozone (O-3) effects on daily asthma status have not used personal O-3 exposures and have often lacked well-characterized allergen exposures. To address this, we studied 12 asthmatic subjects aged 9 to 16 yr, who recorded daily asthma symptoms (functional levels 0 to 5) and as-needed inhaler use during September and October 1993 in San Diego, California. Outdoor aeroallergens, O-3, and fine particle concentrations were measured at a central outdoor site, and personal 12-h daytime exposures to O-3 were measured daily. Personal O-3 differed greatly between subjects and was 27% of mean outdoor O-3. In random-effects autoregression models controlling for weekend days and fungal spores, personal O-3 was associated with asthma severity: for a 90th percentile increase in O-3 (25 ppb), symptom scores increased by 25% (95% CI: 0 to 49%) and inhaler use increased by 26% (95% CI: 3 to 48%) over their averages. Outdoor 12-h O-3, but not 1-h maximum O-3, was associated with inhaler use (p lt 0.03). Fungal spores were significantly associated with symptoms (scores increased by 0.1 to 0.3/1,000 spores/m-3) and inhaler use (0.1 to 0.4 puffs/1,000 spores/m-3) across speciated groups. Pollen and fine particles (low levels) were not associated with any outcomes. These findings illustrate that the epidemiologic importance of O-3 and allergenic cofactors can be underestimated by failure to account for personal O-3 and fungal exposures.

# Delfino, R. J., et al. (2008). "Personal and ambient air pollution exposures and lung function decrements in children with asthma." Environmental Health Perspectives 116(4): 550-558.

BACKGROUND: Epidemiologic studies have shown associations between asthma outcomes and outdoor air pollutants such as nitrogen dioxide and particulate matter mass < 2.5 microm in diameter (PM(2.5)). Independent effects of specific pollutants have been difficult to detect because most studies have relied on highly correlated central-site measurements. OBJECTIVES: This study was designed to evaluate the relationship of daily changes in percent-predicted forced expiratory volume in 1 sec (FEV(1)) with personal and ambient air pollutant exposures. METHODS: For 10 days each, we followed 53 subjects with asthma who were 9-18 years of age and living in the Los Angeles, California, air basin. Subjects self-administered home spirometry in the morning, afternoon, and evening. We measured personal hourly PM(2.5) mass, 24-hr PM(2.5) elemental and organic carbon (EC-OC), and 24-hr NO(2), and the same 24-hr average outdoor central-site(ambient) exposures. We analyzed data with transitional mixed models controlling for personal temperature and humidity, and as-needed beta(2)-agonist inhaler use. RESULTS: FEV(1) decrements were significantly associated with increasing hourly peak and daily average personal PM(2.5), but not ambient PM(2.5). Personal NO(2) was also inversely associated with FEV(1). Ambient NO(2) was more weakly associated. We found stronger associations among 37 subjects not taking controller bronchodilators as follows: Personal EC-OC was inversely associated with morning FEV(1); for an interquartile increase of 71 microg/m(3) 1-hr maximum personal PM(2.5), overall percent-predicted FEV(1) decreased by 1.32% [95% confidence interval (CI), -2.00 to -0.65%]; and for an interquartile increase of 16.8 ppb 2-day average personal NO(2), overall percent-predicted FEV(1) decreased by 2.45% (95% CI, -3.57 to -1.33%). Associations of both personal PM(2.5) and NO(2) with FEV(1) remained when co-regressed, and both confounded ambient NO(2). CONCLUSIONS: Independent pollutant associations with lung function might be missed using ambient data alone. Different sets of causal components are suggested by independence of FEV(1) associations with personal PM(2.5) mass from associations with personal NO(2).

# Delfino, R. J., et al. (2009). "Air pollution exposures and circulating biomarkers of effect in a susceptible population: Clues to potential causal component mixtures and mechanisms." Environmental Health Perspectives 117(8): 1232-1238.

BACKGROUND: Mechanisms involving oxidative stress and inflammation have been proposed to explain associations of ambient air pollution with cardiovascular morbidity and mortality. Experimental evidence suggests that organic components and ultrafine particles (UFP) are important. METHODS: We conducted a panel study of 60 elderly subjects with coronary artery disease living in retirement communities within the Los Angeles, California, air basin. Weekly biomarkers of inflammation included plasma interleukin-6, tumor necrosis factor-alpha soluble receptor II (sTNF-RII), soluble platelet selectin (sP-selectin), and C-reactive protein (CRP). Biomarkers of erythrocyte antioxidant activity included glutathione peroxidase-1 and superoxide dismutase. Exposures included outdoor home daily particle mass [particulate matter < 0.25, 0.25-2.5, and 2.5-10 microm in aerodynamic diameter (PM(0.25), PM(0.25-2.5), PM(2.5-10))], and hourly elemental and black carbon (EC-BC), estimated primary and secondary organic carbon (OC(pri), SOC), particle number (PN), carbon monoxide (CO), and nitrogen oxides-nitrogen dioxide (NO(x)-NO(2)). We analyzed the relation of biomarkers to exposures with mixed effects models adjusted for potential confounders. RESULTS: Primary combustion markers (EC-BC, OC(pri), CO, NO(x)-NO(2)), but not SOC, were positively associated with inflammatory biomarkers and inversely associated with erythrocyte anti-oxidant enzymes (n = 578). PN and PM(0.25) were more strongly associated with biomarkers than PM(0.25-2.5). Associations for all exposures were stronger during cooler periods when only OC(pri), PN, and NO(x) were higher. We found weaker associations with statin (sTNF-RII, CRP) and clopidogrel use (sP-selectin). CONCLUSIONS: Traffic-related air pollutants are associated with increased systemic inflammation, increased platelet activation, and decreased erythrocyte antioxidant enzyme activity, which may be partly behind air pollutant-related increases in systemic inflammation. Differences in association by particle size, OC fraction, and seasonal period suggest components carried by UFP are important.

# Delfino, R. J., et al. (2008). "Circulating biomarkers of inflammation, antioxidant activity, and platelet activation are associated with primary combustion aerosols in subjects with coronary artery disease." Environmental Health Perspectives 116(7): 898-906.

BACKGROUND: Biomarkers of systemic inflammation have been associated with risk of cardiovascular morbidity and mortality. OBJECTIVES: We aimed to clarify associations of particulate matter (PM) air pollution with systemic inflammation using models based on size-fractionated PM mass and markers of primary and secondary aerosols. METHODS: We followed a panel of 29 nonsmoking elderly subjects with a history of coronary artery disease (CAD) living in retirement communities in the Los Angeles, California, air basin. Blood plasma biomarkers were measured weekly over 12 weeks and included C-reactive protein (CRP), fibrinogen, tumor necrosis factor-alpha (TNF-alpha) and its soluble receptor-II (sTNF-RII), interleukin-6 (IL-6) and its soluble receptor (IL-6sR), fibrin D-dimer, soluble platelet selectin (sP-selectin), soluble vascular cell adhesion molecule-1 (sVCAM-1), intracellular adhesion molecule-1 (sICAM-1), and myeloperoxidase (MPO). To assess changes in antioxidant capacity, we assayed erythrocyte lysates for glutathione peroxidase-1 (GPx-1) and copper-zinc superoxide dismutase (Cu, Zn-SOD) activities. We measured indoor and outdoor home daily size-fractionated PM mass, and hourly pollutant gases, total particle number (PN), fine PM elemental carbon (EC) and organic carbon (OC), estimated secondary organic aerosol (SOA) and primary OC (OCpri) from total OC, and black carbon (BC). We analyzed data with mixed models controlling for temperature and excluding weeks with infections. RESULTS: We found significant positive associations for CRP, IL-6, sTNF-RII, and sP-selectin with outdoor and/or indoor concentrations of quasi-ultrafine PM < or = 0.25 microm in diameter, EC, OCpri, BC, PN, carbon monoxide, and nitrogen dioxide from the current-day and multiday averages. We found consistent positive but largely nonsignificant coefficients for TNF-alpha, sVCAM-1, and sICAM-1, but not fibrinogen, IL-6sR, or D-dimer. We found inverse associations for erythrocyte Cu, Zn-SOD with these pollutants and other PM size fractions (0.25-2.5 and 2.5-10 microm). Inverse associations of GPx-1 and MPO with pollutants were largely nonsignificant. Indoor associations were often stronger for estimated indoor EC, OCpri, and PN of outdoor origin than for uncharacterized indoor measurements. There was no evidence for positive associations with SOA. CONCLUSIONS: Results suggest that traffic emission sources of OCpri and quasi-ultrafine particles lead to increased systemic inflammation and platelet activation and decreased antioxidant enzyme activity in elderly people with CAD.

# Delgado-Saborit, J. M. (2012). "Use of real-time sensors to characterise human exposures to combustion related pollutants." Journal of Environmental Monitoring 14(7): 1824-1837.

Concentrations of black carbon and nitrogen dioxide have been collected concurrently using a MicroAeth AE-51 and an Aeroqual GSS NO(2) sensor. Forty five sampling events with a duration spanning between 16 and 22 hours have collected 10,800 5 min data in Birmingham (UK) from July to October 2011. The high temporal resolution database allowed identification of peak exposures and which activities contributed the most to these peaks, such as cooking and commuting. Personal exposure concentrations for non-occupationally exposed subjects ranged between 0.01 and 50 μg m(-3) for BC with average values of 1.3 ± 2.2 μg m(-3) (AM Â± SD). Nitrogen dioxide exposure concentrations were in the range LOD to 800 ppb with average concentrations of 23 ± 50 ppb. The correlation between personal exposures (PEs) and central site (A) concentrations was evaluated, with only NO(2) exposures averaged over the sampling event significantly correlating with central site levels. The PE/A ratio ranged between 1.1 (BC) and 0.2-0.7 (NO(2)) in the absence of combustion sources to 13 (BC) for subjects commuting in trains and 2.9 (NO(2)) for subjects cooking with gas appliances.

# Demokritou, P., et al. (2001). "Development and laboratory performance evaluation of a personal multipollutant sampler for simultaneous measurements for particulate and gaseous pollutants." Aerosol Science and Technology 35(3): 741-752.

A personal multipollutant sampler has been developed. This sampler can be used for measuring exposures to particulate matter and criteria gases. The system uses a single personal sampling pump that operates at a flow rate of 5.2 l/min. The basic unit consists of two impaction-based samplers for PM2.5 and PM10 attached to a single elutriator. Two mini PM2.5 samplers are also attached to the elutriator for organic carbon (OC), elemental carbon (EC), sulfate, and nitrate measurements. For the collection of nitrate and sulfate, the mini sampler includes a miniaturized honeycomb glass denuder that is placed upstream of the filter to remove nitric acid and sulfur dioxide and to minimize artifacts. Two passive samplers can also be attached to the elutriator for measurements of gaseous copollutants such as O3, SO2, and NO2. The performance of the multipollutant sampler was examined through a series of laboratory chamber tests. The results showed a good agreement between the multipollutant sampler and the reference methods. The overall sampler performance demonstrates its suitability for personal exposure assessment studies.

# Dimitriou, K. and P. Kassomenos (2014). "Local and regional sources of fine and coarse particulate matter based on traffic and background monitoring." Theoretical and Applied Climatology 116(3-4): 413-433.

The aim of this study was to identify local and exogenous sources affecting particulate matter (PM) levels in five major cities of Northern Europe namely: London, Paris, Hamburg, Copenhagen and Stockholm. Besides local emissions, PM profile at urban and suburban areas of the European Union (EU) is also influenced by regional PM sources due to atmospheric transport, thus geographical city distribution is of a great importance. At each city, PM10, PM2.5, NO2, SO2, CO and O-3 air pollution data from two air pollution monitoring stations of the EU network were used. Different background characteristics of the selected two sampling sites at each city facilitated comparisons, providing a more exact analysis of PM sources. Four source apportionment methods: Pearson correlations among the levels of particulates and gaseous pollutants, characterisation of primal component analysis components, long-range transport analysis and extrapolation of PM size distribution ratios were applied. In general, fine (PM2.5) and coarse (PM10) particles were highly correlated, thus common sources are suggested. Combustion-originated gaseous pollutants (CO, NO2, SO2) were strongly associated to PM10 and PM2.5, primarily at areas severely affected by traffic. On the contrary, at background stations neighbouring important natural sources of particles or situated in suburban areas with rural background, natural emissions of aerosols were indicated. Series of daily PM2.5/PM10 ratios showed that minimum fraction values were detected during warm periods, due to higher volumes of airborne biogenic PM coarse, mainly at stations with important natural sources of particles in their vicinity. Hybrid single-particle Lagrangian integrated trajectory model was used, in order to extract 4-day backward air mass trajectories that arrived in the five cities which are under study during days with recorded PM10 exceedances. At all five cities, a significantly large fraction of those trajectories were classified in short- and medium-range clusters, thus transportation of particulates along with slow moving air masses was identified. A finding that supports the assumption of long-range transport is that, at background stations, long-range transportation effects were stronger, in comparison to traffic stations, due to less local particle emissions. Short-range trajectories associated to PM transport in Stockholm, Copenhagen and Hamburg were mainly of a continental origin. All three cities were approached by slow moving air masses originated from Poland and the Czech Republic, whereas Copenhagen and Stockholm were also influenced by short-range trajectories from Germany and France and from Jutland Peninsula and Scandinavian Peninsula, respectively. London and Paris are located to the north-west part of Europe. Trajectories of short and medium length arrived to these two megacities mainly through France, Germany, UK and North Atlantic.

# Dionisio, K. L., et al. (2014). "An empirical assessment of exposure measurement error and effect attenuation in bipollutant epidemiologic models." Environmental Health Perspectives 122(11): 1216-1224.

BACKGROUND: Using multipollutant models to understand combined health effects of exposure to multiple pollutants is becoming more common. However, complex relationships between pollutants and differing degrees of exposure error across pollutants can make health effect estimates from multipollutant models difficult to interpret.

OBJECTIVES: To quantify relationships between multiple pollutants and their associated exposure errors across metrics of exposure, and use empirical values to evaluate potential attenuation of coefficients in epidemiologic models.

METHODS: We used three daily exposure metrics (central-site measurements, air quality model estimates, population exposure model estimates) for 193 ZIP codes in the Atlanta, Georgia metropolitan area, from 1999-2002, for PM2.5 and its components (EC, SO4), O3, CO, and NOx, to construct three types of exposure error: δspatial (comparing air quality model estimates to central-site measurements), δpopulation (comparing population exposure model estimates to air quality model estimates), and δtotal (comparing population exposure model estimates to central-site measurements). We compared exposure metrics and exposure errors within and across pollutants, and present derived attenuation factors (ratio of observed to true coefficient for pollutant of interest) for single and bipollutant model coefficients.

RESULTS: Pollutant concentrations and their exposure errors were moderately to highly correlated (typically > 0.5), especially for CO, NOx, and EC (i.e., "local" pollutants); correlations differed across exposure metrics and types of exposure error. Spatial variability was evident, with variance of exposure error for local pollutants ranging from 0.25-0.83 for δspatial and δtotal. The attenuation of model coefficients in single and bipollutant epidemiologic models relative to the true value differed across types of exposure error, pollutants, and space.

CONCLUSIONS: Under a classical exposure error framework, attenuation may be substantial for local pollutants due to δspatial and δtotal, with true coefficients reduced by a factor typically < 0.6 (results vary for δpopulation and regional pollutants).

# Dionisio, K. L., et al. (2013). "Development and evaluation of alternative approaches for exposure assessment of multiple air pollutants in Atlanta, Georgia." Journal of Exposure Science and Environmental Epidemiology 23(6): 581-592.

Measurements from central site (CS) monitors are often used as estimates of exposure in air pollution epidemiological studies. As these measurements are typically limited in their spatiotemporal resolution, true exposure variability within a population is often obscured, leading to potential measurement errors. To fully examine this limitation, we developed a set of alternative daily exposure metrics for each of the 169 ZIP codes in the Atlanta, GA, metropolitan area, from 1999 to 2002, for PM(2.5) and its components (elemental carbon (EC), SO(4)), O(3), carbon monoxide (CO), and nitrogen oxides (NOx). Metrics were applied in a study investigating the respiratory health effects of these pollutants. The metrics included: (i) CS measurements (one CS per pollutant); (ii) air quality model results for regional background pollution; (iii) local-scale AERMOD air quality model results; (iv) hybrid air quality model estimates (a combination of (ii) and (iii)); and (iv) population exposure model predictions (SHEDS and APEX). Differences in estimated spatial and temporal variability were compared by exposure metric and pollutant. Comparisons showed that: (i) both hybrid and exposure model estimates exhibited high spatial variability for traffic-related pollutants (CO, NO(x), and EC), but little spatial variability among ZIP code centroids for regional pollutants (PM(2.5), SO(4), and O(3)); (ii) for all pollutants except NO(x), temporal variability was consistent across metrics; (iii) daily hybrid-to-exposure model correlations were strong (r>0.82) for all pollutants, suggesting that when temporal variability of pollutant concentrations is of main interest in an epidemiological application, the use of estimates from either model may yield similar results; (iv) exposure models incorporating infiltration parameters, time-location-activity budgets, and other exposure factors affect the magnitude and spatiotemporal distribution of exposure, especially for local pollutants. The results of this analysis can inform the development of more appropriate exposure metrics for future epidemiological studies of the short-term effects of particulate and gaseous ambient pollutant exposure in a community.

# Dong, G. H., et al. (2011). "Gender differences and effect of air pollution on asthma in children with and without allergic predisposition: Northeast Chinese children health study." PLoS ONE 6(7): e22470.

Background: Males and females exhibit different health responses to air pollution, but little is known about how exposure to air pollution affects juvenile respiratory health after analysis stratified by allergic predisposition. The aim of the present study was to assess the relationship between air pollutants and asthmatic symptoms in Chinese children selected from multiple sites in a heavily industrialized province of China, and investigate whether allergic predisposition modifies this relationship. Methodology/Principal Findings: 30139 Chinese children aged 3-to-12 years were selected from 25 districts of seven cities in northeast China in 2009. Information on respiratory health was obtained using a standard questionnaire from the American Thoracic Society. Routine air-pollution monitoring data was used for particles with an aerodynamic diameter <= 10 mu m (PM(10)), sulfur dioxide (SO(2)), nitrogen dioxides (NO(2)), ozone (O(3)) and carbon monoxide (CO). A two-stage regression approach was applied in data analyses. The effect estimates were presented as odds ratios (ORs) per interquartile changes for PM(10), SO(2), NO(2), O(3), and CO. The results showed that children with allergic predisposition were more susceptible to air pollutants than children without allergic predisposition. Amongst children without an allergic predisposition, air pollution effects on asthma were stronger in males compared to females; Current asthma prevalence was related to PM(10) (ORs = 1.36 per 31 mu g/m(3); 95% CI, 1.08-1.72), SO(2) (ORs = 1.38 per 21 mu g/m(3); 95% CI, 1.12-1.69) only among males. However, among children with allergic predisposition, more positively associations between air pollutants and respiratory symptoms and diseases were detected in females; An increased prevalence of doctor-diagnosed asthma was significantly associated with SO(2) (ORs = 1.48 per 21 mu g/m(3); 95% CI, 1.21-1.80), NO(2) (ORs = 1.26 per 10 mu g/m(3); 95% CI, 1.01-1.56), and current asthma with O(3) (ORs = 1.55 per 23 mu g/m(3); 95% CI, 1.18-2.04) only among females. Conclusion/Significance: Ambient air pollutions were more evident in males without an allergic predisposition and more associations were detected in females with allergic predisposition.

# Dons, E. v., et al. (2011). "Impact of time-activity patterns on personal exposure to black carbon." Atmospheric Environment 45(21): 3594-3602.

Time-activity patterns are an important determinant of personal exposure to air pollution. This is demonstrated by measuring personal exposure of 16 participants for 7 consecutive days: 8 couples of which one person was a full-time worker and the other was a homemaker; both had a very different time-activity pattern. We used portable aethalometers to measure black carbon levels with a high temporal resolution and a PDA with GPS-logger and electronic diary. The exposure to black carbon differs between partners by up to 30%, although they live at the same location. The activity contributing most to this difference is transport: Average exposure in transport is 6445 ng m(-3), followed by exposure during shopping (2584 ng m(-3)). Average exposure is lowest while sleeping (1153 ng m(-3)) and when doing home-based activities (1223 ng m(-3)). Full-time workers spend almost twice as much time in transport as the homemakers. As a result of the study design we measured in several different homes, shops, cars, etc. enabling a better insight in true overall exposure in those microenvironments. Other factors influencing personal exposure are: background concentrations and location of residence in an urban, suburban or rural environment. (C) 2011 Elsevier Ltd. All rights reserved.

# Ducret-Stich, R. E., et al. (2013). "Role of highway traffic on spatial and temporal distributions of air pollutants in a Swiss Alpine valley." Science of the Total Environment 456-457: 50-60.

Traffic-related air pollutants show high spatial variability near roads, posing a challenge to adequately assess exposures. Recent modeling approaches (e.g. dispersion models, land-use regression (LUR) models) have addressed this but mostly in urban areas where traffic is abundant. In contrast, our study area was located in a rural Swiss Alpine valley crossed by the main North-south transit highway of Switzerland. We conducted an extensive measurement campaign collecting continuous nitrogen dioxide (NO₂), particulate number concentrations (PN), daily respirable particulate matter (PM10), elemental carbon (EC) and organic carbon (OC) at one background, one highway and seven mobile stations from November 2007 to June 2009. Using these measurements, we built a hybrid model to predict daily outdoor NO₂ concentrations at residences of children participating in an asthma panel study. With the exception of OC, daily variations of the pollutants followed the temporal trends of heavy-duty traffic counts on the highway. In contrast, variations of weekly/seasonal means were strongly determined by meteorological conditions, e.g., winter inversion episodes. For pollutants related to primary exhaust emissions (i.e. NO₂, EC and PN) local spatial variation strongly depended on proximity to the highway. Pollutant concentrations decayed to background levels within 150 to 200 m from the highway. Two separate daily NO₂ prediction models were built using LUR approaches with (a) short-term traffic and weather data (model 1) and (b) subsequent addition of daily background NO₂ to previous model (model 2). Models 1 and 2 explained 70% and 91% of the variability in outdoor NO₂ concentrations, respectively. The biweekly averaged predictions from the final model 2 agreed very well with the independent biweekly integrated passive measurements taken at thirteen homes and nine community sites (validation R(2)=0.74). The excellent spatio-temporal performance of our model provides a very promising basis for the health effect assessment of the panel study.

# Dunlea, E. J., et al. (2007). "Evaluation of nitrogen dioxide chemiluminescence monitors in a polluted urban environment." Atmospheric Chemistry and Physics 7(10): 2691-2704.

Data from a recent field campaign in Mexico City are used to evaluate the performance of the EPA Federal Reference Method for monitoring the ambient concentrations of NO2. Measurements of NO2 from standard chemiluminescence monitors equipped with molybdenum oxide converters are compared with those from Tunable Infrared Laser Differential Absorption Spectroscopy (TILDAS) and Differential Optical Absorption Spectroscopy (DOAS) instruments. A significant interference in the chemiluminescence measurement is shown to account for up to 50% of ambient NO2 concentration during afternoon hours. As expected, this interference correlates well with non-NOx reactive nitrogen species (NOz) as well as with ambient O3 concentrations, indicating a photochemical source for the interfering species. A combination of ambient gas phase nitric acid and alkyl and multifunctional alkyl nitrates is deduced to be the primary cause of the interference. Observations at four locations at varying proximities to emission sources indicate that the percentage contribution of HNO3 to the interference decreases with time as the air parcel ages. Alkyl and multifunctional alkyl nitrate concentrations are calculated to reach concentrations as high as several ppb inside the city, on par with the highest values previously observed in other urban locations. Averaged over the MCMA-2003 field campaign, the chemiluminescence monitor interference resulted in an average measured NO2 concentration up to 22% greater than that from co-located spectroscopic measurements. Thus, this interference has the potential to initiate regulatory action in areas that are close to non-attainment and may mislead atmospheric photochemical models used to assess control strategies for photochemical oxidants.

# Ebisu, K. and M. L. Bell (2012). "Airborne PM2.5 chemical components and low birth weight in the Northeastern and Mid-Atlantic regions of the United States." Environmental Health Perspectives 120(12): 1746-1752.

Background: Previous studies on air pollutants and birth outcomes have reported inconsistent results. Chemical components of particulate matter <2.5μm (PM2.5) composition are spatially heterogeneous, which might contribute to discrepancies across PM2.5 studies. Objectives: We explored whether birth weight at term is affected by PM2.5, PM10 and gaseous pollutants. Methods: Exposures during gestation and each trimester were calculated for PM2.5 chemical components, PM10, PM2.5, carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide for births in 2000-2007 for states in the northeastern and mid-Atlantic U.S. Associations between exposures and risk of low birth weight (LBW) were adjusted by family and individual characteristics and region. Interaction terms were used to investigate whether risk differs by race or sex. Results: Several PM2.5 chemical components were associated with LBW. Risk increased 4.9% (95% confidence interval: 3.4, 6.5%), 4.7% (3.2, 6.2%), 5.7 (2.7, 8.8%) and 5.0% (3.1,7.0%) per interquartile range increase of PM2.5 aluminum, elemental carbon, nickel, and titanium, respectively. Other PM2.5 chemical components and gaseous pollutants showed associations, but were not statistically significant in multi-pollutant models. The trimester associated with the highest relative risk differed among pollutants. Effect estimates for PM2.5 elemental carbon and nickel were higher for infants of white mothers than African-American mothers, and for males than females. Conclusions: Most exposure levels in our study area were in compliance with U.S. Environmental Protection Agency air pollution standards; however, we identified associations between PM2.5 components and LBW. Findings suggest that some PM2.5 components may be more harmful than others, and that some groups may be particularly susceptible.

# Eeftens, M., et al. (2012). "Spatial variation of PM2.5, PM10, PM2.5 absorbance and PMcoarse concentrations between and within 20 European study areas and the relationship with NO2 - Results of the ESCAPE project." Atmospheric Environment 62: 303-317.

The ESCAPE study (European Study of Cohorts for Air Pollution Effects) investigates relationships between long-term exposure to outdoor air pollution and health using cohort studies across Europe. This paper analyses the spatial variation of PM2.5, PM2.5 absorbance, PM10 and PMcoarse concentrations between and within 20 study areas across Europe. We measured NO2, NOx, PM2.5, PM2.5 absorbance and PM10 between October 2008 and April 2011 using standardized methods. PMcoarse was determined as the difference between PM10 and PM2.5. In each of the twenty study areas, we selected twenty PM monitoring sites to represent the variability in important air quality predictors, including population density, traffic intensity and altitude. Each site was monitored over three 14-day periods spread over a year, using Harvard impactors. Results for each site were averaged after correcting for temporal variation using data obtained from a reference site, which was operated year-round. Substantial concentration differences were observed between and within study areas. Concentrations for all components were higher in Southern Europe than in Western and Northern Europe, but the pattern differed per component with the highest average PM2.5 concentrations found in Turin and the highest PMcoarse in Heraklion. Street/urban background concentration ratios for PMcoarse (mean ratio 1.42) were as large as for PM2.5 absorbance (mean ratio 1.38) and higher than those for PM2.5 (1.14) and PM10 (1.23), documenting the importance of non-tailpipe emissions. Correlations between components varied between areas, but were generally high between NO2 and PM2.5 absorbance (average R2 = 0.80). Correlations between PM2.5 and PMcoarse were lower (average R2 = 0.39). Despite high correlations, concentration ratios between components varied, e.g. the NO2/PM2.5 ratio varied between 0.67 and 3.06. In conclusion, substantial variability was found in spatial patterns of PM2.5, PM2.5 absorbance, PM10 and PMcoarse. The highly standardized measurement of particle concentrations across Europe will contribute to a consistent assessment of health effects across Europe.

# EPA, U. S. (1993). Air quality criteria for oxides of nitrogen, vol. 1-3. Research Triangle Park, NC, U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office. EPA, U. S. (2006). Air quality criteria for ozone and related photochemical oxidants. Research Triangle Park, NC, U.S. Environmental Protection Agency, National Center for Environmental Assessment.

Tropospheric or surface-level ozone (O3) is one of six major air pollutants regulated by National Ambient Air Quality Standards (NAAQS) under the U.S. Clean Air Act. As mandated by the Clean Air Act, the U.S. Environmental Protection Agency (EPA) must periodically review the scientific bases (or criteria) for the various NAAQS by assessing newly available scientific information on a given criteria air pollutant. This document, Air Quality Criteria for Ozone and Other Photochemical Oxidants, is an updated revision of the 1996 Ozone Air Quality Criteria Document (O3 AQCD) that provided scientific bases for the current O3 NAAQS set in 1997.

# EPA, U. S. (2008). Integrated science assessment for sulfur oxides: Health criteria. Research Triangle Park, NC, U.S. Environmental Protection Agency, National Center for Environmental Assessment.

EPA has announced the release of the Integrated Science Assessment (ISA) for Sulfur Oxides – Health Criteria final assessment. This ISA represents a concise synthesis and evaluation of the most policy-relevant science and will ultimately provide the scientific bases for EPA’s decision regarding whether the current standard for SO2 sufficiently protects public health.

# EPA, U. S. (2010). Integrated science assessment for carbon monoxide. Research Triangle Park, NC, U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment.

EPA has released the final Integrated Science Assessment (ISA) for Carbon Monoxide (CO). This is EPA’s latest evaluation of the scientific literature on the potential human health and welfare effects associated with ambient exposures to CO. The development of this document is part of the Agency's periodic review of the national ambient air quality standards (NAAQS) for CO. The recently completed CO ISA and supplementary annexes, in conjunction with additional technical and policy assessments developed by EPA’s Office of Air and Radiation, will provide the scientific basis to inform EPA decisions related to the review of the current CO NAAQS.

# EPA, U. S. (2013). "2008 National Emissions Inventory, version 3." Retrieved April 18, 2013, from http://www.epa.gov/ttn/chief/net/2008inventory.html.

The National Emissions Inventory (NEI) is a comprehensive and detailed estimate of air emissions of both Criteria and Hazardous air pollutants from all air emissions sources. The NEI is prepared every three years by the USEPA based primarily upon emission estimates and emission model inputs provided by State, Local, and Tribal air agencies for sources in their jurisdictions, and supplemented by data developed by the USEPA. The 2008 NEI was built from emissions data in the Emissions Inventory System (EIS). The data presented below are for the 2008 NEI version 3. For a detailed list of caveats and changes from version 2, and older versions, please see the Version 3 issues file. Version History: Data from previous versions of the 2008 inventory are no longer available. Version 3 (March 1, 2013): Key updates are the use of the publicly-released MOVES2010b model for onroad mobile sources, updates to commercial marine vessel and residential wood emissions, additional VOC from biogenic emissions, addition of missing boiler mercury, addition of Puerto Rico emissions, review and update of lead emissions, and corrections to many issues identified in Version 2. Version 2 (April 10, 2012): Key updates are the use a draft version of the MOVES model for onroad mobile sources, a review and update of hazardous air pollutant emissions and additions of wildfires, prescribed burning and biogenic emissions. Version 1.5 (released May 16, 2011): Key updates are to include the nonpoint data and major updates to point sources in Indiana, Maryland, Nebraska, and Lincoln/Lancaster air agencies. Version 1 (released April 4, 2011) A description of each of the five data categories Point, NonPoint, OnRoad, NonRoad, and Event is shown below. Documentation for Version 3 will be available later this spring.

# EPA, U. S. (2015). Integrated science assessment for sulfur oxides - Health criteria (External review draft). Research Triangle Park, NC, U.S. Environmental Protection Agency, National Center for Environmental Assessment. EPA, U. S. (2015). Preamble to the Integrated Science Assessments. Research Triangle Park, NC, National Center for Environmental Assessment, Office of Research and Development. EPA, U. S. (2016). Integrated science assessment for oxides of nitrogen (final report). Research Triangle Park, NC, U.S. Environmental Protection Agency, National Center for Environmental Assessment.

The Integrated Science Assessment (ISA) for Oxides of Nitrogen – Health Criteria document represents a concise synthesis and evaluation of the most policy-relevant science and will ultimately provide the scientific basis for EPA’s decision regarding whether the current standard for NO2 sufficiently protects public health.

# Faiz, A. S., et al. (2012). "Ambient air pollution and the risk of stillbirth." American Journal of Epidemiology 176(4): 308-316.

The purpose of the present study was to examine the risk of stillbirth associated with ambient air pollution during pregnancy. Using live birth and fetal death data from New Jersey from 1998 to 2004, the authors assigned daily concentrations of air pollution to each birth or fetal death. Generalized estimating equation models were used to estimate the relative odds of stillbirth associated with interquartile range increases in mean air pollutant concentrations in the first, second, and third trimesters and throughout the entire pregnancy. The relative odds of stillbirth were significantly increased with each 10-ppb increase in mean nitrogen dioxide concentration in the first trimester (odds ratio (OR) = 1.16, 95% confidence interval (CI): 1.03, 1.31), each 3-ppb increase in mean sulfur dioxide concentration in the first (OR = 1.13, 95% CI: 1.01, 1.28) and third (OR = 1.26, 95% CI: 1.03, 1.37) trimesters, and each 0.4-ppm increase in mean carbon monoxide concentration in the second (OR = 1.14, 95% CI: 1.01, 1.28) and third (OR = 1.14, 95% CI: 1.06, 1.24) trimesters. Although ambient air pollution during pregnancy appeared to increase the relative odds of stillbirth, further studies are needed to confirm these findings and examine mechanistic explanations.

# Faiz, A. S., et al. (2013). "Does ambient air pollution trigger stillbirth?" Epidemiology 24(4): 538-544.

OBJECTIVE: We previously reported an increased risk of stillbirth associated with increases in trimester-specific ambient air pollutant concentrations. Here, we consider whether sudden increase in the mean ambient air pollutant concentration immediately before delivery triggers stillbirth.

METHODS: We used New Jersey linked fetal death and hospital discharge data and hourly ambient air pollution measurements from particulate matter ≤2.5 mm (PM2.5), carbon monoxide (CO), nitrogen dioxide (NO2), and sulfur dioxide (SO2) monitors across New Jersey for the years 1998-2004. For each stillbirth, we assigned the concentration of air pollutants from the closest monitoring site within 10 km of the maternal residence. Using a time-stratified case-crossover design and conditional logistic regression, we estimated the relative odds of stillbirth associated with interquartile range (IQR) increases in the mean pollutant concentrations on lag day 2 and lag days 2 through 6 before delivery, and whether these associations were modified by maternal risk factors.

RESULTS: The relative odds of stillbirth increased with IQR increases in the mean concentrations of CO (odds ratio [OR] = 1.20, 95% confidence interval [CI] = 1.05-1.37), SO2 (OR = 1.11, 95% CI = 1.02-1.22), NO2 (OR = 1.11, 95% CI = 0.97-1.26), and PM2.5 (OR = 1.07, 95% CI = 0.93-1.22) 2 days before delivery. We found similar associations with increases in pollutants 2 through 6 days before delivery. These associations were not modified by maternal risk factors.

CONCLUSION: Short-term increases in ambient air pollutant concentrations immediately before delivery may trigger stillbirth.

# Faustini, A., et al. (2011). "The relationship between ambient particulate matter and respiratory mortality: A multi-city study in Italy." European Respiratory Journal 38(3): 538-547.

The association of air pollutants with natural and respiratory mortality has been consistently reported. However, several aspects of the relationship between particles with an aerodynamic diameter of less than 10 micrometers (PM10) and respiratory mortality require further investigation. To assess the PM10 - respiratory mortality association in Italy and to examine potentially susceptible groups. All natural (n. 276,205) and respiratory deaths (n. 19,629) occurring among 35-plus-year-olds in ten northern, central and southern Italian cities in 2001-2005 were selected. Data for 10-micron particulate matter, nitrogen dioxide and ozone were obtained. A time-stratified case-crossover analysis was carried out. Different cumulative lags were selected to analyse immediate, delayed, prolonged and best-time effects of air pollution. The shape of the exposure-response relationship was analysed. Age, gender, chronic conditions and death site were investigated as potential effect modifiers. We found a 2.29% (IC95%=1.03; 3.58) increase in respiratory mortality at 0-3 lags. The increase in respiratory mortality was higher in summer (7.57%). The exposure-response curve had a linear shape without any threshold. Gender and chronic diseases modified the relationship between particulate matter and respiratory mortality. The effect of particulate on respiratory mortality was stronger and more persistent than that on natural mortality. Females and chronic disease sufferers were more likely to die of a respiratory disease caused by air pollution than males and healthy people.

# Fehsenfeld, F. C., et al. (1987). "A ground-based intercomparison of NO, NOx, and NOy measurement techniques." Journal of Geophysical Research 92(D12): 14,710-714,722.

At a site near Boulder, Colorado, simultaneous atmospheric measurements were made of NO, NOx, and NO in a field intercomparison of instruments involving two currently employed techniques of NOx and NOy measurement. Both NOy instruments depended upon the reduction of the NOy species to NO with detection by chemiluminescence, but different catalysts were employed for the reduction: (1) a gold catalyst (with addition of 0.3% CO) at 300 degrees C, or (2) a molybdenum catalyst at 400 degrees C. The two systems of NO detection involved (1) photolysis of NO2, and (2) reduction of NO3 by solid ferrous sulfate. Several times during the intercomparison the response to calibrated samples of reference compounds NO, NO2. PAN, HNO3, n-propyl nitrate (NPN), and NH3 was measured. From the results the following conclusions were made: (1) The two NO instruments agreed on NO mixing ratios that were measured during the daytime hours over a range from the limits of detection to 35 parts per billion by volume (ppbv), (2) the two NOy instruments gave similar estimates of NOy in ambient air over a wide range of mixing ratios (0.4-10 ppbv), and (3) the ferrous sulfate converter used for NOx detection showed a significant interference from NPN and PAN.

# Filleul, L., et al. (2005). "Twenty five year mortality and air pollution: Results from the French PAARC survey." Occupational and Environmental Medicine 62(7): 453-460.

AIMS AND METHODS: Long term effects of air pollution on mortality were studied in 14,284 adults who resided in 24 areas from seven French cities when enrolled in the PAARC survey (air pollution and chronic respiratory diseases) in 1974. Daily measurements of sulphur dioxide, total suspended particles, black smoke, nitrogen dioxide, and nitric oxide were made in 24 areas for three years (1974-76). Cox proportional hazards models controlling for individual confounders (smoking, educational level, body mass index, occupational exposure) were applied, and frailty models used to take into account spatial correlation. Indicators of air pollution were the mean concentration. RESULTS: Models were run before and after exclusion of six area monitors influenced by local traffic (NO/NO2 >3 in ppb). After exclusion of these areas, analyses showed that adjusted risk ratios (95% CI) for TSP, BS, NO2, and NO for non-accidental mortality were 1.05 (1.02 to 1.08), 1.07 (1.03 to 1.10), 1.14 (1.03 to 1.25), and 1.11 (1.05 to 1.17) for 10 microg/m3 respectively. Consistent patterns for lung cancer and cardiopulmonary causes were observed. CONCLUSIONS: Urban air pollution assessed in the 1970s was associated with increased mortality over 25 years in France.

# Foley, K. M., et al. (2010). "Incremental testing of the Community Multiscale Air Quality (CMAQ) modeling system version 4.7." Geoscientific Model Development 3(1): 205-226.

This paper describes the scientific and structural updates to the latest release of the Community Multiscale Air Quality (CMAQ) modeling system version 4.7 (v4.7) and points the reader to additional resources for further details. The model updates were evaluated relative to observations and results from previous model versions in a series of simulations conducted to incrementally assess the effect of each change. The focus of this paper is on five major scientific upgrades: (a) updates to the heterogeneous N2O5 parameterization, (b) improvement in the treatment of secondary organic aerosol (SOA), (c) inclusion of dynamic mass transfer for coarse-mode aerosol, (d) revisions to the cloud model, and (e) new options for the calculation of photolysis rates. Incremental test simulations over the eastern United States during January and August 2006 are evaluated to assess the model response to each scientific improvement, providing explanations of differences in results between v4.7 and previously released CMAQ model versions. Particulate sulfate predictions are improved across all monitoring networks during both seasons due to cloud module updates. Numerous updates to the SOA module improve the simulation of seasonal variability and decrease the bias in organic carbon predictions at urban sites in the winter. Bias in the total mass of fine particulate matter (PM2.5) is dominated by overpredictions of unspeciated PM2.5 (PMother) in the winter and by underpredictions of carbon in the summer. The CMAQv4.7 model results show slightly worse performance for ozone predictions. However, changes to the meteorological inputs are found to have a much greater impact on ozone predictions compared to changes to the CMAQ modules described here. Model updates had little effect on existing biases in wet deposition predictions.

# Forbes, L. J. L., et al. (2009). "Chronic exposure to outdoor air pollution and lung function in adults." Thorax 64(8): 657-663.

Background: The extent to which chronic exposure to outdoor air pollutants influences lung function in adults is unclear. The aim of this study was to measure the association between chronic exposure to outdoor air pollutants and adult lung function. Methods: The relationship between measures of lung function (forced expiratory volume in 1 s (FEV1) and FEV1 as a percentage of forced vital capacity (FVC)) and average exposure to particulate matter ,10 mm in diameter, nitrogen dioxide, sulfur dioxide and ozone was examined in four representative cross-sectional surveys of the English population aged >16 in 1995, 1996, 1997 and 2001. Year-specific estimates were pooled using fixed effects meta-analysis. Results: Greater exposure to particulate matter ,10 mm in diameter, nitrogen dioxide and sulfur dioxide was associated with lower adult FEV1. The size of the effect on population mean FEV1 was about 3% for particulate matter ,10 mm, and 0.7% for nitrogen dioxide and sulfur dioxide, for a 10 mg/m3 increase in pollutant concentration. The effects were most marked in men, older adults and ex-smokers. FEV1 was not associated with ozone concentration. No associations were found between the pollutants and FEV1 as a percentage of FVC. Conclusions: Chronic exposure to outdoor air pollution is associated with modestly reduced FEV1 in adults.

# Friberg, M. D., et al. (2017). "Daily ambient air pollution metrics for five cities: Evaluation of data-fusion-based estimates and uncertainties." Atmospheric Environment 158: 36-50.

Spatiotemporal characterization of ambient air pollutant concentrations is increasingly relying on the combination of observations and air quality models to provide well-constrained, spatially and temporally complete pollutant concentration fields. Air quality models, in particular, are attractive, as they characterize the emissions, meteorological, and physiochemical process linkages explicitly while providing continuous spatial structure. However, such modeling is computationally intensive and has biases. The limitations of spatially sparse and temporally incomplete observations can be overcome by blending the data with estimates from a physically and chemically coherent model, driven by emissions and meteorological inputs. We recently developed a data fusion method that blends ambient ground observations and chemical transport -modeled (CTM) data to estimate daily, spatially resolved pollutant concentrations and associated correlations. In this study, we assess the ability of the data fusion method to produce daily metrics (i.e., 1-hr max, 8-hr max, and 24-hr average) of ambient air pollution that capture spatiotemporal air pollution trends for 12 pollutants (CO, NO2, NOx, O-3, SO2, PM10, PM2.5, and five PM2.5 components) across five metropolitan areas (Atlanta, Birmingham, Dallas, Pittsburgh, and St. Louis), from 2002 to 2008.

Three sets of comparisons are performed: (1) the CTM concentrations are evaluated for each pollutant and metropolitan domain, (2) the data fusion concentrations are compared with the monitor data, (3) a comprehensive cross-validation analysis against observed data evaluates the quality of the data fusion model simulations across multiple metropolitan domains. The resulting daily spatial field estimates of air pollutant concentrations and uncertainties are not only consistent with observations, emissions, and meteorology, but substantially improve CTM-derived results for nearly all pollutants and all cities, with the exception of NO2 for Birmingham. The greatest improvements occur for O-3 and PM2.5. Squared spatiotemporal correlation coefficients range between simulations and observations determined using cross-validation across all cities for air pollutants of secondary and mixed origins are R-2 = 0.88-0.93 (O-3), 0.81-0.89 (SO4), 0.67-0.83 (PM2.5), 0.52-0.72 (NO3), 0.43-0.80 (NH4), 0.32-0.51 (OC), and 0.14-0.71 (PM10).

Results for relatively homogeneous pollutants of secondary origin, tend to be better than those for more spatially heterogeneous (larger spatial gradients) pollutants of primary origin (NOx, CO, SO2 and EC). Generally, background concentrations and spatial concentration gradients reflect interurban airshed complexity and the effects of regional transport, whereas daily spatial pattern variability shows intraurban consistency in the fused data. With sufficiently high CTM spatial resolution, traffic-related pollutants exhibit gradual concentration gradients that peak toward the urban centers. Ambient pollutant concentration uncertainty estimates for the fused data are both more accurate and smaller than those for either the observations or the model simulations alone. (C) 2017 Elsevier Ltd. All rights reserved.

# Fung, K. Y., et al. (2006). "Association between air pollution and multiple respiratory hospitalizations among the elderly in Vancouver, Canada." Inhalation Toxicology 18(13): 1005-1011.

Recurrent events, such as repeated hospital admissions for the same health outcome, occur frequently in environmental health studies. In this study, we conducted an analysis of data on repeated respiratory hospitalizations among the elderly in Vancouver, Canada, for the period of June 1, 1995, to March 31, 1999, using a new method proposed by (Dewanji and Moolgavkar 2000, 2002) for recurrent events, and compared it with some traditional methods. In particular, we assessed the impact of ambient gaseous (SO2, NO2, CO, and O3) and particulate pollutants (PM10, PM2.5, and PM10-2.5) as well as the coefficient of haze (CoH) on recurrent respiratory hospital admissions. Using the new procedure, significant associations were found between admissions and 3-day, 5-day, and 7-day moving averages of the ambient SO2 concentrations, with the strongest association observed at the 7-day lag (RR = 1.044, 95% CI: 1.018-1.070). We also found PM10-2.5 for 3-day and 5-day lag to be significant, with the strongest association at 5-day lag (RR = 1.020, 95% CI: 1.001-1.039). No significant associations with admission were found with current day exposure.

# Gan, W. Q., et al. (2012). "Association of long-term exposure to community noise and traffic-related air pollution with coronary heart disease mortality." American Journal of Epidemiology 175(9): 898-906.

In metropolitan areas, road traffic is a major contributor to ambient air pollution and the dominant source of community noise. The authors investigated the independent and joint influences of community noise and traffic-related air pollution on risk of coronary heart disease (CHD) mortality in a population-based cohort study with a 5-year exposure period (January 1994-December 1998) and a 4-year follow-up period (January 1999-December 2002). Individuals who were 45-85 years of age and resided in metropolitan Vancouver, Canada, during the exposure period and did not have known CHD at baseline were included (n = 445,868). Individual exposures to community noise and traffic-related air pollutants, including black carbon, particulate matter less than or equal to 2.5 μm in aerodynamic diameter, nitrogen dioxide, and nitric oxide, were estimated at each person's residence using a noise prediction model and land-use regression models, respectively. CHD deaths were identified from the provincial death registration database. After adjustment for potential confounders, including traffic-related air pollutants or noise, elevations in noise and black carbon equal to the interquartile ranges were associated with 6% (95% confidence interval: 1, 11) and 4% (95% confidence interval: 1, 8) increases, respectively, in CHD mortality. Subjects in the highest noise decile had a 22% (95% confidence interval: 4, 43) increase in CHD mortality compared with persons in the lowest decile. These findings suggest that there are independent effects of traffic-related noise and air pollution on CHD mortality.

# Gauderman, W. J., et al. (2004). "The effect of air pollution on lung development from 10 to 18 years of age." New England Journal of Medicine 351(11): 1057-1067.

Background--Whether exposure to air pollution adversely affects the growth of lung function during the period of rapid lung development that occurs between the ages of 10 and 18 years is unknown. Methods--In this prospective study, we recruited 1759 children (average age, 10 years) from schools in 12 southern California communities and measured lung function annually for eight years. The rate of attrition was approximately 10 percent per year. The communities represented a wide range of ambient exposures to ozone, acid vapor, nitrogen dioxide, and particulate matter. Linear regression was used to examine the relationship of air pollution to the forced expiratory volume in one second (FEV1) and other spirometric measures. Results--Over the eight-year period, deficits in the growth of FEV1 were associated with exposure to nitrogen dioxide (P=0.005), acid vapor (P=0.004), particulate matter with an aerodynamic diameter of less than 2.5 µm (PM2.5) (P=0.04), and elemental carbon (P=0.007), even after adjustment for several potential confounders and effect modifiers. Associations were also observed for other spirometric measures. Exposure to pollutants was associated with clinically and statistically significant deficits in the FEV1 attained at the age of 18 years. For example, the estimated proportion of 18-year-old subjects with a low FEV1 (defined as a ratio of observed to expected FEV1 of less than 80 percent) was 4.9 times as great at the highest level of exposure to PM2.5 as at the lowest level of exposure (7.9 percent vs. 1.6 percent, P=0.002). Conclusions--The results of this study indicate that current levels of air pollution have chronic, adverse effects on lung development in children from the age of 10 to 18 years, leading to clinically significant deficits in attained FEV1 as children reach adulthood.

# Georgopoulos, P. G., et al. (1997). "Comparative evaluation of methods for estimating potential human exposure to ozone: Photochemical modeling and ambient monitoring." Journal of Exposure Analysis and Environmental Epidemiology 7(2): 191-215.

NJ Department of Environmental Protection; U.S. Environmental Protection Agency. Photochemical modeling and ambient monitoring of ground-level ozone concentrations provide two alternative/complementary methods for calculating potential population exposure estimates. A comparative evaluation of these methods was undertaken over a study area comprised of the entire state of New Jersey and neighboring parts of Delaware, Maryland, Pennsylvania and New York. Kriging, a geostatistical interpolation technique, was used for the interpolation of hourly ozone data from 38 air quality monitoring stations operating within the study area, to derive concentration fields for the entire domain. The Urban Airshed Model(UAM-IV), a comprehensive photochemical grid-based model, was then used to calculate the same concentrations from emissions and meteorology inputs. Concentration fields, thus developed were linked with corresponding population data to calculate potential population exposure estimates to outdoor ozone (E(p,o)). The adequacy of kriging as an interpolation technique was evaluated by comparing E(p,o) estimates derived via photochemical UAM modeling with those calculated by using concentrations obtained from kriging UAM-calculated values at the locations of the monitoring stations. In general, UAM was found to predict higher E(p,o)compared to those derived by kriging observations. In order to test the robustness of the interpolation methodology with respect to assumptions of statistical correlation, two different semivariogram models, spherical and exponential, were used for kriging. Application of the different semivariograms yielded almost identical E(p,o) patterns.

# Georgopoulos, P. G., et al. (2005). "A source-to-dose assessment of population exposures to fine PM and ozone in Philadelphia, PA, during a summer 1999 episode." Journal of Exposure Analysis and Environmental Epidemiology 15(5): 439-457.

A novel source-to-dose modeling study of population exposures to fine particulate matter (PM2.5) and ozone (O3) was conducted for urban Philadelphia. The study focused on a 2-week episode, 11-24 July 1999, and employed the new integrated and mechanistically consistent source-to-dose modeling framework of MENTOR/SHEDS (Modeling Environment for Total Risk studies/Stochastic Human Exposure and Dose Simulation). The MENTOR/SHEDS application presented here consists of four components involved in estimating population exposure/dose: (1) calculation of ambient outdoor concentrations using emission-based photochemical modeling, (2) spatiotemporal interpolation for developing census-tract level outdoor concentration fields, (3) calculation of microenvironmental concentrations that match activity patterns of the individuals in the population of each census tract in the study area, and (4) population-based dosimetry modeling. It was found that the 50th percentiles of calculated microenvironmental concentrations of PM2.5 and O3 were significantly correlated with census-tract level outdoor concentrations, respectively. However, while the 95th percentiles of O3 microenvironmental concentrations were strongly correlated with outdoor concentrations, this was not the case for PM2.5. By further examining the modeled estimates of the 24-h aggregated PM2.5 and O3 doses, it was found that indoor PM2.5 sources dominated the contributions to the total PM2.5 doses for the upper 5 percentiles, Environmental Tobacco Smoking (ETS) being the most significant source while O3 doses due to time spent outdoors dominated the contributions to the total O3 doses for the upper 5 percentiles. The MENTOR/SHEDS system presented in this study is capable of estimating intake dose based on activity level and inhalation rate, thus completing the source-to-dose modeling sequence. The MENTOR/SHEDS system also utilizes a consistent basis of source characterization, exposure factors, and human activity patterns in conducting population exposure assessment of multiple co-occurring air pollutants, and this constitutes a primary distinction from previous studies of population exposure assessment, where different exposure factors and activity patterns would be used for different pollutants. Future work will focus on incorporating the effects of commuting patterns on population exposure/dose assessments as well as on extending the MENTOR/SHEDS applications to seasonal/annual studies and to other areas in the U.S.

# Geyh, A. S., et al. (1999). "Initial field evaluation of the Harvard active ozone sampler for personal ozone monitoring." Journal of Exposure Analysis and Environmental Epidemiology 9(2): 143-149.

Assessing personal exposure to ozone has only been feasible recently with the introduction of passive ozone samplers. These devices are easy to use, but changes in air velocity across their collection surfaces can affect performance. The Harvard active ozone sampler (AS) was developed in response to problems with the passive methods. This active sampler has been tested extensively as a microenvironmental sampler. To test for personal sampling, 40 children attending summer day-camp in Riverside, California wore the active ozone sampler for approximately 2.6 h on July 19 and 21, 1994, when ozone concentrations were about 100 ppb and 140 ppb, respectively. The children spent 94-100% of the sampling period outside, staying within a well-defined area while participating in normal camp activities. Ambient ozone concentrations across this area were monitored by two UV photometric ozone monitors. The active sampler was worn in a small backpack that was also equipped with a passive ozone sampler. Device precision, reported as the percent difference between duplicate pairs of samplers, was +/- 3.7% and +/- 4.2% for the active and passive samplers, respectively. The active sampler measured, on average, 94.5 +/- 8.2% of the ambient ozone while the passive samplers measured, on average, 124.5 +/- 18.8%. The samplers were worn successfully for the entire sampling period by all participating children.

# Geyh, A. S., et al. (1997). "Development and evaluation of a small active ozone sampler." Environmental Science and Technology 31(8): 2326-2330.

Current methods for monitoring ambient and microenvironmental ozone include continuous measurement instruments, such as UV photometric and chemiluminescence monitors, open-path diffusion optical absorption spectrometer, and passive sampling devices. This paper introduces a new small active ozone sampler that utilizes a single etched glass denuder as the collection substrate. The denuder is coated with a solution containing the nitrite ion that reacts with ozone to produce nitrate. It is attached to a small personal pump driven by a 9-V battery. When compared with UV photometric measurements, the active sampler demonstrated very good accuracy (active sampler/UV photometer = 0.94-1.00) and precision (%P = ±4.1-6.5%) under laboratory and ambient conditions for sampling period from 1 to 60 h. The Harvard active ozone sampler performed as well as the Timed Exposure Diffusion sampler, the only other active ozone sampler currently in use. Sampler performance was found to be insensitive to variations in relative humidity (active sampler/UV photometer "approx" 1.00 at 20-80% RH) except at very low relative humidity (active/UV photometer = 0.81 at 12%). A low limit of detection of 10 ppb allows for sampling at very low concentrations.

# Geyh, A. S., et al. (2000). "The Harvard Southern California chronic ozone exposure study: Assessing ozone exposure of grade-school-age children in two southern California communities." Environmental Health Perspectives 108(3): 265-270.

The Harvard Southern California Chronic Ozone Exposure Study measured personal exposure to, and indoor and outdoor ozone concentrations of, approximately 200 elementary school children 6-12 years of age for 12 months (June 1995-May 1996). We selected two Southern California communities, Upland and several towns located in the San Bernardino mountains, because certain characteristics of those communities were believed to affect personal exposures. On 6 consecutive days during each study month, participant homes were monitored for indoor and outdoor ozone concentrations, and participating children wore a small passive ozone sampler to measure personal exposure. During each sampling period, the children recorded time-location-activity information in a diary. Ambient ozone concentration data were obtained from air quality monitoring stations in the study areas. We present ozone concentration data for the ozone season (June-September 1995 and May 1996) and the nonozone season (October 1995-April 1996). During the ozone season, outdoor and indoor concentrations and personal exposure averaged 48.2, 11.8, and 18.8 ppb in Upland and 60.1, 21.4, and 25.4 ppb in the mountain towns, respectively. During the nonoxone season, outdoor and indoor concentrations and personal exposure averaged 21.1, 3.2, and 6.2 ppb in Upland, and 35.7, 2.8, and 5.7 ppb in the mountain towns, respectively. Personal exposure differed by community and sex, but not by age group.

# Ghosh, J. K. C., et al. (2012). "Assessing the influence of traffic-related air pollution on risk of term low birth weight on the basis of land-use-based regression models and measures of air toxics." American Journal of Epidemiology 175(12): 1262-1274.

Few studies have examined associations of birth outcomes with toxic air pollutants (air toxics) in traffic exhaust. This study included 8,181 term low birth weight (LBW) children and 370,922 term normal-weight children born between January 1, 1995, and December 31, 2006, to women residing within 5 miles (8 km) of an air toxics monitoring station in Los Angeles County, California. Additionally, land-use-based regression (LUR)-modeled estimates of levels of nitric oxide, nitrogen dioxide, and nitrogen oxides were used to assess the influence of small-area variations in traffic pollution. The authors examined associations with term LBW (â‰¥37 weeks' completed gestation and birth weight <2,500 g) using logistic regression adjusted for maternal age, race/ethnicity, education, parity, infant gestational age, and gestational age squared. Odds of term LBW increased 2%-5% (95% confidence intervals ranged from 1.00 to 1.09) per interquartile-range increase in LUR-modeled estimates and monitoring-based air toxics exposure estimates in the entire pregnancy, the third trimester, and the last month of pregnancy. Models stratified by monitoring station (to investigate air toxics associations based solely on temporal variations) resulted in 2%-5% increased odds per interquartile-range increase in third-trimester benzene, toluene, ethyl benzene, and xylene exposures, with some confidence intervals containing the null value. This analysis highlights the importance of both spatial and temporal contributions to air pollution in epidemiologic birth outcome studies.

# Goldman, G. T., et al. (2012). "Characterization of ambient air pollution measurement error in a time-series health study using a geostatistical simulation approach." Atmospheric Environment 57: 101-108.

In recent years, geostatistical modeling has been used to inform air pollution health studies. In this study, distributions of daily ambient concentrations were modeled over space and time for 12 air pollutants. Simulated pollutant fields were produced for a 6-year time period over the 20-county metropolitan Atlanta area using the Stanford Geostatistical Modeling Software (SGeMS). These simulations incorporate the temporal and spatial autocorrelation structure of ambient pollutants, as well as season and day-of-week temporal and spatial trends; these fields were considered to be the true ambient pollutant fields for the purposes of the simulations that followed. Simulated monitor data at the locations of actual monitors were then generated that contain error representative of instrument imprecision. From the simulated monitor data, four exposure metrics were calculated: central monitor and unweighted, population-weighted, and area-weighted averages. For each metric, the amount and type of error relative to the simulated pollutant fields are characterized and the impact of error on an epidemiologic time-series analysis is predicted. The amount of error, as indicated by a lack of spatial autocorrelation, is greater for primary pollutants than for secondary pollutants and is only moderately reduced by averaging across monitors; more error will result in less statistical power in the epidemiologic analysis. The type of error, as indicated by the correlations of error with the monitor data and with the true ambient concentration, varies with exposure metric, with error in the central monitor metric more of the classical type (i.e., independent of the monitor data) and error in the spatial average metrics more of the Berkson type (i.e., independent of the true ambient concentration). Error type will affect the bias in the health risk estimate, with bias toward the null and away from the null predicted depending on the exposure metric; population-weighting yielded the least bias.

# Goldman, G. T., et al. (2010). "Ambient air pollutant measurement error: characterization and impacts in a time-series epidemiologic study in Atlanta." Environmental Science and Technology 44(19): 7692-7698.

In time-series studies of ambient air pollution and health in large urban areas, measurement errors associated with instrument precision and spatial variability vary widely across pollutants. In this paper, we characterize these errors for selected air pollutants and estimate their impacts on epidemiologic results from an ongoing study of air pollution and emergency department visits in Atlanta. Error was modeled for daily measures of 12 air pollutants using collocated monitor data to characterize instrument precision and data from multiple study area monitors to estimate population-weighted spatial variance. Time-series simulations of instrument and spatial error were generated for each pollutant, added to a reference pollutant time-series, and used in a Poisson generalized linear model of air pollution and cardiovascular emergency department visits. Reductions in risk ratio due to instrument precision error were less than 6%. Error due to spatial variability resulted in average risk ratio reductions of less than 16% for secondary pollutants (O(3), PM(2.5) sulfate, nitrate and ammonium) and between 43% and 68% for primary pollutants (NO(x), NO(2), SO(2), CO, PM(2.5) elemental carbon); pollutants of mixed origin (PM(10), PM(2.5), PM(2.5) organic carbon) had intermediate impacts. Quantifying impacts of measurement error on health effect estimates improves interpretation across ambient pollutants.

# Goldman, G. T., et al. (2011). "Impact of exposure measurement error in air pollution epidemiology: Effect of error type in time-series studies." Environmental Health: A Global Access Science Source 10: 61.

Background: Two distinctly different types of measurement error are Berkson and classical. Impacts of measurement error in epidemiologic studies of ambient air pollution are expected to depend on error type. We characterize measurement error due to instrument imprecision and spatial variability as multiplicative (i.e. additive on the log scale) and model it over a range of error types to assess impacts on risk ratio estimates both on a per measurement unit basis and on a per interquartile range (IQR) basis in a time-series study in Atlanta.

Methods: Daily measures of twelve ambient air pollutants were analyzed: NO2, NOx, O3, SO2, CO, PM10 mass, PM2.5 mass, and PM2.5 components sulfate, nitrate, ammonium, elemental carbon and organic carbon. Semivariogram analysis was applied to assess spatial variability. Error due to this spatial variability was added to a reference pollutant time-series on the log scale using Monte Carlo simulations. Each of these time-series was exponentiated and introduced to a Poisson generalized linear model of cardiovascular disease emergency department visits.

Results: Measurement error resulted in reduced statistical significance for the risk ratio estimates for all amounts (corresponding to different pollutants) and types of error. When modelled as classical-type error, risk ratios were attenuated, particularly for primary air pollutants, with average attenuation in risk ratios on a per unit of measurement basis ranging from 18% to 92% and on an IQR basis ranging from 18% to 86%. When modelled as Berkson-type error, risk ratios per unit of measurement were biased away from the null hypothesis by 2% to 31%, whereas risk ratios per IQR were attenuated (i.e. biased toward the null) by 5% to 34%. For CO modelled error amount, a range of error types were simulated and effects on risk ratio bias and significance were observed.

Conclusions: For multiplicative error, both the amount and type of measurement error impact health effect estimates in air pollution epidemiology. By modelling instrument imprecision and spatial variability as different error types, we estimate direction and magnitude of the effects of error over a range of error types.

# Gorai, A. K., et al. (2014). "A GIS based approach for assessing the association between air pollution and asthma in New York State, USA." International Journal of Environmental Research and Public Health 11(5): 4845-4869.

Studies on asthma have shown that air pollution can lead to increased asthma prevalence. The aim of this study is to examine the association between air pollution (fine particulate matter (PM2.5), sulfur dioxide (SO2) and ozone (O3)) and human health (asthma emergency department visit rate (AEVR) and asthma discharge rate (ADR)) among residents of New York, USA during the period 2005 to 2007. Annual rates of asthma were calculated from population estimates for 2005, 2006, and 2007 and number of asthma hospital discharge and emergency department visits. Population data for New York were taken from US Bureau of Census, and asthma data were obtained from New York State Department of Health, National Asthma Survey surveillance report. Data on the concentrations of PM2.5, SO2 and ground level ozone were obtained from various air quality monitoring stations distributed in different counties. Annual means of these concentrations were compared to annual variations in asthma prevalence by using Pearson correlation coefficient. We found different associations between the annual mean concentration of PM2.5, SO2 and surface ozone and the annual rates of asthma discharge and asthma emergency visit from 2005 to 2007. A positive correlation coefficient was observed between the annual mean concentration of PM2.5, and SO2 and the annual rates of asthma discharge and asthma emergency department visit from 2005 to 2007. However, the correlation coefficient between annual mean concentrations of ground ozone and the annual rates of asthma discharge and asthma emergency visit was found to be negative from 2005 to 2007. Our study suggests that the association between elevated concentrations of PM2.5 and SO2 and asthma prevalence among residents of New York State in USA is consistent enough to assume concretely a plausible and significant association.

# Greenwald, R., et al. (2013). "Associations between source-indicative pollution metrics and increases in pulmonary inflammation and reduced lung function in a panel of asthmatic children." Air Quality, Atmosphere and Health 6(2): 487-499.

Exposure to traffic-related air pollution may pose an elevated risk of respiratory harm to asthmatic children. The goal of this study was to investigate the association between exposure to specific classes of air pollutants and respiratory response in a panel of asthmatic children in El Paso, Texas. Air pollution and health response was measured at two elementary schools in El Paso with different levels of air pollution exposure. A high-exposure school was adjacent to the U.S.–Mexico border in close proximity to a major border crossing for diesel truck traffic, while the low-exposure school was in a suburban area distant from major roadways. The indoor and outdoor concentration of particle- and gas-phase pollutants was measured at each school for 13 weeks. Speciation of pollutants was performed to help identify sources. Each week, a panel of 38 asthmatic students performed pulmonary function and exhaled nitric oxide tests and completed asthma symptom questionnaires. Changes in both lung function and airway inflammation were significantly associated with pollutants with known traffic-related sources. FEV1 declined by up to 5 % in association with an interquartile range increase in the concentration of volatile organic compounds with traffic sources. Exhaled nitric oxide increased 1–5 % in association with these same compounds as well as with particulate black carbon (which also has a traffic-related source). No associations were observed between health response and pollutants with non-roadway sources. Exposure to traffic-related air pollution may lead to increased airway inflammation and decreased lung function in asthmatic children.

# Grosjean, D. and M. W. M. Hisham (1992). "A passive sampler for atmospheric ozone." Journal of the Air and Waste Management Association 42(2): 169-173.

A simple, cost-effective passive sampler has been developed for the determination of atmospheric ozone. This passive sampler is based on a colorant which fades upon reaction with ozone, whose concentration can be determined by reflectance measurement of the color change. Direct, on-site measurements are possible, and no chemical analyses are needed.

Sampler design and validation studies have been carried out and included quantitative determination of color change vs exposure time (1-8 days), color change vs. ozone concentration (30-350 ppb), and response to changes in sampler configuration that modify the passive sampling rate. With indigo carmine as the colorant, the detection limits are 30 ppb. day and 120 ppb. day using a plastic grid and a Teflon filter, respectively, as diffusion barriers. Interferences from nitrogen dioxide, formaldehyde and peroxyacetyl nitrate are 15, 4 and 16 percent, respectively, thus resulting in a negligible bias when measuring ozone in ambient air.

# Gryparis, A., et al. (2007). "Controlling for confounding in the presence of measurement error in hierarchical models: A Bayesian approach." Journal of Exposure Science and Environmental Epidemiology 17: S20-S28.

# Gryparis, A., et al. (2009). "Measurement error caused by spatial misalignment in environmental epidemiology." Biostatistics 10(2): 258-274.

In many environmental epidemiology studies, the locations and/or times of exposure measurements and health assessments do not match. In such settings, health effects analyses often use the predictions from an exposure model as a covariate in a regression model. Such exposure predictions contain some measurement error as the predicted values do not equal the true exposures. We provide a framework for spatial measurement error modeling, showing that smoothing induces a Berkson-type measurement error with nondiagonal error structure. From this viewpoint, we review the existing approaches to estimation in a linear regression health model, including direct use of the spatial predictions and exposure simulation, and explore some modified approaches, including Bayesian models and out-of-sample regression calibration, motivated by measurement error principles. We then extend this work to the generalized linear model framework for health outcomes. Based on analytical considerations and simulation results, we compare the performance of all these approaches under several spatial models for exposure. Our comparisons underscore several important points. First, exposure simulation can perform very poorly under certain realistic scenarios. Second, the relative performance of the different methods depends on the nature of the underlying exposure surface. Third, traditional measurement error concepts can help to explain the relative practical performance of the different methods. We apply the methods to data on the association between levels of particulate matter and birth weight in the greater Boston area.

# Guay, M., et al. (2011). "Assessment of long-term exposure to air pollution in a longitudinal national health survey." Journal of Exposure Science and Environmental Epidemiology 21(4): 337-342.

Self-reported data on the municipality of residence were used to assess long-term exposure to outdoor air pollution from 1980 to 2002 in the longitudinal Canadian National Population Health Survey. Exposure to carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, and particulate matter was determined using data obtained from fixed-site air pollution monitors operated principally in urban areas. Four different methods of attributing pollution exposure were used based on residence in (1) 1980, (2) 1994, (3) 1980 and 1994, and (4) at all locations between 1980 and 2002. Between 1,693 and 4,274 of 10,515 members of the cohort could be assigned exposures to individual pollutants using these methods. On average, subjects spent 71.4% of the 1980-2002 period in the census subdivision where they lived in 1980. A single exposure measure in 1980 or 1994 or a mean of the two measures was highly correlated (r>0.7, P<0.0001) with a measure which accounted for all moves between 1980 and 2002. Although our ability to characterize long-term exposure was constrained by a lack of data from fixed-site monitors, the low frequency of moves meant that measures based on a single year generally provided a good approximation of long-term exposure at the census subdivision level.

# Guo, Y., et al. (2009). "The association between fine particulate air pollution and hospital emergency room visits for cardiovascular diseases in Beijing, China." Science of the Total Environment 407(17): 4826-4830.

BACKGROUND: Because epidemiological studies have yielded different results, the association between exposure to fine particulate matter less than 2.5 microm in aerodynamic diameter (PM(2.5)) and acute events of cardiovascular diseases (CVD) is unknown. Additionally, no research has been conducted to explore the association between PM(2.5) and hospital emergency room (ER) visits of cardiovascular diseases in Beijing, China.

OBJECTIVE: To explore the association between PM(2.5) and the hospital ER visits in Beijing, China for CVD {(International Classification of Diseases, 10th vision (ICD-10): I00-I99)}.

METHODS: We collected data for daily hospital ER visits for CVD from the Peking University Third Hospital, daily ambient PM(2.5) data from a fixed monitor site at Peking University, and data on the daily level of gaseous air pollutants {sulfur dioxide (SO(2)) and nitrogen dioxide (NO(2))} from the Beijing Municipal Environmental Monitoring Center between June 1, 2004 and December 31, 2006. A time-stratified case-crossover design was used to evaluate associations between CVD health outcomes and ambient air pollutants.

RESULTS: 8377 hospital ER visits of CVD were collected in our study. After adjusting the temperature and the relative humidity, the associations for 10 microg/m(3) increases in levels of PM(2.5), SO(2), or NO(2) and hospital ER visits for cardiovascular diseases were statistically significant with odds ratios (ORs) of 1.005{95% confidence interval (CI): 1.001-1.009}, 1.014(95% CI: 1.004-1.024), and 1.016(95% CI: 1.003-1.029), respectively.

CONCLUSION: These findings suggest that elevated levels of ambient air pollutants are associated with the increase in hospital ER visits for CVD in Beijing, China.

# Ha, E. H., et al. (2001). "Is air pollution a risk factor for low birth weight in Seoul?" Epidemiology 12(6): 643-648.

Environmental factors contributing to reduced birth weight are of great concern because of the well-known relation of birth weight to infant mortality and adverse effects in later life. We examined the associations between air pollution exposures during pregnancy and low birth weight among all full-term births (gestational age 37-44 weeks) for a 2-year period (January 1996 through December 1997) in Seoul, South Korea. We evaluated these associations with a generalized additive logistic regression adjusting for gestational age, maternal age, parental educational level, parity, and infant sex. We used smoothing plots with generalized additive models to analyze the exposure-response relation for each air pollutant. The adjusted relative risk of low birth weight was 1.08 [95% confidence interval (CI) = 1.04-1.12] for each interquartile increase for carbon monoxide concentrations during the first trimester of pregnancy. The relative risks were 1.07 (95% CI = 1.03-1.11) for nitrogen dioxide, 1.06 (95% CI = 1.02-1.10) for sulfur dioxide, and 1.04 (95% CI = 1.00-1.08) for total suspended particles also for interquartile increase in exposure. Carbon monoxide, nitrogen dioxide, sulfur dioxide, and total suspended particle concentrations in the first trimester of pregnancy period are risk factors for low birth weight.

# Hagenbjork-Gustafsson, A., et al. (2009). "Field evaluation of the Ogawa Diffusive Sampler for NO(2)/NO(x) in a cold climate." Epidemiology 20(6): S161.

Background and Objective: The Ogawa diffusive sampler is used for NO2/NOx measurements in ambient air monitoring networks. Field comparisons with reference monitors have been carried out in Texas and Michigan. The sampler is currently used in the ESCAPE project measuring spatial variation in 40 different areas in Europe. Aims; assess NO2 and NOx uptake rates, and perform field comparisons with chemiluminescence monitors, in a cold climate. Methods: Weekly parallel measurements of NO2 (NOx) were conducted at 13(4) occasions in Umeå, Sweden and at 11(11) occasions at two sites in Malmö, Sweden (°C = 2,4–17,3). Nineteen(9) parallel measurements of NO2 (NOx) were conducted at three sites in Umeå (°C = -0,3–(-13,8)). Results: For temperatures above zero the mean sampling rate for NO2 (NOx) was 8,69 (9,88) ml/min with a coefficient of variation of 14(16)% (N = 35(26)). The mean sampling rate for temperatures below zero was 7,04 (7,13) ml/min with a coefficient of variation of 16(12)% (N = 19(9)). The mean difference between the NO2 concentration estimated with Ogawa and with chemiluminescence was 0,6% (N = 54). The concentration of NO2 fell between 10 and 54 µg /m3. Regression analysis of Ogawa versus the reference method for NO2 showed a good agreement (R2 = 0.85). The mean difference between the NOx concentration estimated with Ogawa and with chemiluminescence was 0,3% (N = 32). NO2 (NOx) concentrations determined according to the Ogawa protocol differed from chemiluminescence by -4,9% and 23% respectively. The theoretical sampling rate was found to underestimate the nitrogen dioxide concentration with about 27%. Conclusion: The sampler has shown to perform well for NO2 in a cold climate. For NOx it is advisable to use our estimated uptake rate.

# Hanna, S. R., et al. (1993). "Hazardous gas model evaluation with field observations." Atmospheric Environment, Part A: General Topics 27(15): 2265-2285.

# Hanna, S. R., et al. (2001). "Evaluation of the ADMS, AERMOD, and ISC3 dispersion models with the OPTEX, Duke Forest, Kincaid, Indianapolis and Lovett field datasets." International Journal of Environment and Pollution 16: 301-314.

The model evaluation exercise addresses the question of whether the new models, ADMS and AERMOD, produce improvements over ISC3 when compared with a range of field observations. ADMS and AERMOD have similar state-of-the-art scientific components, whereas ISC3 contains 1960s technology. The five sets of field observations used in the statistical evaluation represent a cross-section of typical scenarios encountered by modellers. The OPTEX database deals with non-buoyant tracer releases within an oil refinery complex, and the Duke Forest database involves non-buoyant tracer releases from area and volume sources in an open field. The Kincaid, Indianapolis and Lovett databases all deal with buoyant plumes from tall stacks at power plants. However, the settings for each are quite different, since the Kincaid plant is surrounded by flat farmland, the Indianapolis plant is located in an urban environment, and the Lovett plant is situated in a valley surrounded by complex terrain with monitors at higher elevations than the stack. Analysis of the model performance measures suggests that ISC3 typically overpredicts and has a scatter of about a factor of three. Approximately 33% of its predictions are within a factor of two of observations. The ADMS performance is slightly better than the AERMOD performance and both perform better than ISC3. On average, ADMS underpredicts by about 20% and AERMOD underpredicts by about 40%, and both have a scatter of about a factor of two. Approximately 53% and 46% of the ADMS and AERMOD predictions, respectively, are within a factor of two of observations. Considering only the highest predicted and observed concentrations, ISC3 overpredicts by a factor of seven, on average, while ADMS and AERMOD underpredict by, on average, 20%.

# Hei (2012). Effects of short-term exposure to air pollution on hospital admissions of young children for acute lower respiratory infections in Ho Chi Minh City, Vietnam. Boston, MA, Health Effects Institute, HEI Collaborative Working Group on Air Pollution, Poverty, and Health in Ho Chi Minh City: 5-72; discussion 73-83.

There is emerging evidence, largely from studies in Europe and North America, that economic deprivation increases the magnitude of morbidity and mortality related to air pollution. Two major reasons why this may be true are that the poor experience higher levels of exposure to air pollution, and they are more vulnerable to its effects--in other words, due to poorer nutrition, less access to medical care, and other factors, they experience more health impact per unit of exposure. The relations among health, air pollution, and poverty are likely to have important implications for public health and social policy, especially in areas such as the developing countries of Asia where air pollution levels are high and many live in poverty. The aims of this study were to estimate the effect of exposure to air pollution on hospital admissions of young children for acute lower respiratory infection (ALRI\*) and to explore whether such effects differed between poor children and other children. ALRI, which comprises pneumonia and bronchiolitis, is the largest single cause of mortality among young children worldwide and is responsible for a substantial burden of disease among young children in developing countries. To the best of our knowledge, this is the first study of the health effects of air pollution in Ho Chi Minh City (HCMC), Vietnam. For these reasons, the results of this study have the potential to make an important contribution to the growing literature on the health effects of air pollution in Asia. The study focused on the short-term effects of daily average exposure to air pollutants on hospital admissions of children less than 5 years of age for ALRI, defined as pneumonia or bronchiolitis, in HCMC during 2003, 2004, and 2005. Admissions data were obtained from computerized records of Children's Hospital 1 and Children's Hospital 2 (CH1 and CH2) in HCMC. Nearly all children hospitalized for respiratory illnesses in the city are admitted to one of these two pediatric hospitals. Daily citywide 24-hour average concentrations of particulate matter (PM) < or =10 microm in aerodynamic diameter (PM10), nitrogen dioxide (NO2), and sulfur dioxide (SO2) and 8-hour maximum average concentrations of ozone (O3) were estimated from the HCMC Environmental Protection Agency (HEPA) ambient air quality monitoring network. Daily meteorologic information including temperature and relative humidity were collected from KTTV NB, the Southern Regional Hydro-Meteorological Center. An individual-level indicator of socioeconomic position (SEP) was based on the degree to which the patient was exempt from payment according to hospital financial records. A group-level indicator of SEP was based on estimates of poverty prevalence in the districts of HCMC in 2004, obtained from a poverty mapping project of the Institute of Economic Research in HCMC, in collaboration with the General Statistics Office of Vietnam and the World Bank. Poverty prevalence was defined using the poverty line set by the People's Committee of HCMC of 6 million Vietnamese dong (VND) annual income. Quartiles of district-level poverty prevalence were created based on poverty prevalence estimates for each district. Analyses were conducted using both time-series and case-crossover approaches. In the absence of measurement error, confounding, and other sources of bias, the two approaches were expected to provide estimates that differed only with regard to precision. For the time-series analyses, the unit of observation was daily counts of hospital admissions for ALRI. Poisson regression with smoothing functions for meteorologic variables and variables for seasonal and long-term trends was used. Case-crossover analyses were conducted using time-stratified selection of controls. Control days were every 7th day from the date of admission within the same month as admission. Large seasonal differences were observed in pollutant levels and hospital admission patterns during the investigation period for HCMC. Of the 15,717 ALRI admissions occurring within the study period, 60% occurred in the rainy season (May through October), with a peak in these admissions during July and August of each year. Average daily concentrations for PM10, O3, NO2, and SO2 were 73, 75, 22, and 22 microg/m3, respectively, with higher pollutant concentrations observed in the dry season (November through April) compared with the rainy season. As the time between onset of illness and hospital admission was thought to range from 1 to 6 days, it was not possible to specify a priori a single-day lag. We assessed results for single-day lags from lag 0 to lag 10, but emphasize results for an average of lag 1-6, since this best reflects the case reference period. Results were robust to differences in temperature lags with lag 0 and the average lag (1-6 days); results for lag 0 for temperature are presented. Results differed markedly when analyses were stratified by season, rather than simply adjusted for season. ALRI admissions were generally positively associated with ambient levels of PM10, NO2, and SO2 during the dry season (November-April), but not the rainy season (May-October). Positive associations between O3 and ALRI admissions were not observed in either season. We do not believe that exposure to air pollution could reduce the risk of ALRI in the rainy season and infer that these results could be driven by residual confounding present within the rainy season. The much lower correlation between NO2 and PM10 levels during the rainy season provides further evidence that these pollutants may not be accurate indicators of exposure to air pollution from combustion processes in the rainy season. Results were generally consistent across time-series and case-crossover analyses. In the dry season, risks for ALRI hospital admissions with average pollutant lag (1-6 days) were highest for NO2 and SO2 in the single-pollutant case-crossover analyses, with excess risks of 8.50% (95% CI, 0.80-16.79) and 5.85% (95% CI, 0.44-11.55) observed, respectively. NO2 and SO2 effects remained higher than PM10 effects in both the single-pollutant and two-pollutant models. The two-pollutant model indicated that NO2 confounded the PM10 and SO2 effects. For example, PM10 was weakly associated with an excess risk in the dry season of 1.25% (95% CI, -0.55 to 3.09); after adjusting for SO2 and O3, the risk estimate was reduced but remained elevated, with much wider confidence intervals; after adjusting for NO2, an excess risk was no longer observed. Though the effects seem to be driven by NO2, the statistical limitations of adequately addressing collinearity, given the high correlation between PM10 and NO2 (r = 0.78), limited our ability to clearly distinguish between PM10 and NO2 effects. In the rainy season, negative associations between PM10 and ALRI admissions were observed. No association with O3 was observed in the single-pollutant model, but O3 exposure was negatively associated with ALRI admissions in the two-pollutant model. There was little evidence of an association between NO2 and ALRI admissions. The single-pollutant estimate from the case-crossover analysis suggested a negative association between NO2 and ALRI admissions, but this effect was no longer apparent after adjustment for other pollutants. Although associations between SO2 and ALRI admissions were not observed in the rainy season, point estimates for the case-crossover analyses suggested negative associations, while time-series (Poisson regression) analyses suggested positive associations--an exception to the general consistency between case-crossover and time-series results. Results were robust to differences in seasonal classification. Inclusion of rainfall as a continuous variable and the seasonal reclassification of selected series of data did not influence results. No clear evidence of station-specific effects could be observed, since results for the different monitoring stations had overlapping confidence intervals. In the dry season, increased concentrations of NO2 and SO2 were associated with increased hospital admissions of young children for ALRI in HCMC. PM10 could also be associated with increased hospital admissions in the dry season, but the high correlation of 0.78 between PM10 and NO2 levels limits our ability to distinguish between PM10 and NO2 effects. Nevertheless, the results support the presence of an association between combustion-source pollution and increased ALRI admissions. There also appears to be evidence of uncontrolled negative confounding within the rainy season, with higher incidence of ALRI and lower pollutant concentrations overall. Exploratory analyses made using limited historical and regional data on monthly prevalence of respiratory syncytial virus (RSV) suggest that an unmeasured, time-varying confounder (RSV, in this case) could have, in an observational study like this one, created enough bias to reverse the observed effect estimates of pollutants in the rainy season. In addition, with virtually no RSV incidence in the dry season, these findings also lend some credibility to the notion that RSV could influence results primarily in the rainy season. Analyses were not able to identify differential effects by individual-level indicators of SEP, mainly due to the small number of children classified as poor based on information in the hospitals' financial records. Analyses assessing differences in effect by district-level indicator of SEP did not indicate a clear trend in risk across SEP quartiles, but there did appear to be a slightly higher risk among the residents of districts with the highest quartile of SEP. As these are the districts within the urban center of HCMC, results could be indicative of increased exposures for residents living within the city center. (ABSTRACT TRUNCATED)

# Heinrich, J., et al. (2013). "Long-term exposure to NO2 and PM10 and all-cause and cause-specific mortality in a prospective cohort of women." Occupational and Environmental Medicine 70(3): 179-186.

We assessed whether long-term exposure to air pollution is associated with all-cause and cause-specific mortality during a period of declining particulate matter concentrations. Approximately 4800 women aged 55 years from North Rhine-Westphalia, Germany, were followed for up to 18 years. Exposure to air pollution was assessed in two ways: (1) using the distance between the residential address and the nearest major road, as calculated from Geographic Information System data and (2) calculating 1-year average particulate matter concentrations below 10 µm (PM(10)) and nitrogen dioxide (NO(2)) levels using data from the nearest air-monitoring station data to the subjects' residences. Ninety-two per cent of all subjects lived in the same community during the entire follow-up period. Associations between mortality and exposure were assessed using Cox's proportional hazards models, including confounder adjustment. Sixteen per cent of women passed away during the follow-up period. An increase of 7 μg /m(3) PM(10) (IQR) was associated with an increased HR for all-cause (HR 1.15, 95% CI (1.04 to 1.27)), cardiopulmonary (HR 1.39, 95% CI (1.17 to 1.64)), and lung cancer mortality (HR 1.84, 95% CI (1.23 to 2.74)). An increase of 16 μg /m(3) (IQR) NO(2) exposure was associated with all-cause (HR 1.18, 95% CI (1.07 to 1.30)) and cardiopulmonary mortality (HR 1.55, 95% CI (1.30 to 1.84)). The association between cardiopulmonary mortality and PM(10) was reduced for the extended follow-up period, during which PM(10) concentrations (but not NO(2) concentrations) were lower. Living close to a major road was associated with an increased relative risk for all-cause, cardiopulmonary and respiratory mortality. These associations were temporally stable. Long-term exposure to ambient PM(10) and NO(2) was associated with increased mortality rates.

# Heist, D., et al. (2013). "Estimating near-road pollutant dispersion: A model inter-comparison." Transportation Research Part D: Transport and Environment 25: 93-105.

A model inter-comparison study to assess the abilities of steady-state Gaussian dispersion models to capture near-road pollutant dispersion has been carried out with four models (AERMOD, run with both the area-source and volume-source options to represent roadways, CALINE, versions 3 and 4, ADMS and RLINE). Two field tracer studies are used: the Idaho Falls tracer study and the Caltrans Highway 99 tracer study. Model performance measures are calculated using concentrations (observed and estimated) that are paired in time and space, since many of the health related questions involve outcomes associated with spatially and temporally distributed human activities. All four models showed an ability to estimate the majority of downwind concentrations within a factor of two of the observations. RUNE, AERMOD-V, and ADMS, also have the capability to predict concentrations upwind of the roadway that result from low-speed meandering of the plume. Generally, RLINE, ADMS, and AERMOD (both source types) had overall performance statistics that were broadly similar, while CALINE 3 and 4 both produced a larger degree of scatter in their concentration estimates. The models performed best for near-neutral conditions in both tracer studies, but had mixed results under convective and stable conditions. Published by Elsevier Ltd.

# Héroux, M. E., et al. (2010). "Predictors of indoor air concentrations in smoking and non-smoking residences." International Journal of Environmental Research and Public Health 7(8): 3080-3099.

Indoor concentrations of air pollutants (benzene, toluene, formaldehyde, acetaldehyde, acrolein, nitrogen dioxide, particulate matter, elemental carbon and ozone) were measured in residences in Regina, Saskatchewan, Canada. Data were collected in 106 homes in winter and 111 homes in summer of 2007, with 71 homes participating in both seasons. In addition, data for relative humidity, temperature, air exchange rates, housing characteristics and occupants' activities during sampling were collected. Multiple linear regression analysis was used to construct season-specific models for the air pollutants. Where smoking was a major contributor to indoor concentrations, separate models were constructed for all homes and for those homes with no cigarette smoke exposure. The housing characteristics and occupants' activities investigated in this study explained between 11% and 53% of the variability in indoor air pollutant concentrations, with ventilation, age of home and attached garage being important predictors for many pollutants.

# Hong, J. H., et al. (2007). "Application of an in-situ measurement system to determine HONO levels in an indoor environment." Journal of Korean Society for Atmospheric Environment 23(2): 191-202.

We developed an in-situ analyzer to understand the HONO levels in indoor environments. The in-situ measurement system utilizes a diffusion scrubber and luminol chemiluminescence to measure the HONO concentration with time resolution of 4-minute. Concentrations of NO, NO2, and HONO were determined at an indoor air of an apartment for 9 days using the developed in-situ analyzer. Indoor HONO concentrations were highly elevated when a gas range was operated. Enhancements of the indoor NO, NO2, and HONO concentrations during combustion indicate that the observed indoor HONO was formed by direct emission. In addition to the direct emission, the indoor HONO was partially generated from heterogeneous reactions of NO2 on indoor surfaces, which was supported by strong relationships between peak NO, NO2, and HONO concentrations, high HONO/NO2 ratio and a weak correlation between NO and HONO concentrations. Additionally, three combustion experiments during the whole measurement period were performed to investigate the effects of unvented and vented gas burning on the HONO, NO, and concentrations and their decay. The decay rate of the HONO concentration was significantly less than the NO and NO2 decay rates for all the experiments, indicating that the lifetimes of trace nitrogen species in indoor environment varied in the order approximately HONO>NO2>NO.

# Hsieh, Y. L., et al. (2010). "Air pollution and hospital admissions for myocardial infarction in a subtropical city: Taipei, Taiwan." Journal of Toxicology and Environmental Health, Part A: Current Issues 73(11): 757-765.

This study was undertaken to determine whether there was a correlation between air pollutant levels and hospital admissions for myocardial infarction (MI) in Taipei, Taiwan. Hospital admissions for MI and ambient air pollution data for Taipei were obtained for the period 1996-2006. The relative risk of hospital admissions was estimated using a case-crossover approach, controlling for weather variables, day of the week, seasonality, and long-term time trends. In the single-pollutant models, on warm days (>23 degrees C) statistically significant positive associations were found for all pollutants except sulfur dioxide (SO(2)). On cool days (<23 degrees C), all pollutants were significantly associated with increased MI admissions except SO(2). For the two-pollutant model, ozone (O(3)) and nitrogen dioxide (NO(2)) were significant in combination with each of the other four pollutants both on warm and cool days for higher admissions for MI. This study provides evidence that higher levels of ambient air pollutants increase the risk of hospital admissions for MI.

# Hwang, B. F. and J. J. Jaakkola (2008). "Ozone and other air pollutants and the risk of oral clefts." Environmental Health Perspectives 116(10): 1411-1415.

BACKGROUND: Air pollution influences the development of oral clefts in animals. There are few epidemiologic data on the relation of prenatal air pollution exposure and the risk of oral clefts. OBJECTIVES: Our goal in this study was to assess the relations between exposure to ambient air pollution and the risk of cleft lip with or without cleft palate (CL/P). METHODS: We conducted a population-based case-control study of all 653 cases of CL/P and a random sample of 6,530 control subjects from 721,289 Taiwanese newborns in 2001-2003. We used geographic information systems to form exposure parameters for sulfur dioxide, nitrogen oxides, ozone, carbon monoxide, and particulate matter with an aerodynamic diameter <or= 10 microm (PM10) during the first 3 months of pregnancy using inverse distance weighting method. We present the effect estimates as odds ratios (ORs) per 10-ppb change for SO2, NO(x), and O3, 100-ppb change for CO, and 10-microg/m3 change for PM10. RESULTS: The risk of CL/P was increased in relation to O3 levels in the first gestational month [adjusted OR = 1.20; 95% confidence interval (CI), 1.02-1.39] and second gestational month (adjusted OR = 1.25; 95% CI, 1.03-1.52) in the range from 16.7 ppb to 45.1 ppb, but was not related to CO, NO(x), SO2, or PM10. CONCLUSIONS: The study provides new evidence that exposure to outdoor air O3 during the first and second month of pregnancy may increase the risk of CL/P. Similar levels of O3 are encountered globally by large numbers of pregnant women.

# Hwang, B. F. and Y. L. Lee (2010). "Air pollution and prevalence of bronchitic symptoms among children in Taiwan." Chest 138(4): 956-964.

BACKGROUND: There were limited studies concerning ambient air pollution exposure on development of bronchitic symptoms among children. These studies provided suggestive but inconclusive results. Therefore, the objective of this study is to assess the association between air pollutants and the prevalence of bronchitic symptoms in the Taiwan Children Health Study.

METHODS: We conducted a nationwide cross-sectional study of 5,049 Taiwanese children in 2007. Routine air pollution monitoring data were used for sulfur dioxide (SO(2)), nitrogen dioxides (NO(2)), ozone (O(3)), carbon monoxide (CO), and particles with an aerodynamic diameter ≤ 2.5 μm (PM(2.5)). The exposure parameters were calculated using the between-community 3-year average concentration. The effect estimates were presented as odds ratios (ORs) per interquartile changes for SO(2), NO(2), O(3), CO, and PM(2.5).

RESULTS: In the two-stage hierarchical model adjusting for confounding, the prevalence of bronchitic symptoms with asthma was positively associated with the between-community 3-year average concentrations of NO(2) (adjusted OR, 1.81 per 8.79 ppb; 95% CI, 1.14-2.86), and CO (OR, 1.31 per 105 ppb; 95% CI, 1.04-1.64). The prevalence of phlegm with no asthma was related to O(3) (OR, 1.32 per 8.77 ppb; 95% CI, 1.06-1.63).

CONCLUSIONS: The results suggest that long-term exposure to outdoor air pollutants, such as NO(2), CO, and O(3), may increase the prevalence of bronchitic symptoms among children.

# Hwang, B. F., et al. (2011). "Air pollution and stillbirth: A population-based case-control study in Taiwan." Environmental Health Perspectives 119(9): 1345-1349.

Background: There is limited evidence suggesting that prenatal exposure to ambient air pollutants may increase the risk of stillbirth, but previous epidemiological studies have not elaborated the most susceptible gestational period for the effects of air pollution exposure on stillbirth. Objectives: We estimated associations between exposure to ambient air pollutants and stillbirth, with special reference to the assessment of gestational periods when the fetus is most susceptible. Methods: We conducted a population-based case–control study in Taiwan. The case group consisted of 9,325 stillbirths, and the control group included 93,250 births randomly selected from 1,510,064 Taiwanese singleton newborns in 2001–2007. Adjusted logistic regression models were used to estimate odds ratios (ORs) per 10-ppb change for ozone and nitrogen dioxide, 1-ppb change for sulfur dioxide (SO2), 10-μg/m3 change for particulate matter with aerodynamic diameter ≤ 10 μm (PM10), and 100-ppb change for carbon monoxide during different gestational periods and according to term or preterm (< 37 weeks) birth status. Results: Stillbirth increased in association with a 1-ppb increase in first-trimester SO2 [adjusted OR = 1.02; 95% confidence interval (CI), 1.00–1.04], particularly among preterm births (adjusted OR = 1.04; 95% CI, 1.01–1.07). Stillbirth was also associated with a 10-μg/m3 increase in PM10 during the first (adjusted OR = 1.02; 95% CI, 1.00–1.05) and second (adjusted OR = 1.02; 95% CI, 1.00–1.04) month of gestation, and, as with SO2, associations appeared to be restricted to preterm births (first-trimester adjusted OR = 1.03; 95% CI, 1.00–1.07). Conclusion: The study provides evidence that exposure to outdoor air SO2 and PM10 may increase the risk of stillbirth, especially among preterm births, and that the most susceptible time periods for exposure are during the first trimester of gestation.

# Hyttinen, M., et al. (2006). "Removal of ozone on clean, dusty and sooty supply air filters." Atmospheric Environment 40(2): 315-325.

The removal of ozone (O-3) on supply air filters was studied. Especially, the effects of dust load, diesel soot, relative humidity (RH), and exposure time on the removal of O-3 were investigated. Some loss of O-3 was observed in all the filters, except in an unused G3 pre-filter made of polyester. Dust load and quality influenced the reduction of O-3; especially, diesel soot removed O-3 effectively. Increasing the RH resulted in a larger O-3 removal. The removal of O-3 was highest in the beginning of the test, but it declined within 2 h reaching almost a steady state as the exposure continued. However, the sooty filters continued to remove as much as 25-30% of O-3. Up to 11% of O-3 removed participated in the production of formaldehyde. Small amounts of other oxidation products were also detected. (c) 2005 Elsevier Ltd. All rights reserved.

# Ito, K., et al. (2011). "Fine particulate matter constituents associated with cardiovascular hospitalizations and mortality in New York City." Environmental Health Perspectives 119(4): 467-473.

Background: Recent time-series studies have indicated that both cardiovascular mortality and hospitalizations were associated with particulate matter (PM). However, seasonal patterns of PM associations with these outcomes are not consistent, and PM components responsible for these associations have not been determined. We investigated this issue in New York City, where PM originates from regional and local combustion sources. Methods: We analyzed daily deaths and emergency hospitalizations for cardiovascular diseases (CVD) among those aged 40+ for their associations with fine particle mass (PM2.5), its chemical components, nitrogen dioxide (NO2), carbon monoxide, and sulfur dioxide for the years 2000-2006 using Poisson model adjusting for temporal/seasonal trends, temperature effects, and day-of-week. We estimated excess risks per inter-quartile-range increases at lag 0 through 3 days for warm (April-September) and cold (October-March) seasons. Results: The CVD mortality series exhibit strong seasonal trends, while the CVD hospitalization series show a strong day-of-week pattern. These outcome series were not correlated with each other but were individually associated with a number of PM2.5 chemical components from regional and local sources, each with different seasonal patterns and lags. Coal combustion-related components (e.g., selenium) were associated with CVD mortality in summer and CVD hospitalizations in winter, whereas elemental carbon and NO2 showed associations with these outcomes in both seasons. Conclusion: Local combustion sources, including traffic and residual oil burning, may play a year-round role in the associations between air pollution and CVD outcomes, but transported aerosols may explain the seasonal variation in associations shown by PM2.5 mass.

# Ivy, D., et al. (2008). "Development of ambient air quality population-weighted metrics for use in time-series health studies." Journal of the Air and Waste Management Association 58(5): 711-720.

A robust methodology was developed to compute population-weighted daily measures of ambient air pollution for use in time-series studies of acute health effects. Ambient data, including criteria pollutants and four fine particulate matter (PM) components, from monitors located in the 20-county metropolitan Atlanta area over the time period of 1999-2004 were normalized, spatially resolved using inverse distance-square weighting to Census tracts, denormalized using descriptive spatial models, and population-weighted. Error associated with applying this procedure with fewer than the maximum number of observations was also calculated. In addition to providing more representative measures of ambient air pollution for the health study population than provided by a central monitor alone and dampening effects of measurement error and local source impacts, results were used to evaluate spatial variability and to identify air pollutants for which ambient concentrations are poorly characterized. The decrease in correlation of daily monitor observations with daily population-weighted average values with increasing distance of the monitor from the urban center was much greater for primary pollutants than for secondary pollutants. Of the criteria pollutant gases, sulfur dioxide observations were least representative because of the failure of ambient networks to capture the spatial variability of this pollutant for which concentrations are dominated by point source impacts. Daily fluctuations in PM of particles less than 10 microm in aerodynamic diameter (PM10) mass were less well characterized than PM of particles less than 2.5 microm in aerodynamic diameter (PM2.5) mass because of a smaller number of PM10 monitors with daily observations. Of the PM2.5 components, the carbon fractions were less well spatially characterized than sulfate and nitrate both because of primary emissions of elemental and organic carbon and because of differences in measurement techniques used to assess these carbon fractions.

# Jaffe, D. H., et al. (2003). "Air pollution and emergency department visits for asthma among Ohio Medicaid recipients, 1991-1996." Environmental Research 91(1): 21-28.

We examined the effects of nitrogen dioxide (NO2), ozone (O3), particulate matter of <10 microm aerodynamic diameter (PM10), and sulfur dioxide (SO2) on asthmatics ages 5-34 years enrolled in Medicaid in Cincinnati, Cleveland, and Columbus, OH (N=5416). Our study period was for the summer months, June-August, from July 1, 1991 to June 30, 1996. We preformed Poisson regression analyses for the number of daily emergency department (ED) visits for asthma in each city and on the aggregate data controlling for time trends and minimum temperature. We found a 12% increased likelihood of an asthma ED visit per 50 microg/m3 increase in PM10 in Cleveland [95% confidence interval (CI)=0-27%] and a 35% increase per 50 microg/m3 increase in SO2 in Cincinnati (95% CI=9-21%). When data were analyzed for all three cities combined, the risk of an ED visit increased for all pollutant increases and specifically by 12% (95% CI=1-23%) per 50 microg/m3 increase in SO2. Attributable risk estimates show a five times greater impact on Cleveland over Cincinnati or Columbus. Between 1991 and 1996, air pollutants in Cincinnati, Cleveland, and Columbus increased ED visits for asthmatics enrolled in Medicaid.

# Jalaludin, B., et al. (2008). "Air pollution and ED visits for asthma in Australian children: A case-crossover analysis." International Archives of Occupational and Environmental Health 81(8): 967-974.

Objective We aimed to determine the effects of ambient air pollutants on emergency department (ED) visits for asthma in children. Methods We obtained routinely collected ED visit data for asthma (ICD9 493) and air pollution (PM10, PM2.5, O3, NO2, CO and SO2) and meteorological data for metropolitan Sydney for 1997–2001. We used the time stratified case-crossover design and conditional logistic regression to model the association between air pollutants and ED visits for four age-groups (1–4, 5–9, 10–14 and 1–14 years). Estimated relative risks for asthma ED visits were calculated for an exposure corresponding to the inter-quartile range in pollutant level. We included same day average temperature, same day relative humidity, daily temperature range, school holidays and public holidays in all models. Results Associations between ambient air pollutants and ED visits for asthma in children were most consistent for all six air pollutants in the 1–4 years age-group, for particulates and CO in the 5–9years age-group and for CO in the 10–14 years age-group. The greatest effects were most consistently observed for lag 0 and effects were greater in the warm months for particulates, O3 and NO2. In two pollutant models, effect sizes were generally smaller compared to those derived from single pollutant models. Conclusion We observed the effects of ambient air pollutants on ED attendances for asthma in a city where the ambient concentrations of air pollutants are relatively low.

# Jalaludin, B., et al. (2007). "Impact of ambient air pollution on gestational age is modified by season in Sydney, Australia." Environmental Health: A Global Access Science Source 6: 16.

BACKGROUND: The effect of individual pollutants and the period(s) during pregnancy when pollutant levels are likely to have most impact on preterm birth is not clear. We evaluated the effect of prenatal exposure to six common urban air pollutants in the Sydney metropolitan area on preterm birth. METHODS: We obtained information on all births in metropolitan Sydney between January 1, 1998 and December 31, 2000. For each birth, exposure to each air pollutant was estimated for the first trimester, the three months preceding birth, the first month after the estimated date of conception and the month prior to delivery. Gestational age was analysed as a categorical variable in logistic regression models. RESULTS: There were 123,840 singleton births in Sydney in 1998-2000 and 4.9% were preterm. Preterm birth was significantly associated with maternal age, maternal smoking, male infant, indigenous status and first pregnancy. Air pollutant levels in the month and three months preceding birth had no significant effect on preterm birth after adjusting for maternal and infant covariates. Ozone levels in the first trimester of pregnancy and spring months of conception and sulphur dioxide were associated with increased risks for preterm births. Nitrogen dioxide was associated with a decreased risk of preterm births. CONCLUSION: We found more protective than harmful associations between ambient air pollutants and preterm births with most associations non-significant. In view of these inconsistent associations, it is important to interpret the harmful effects with caution. If our results are confirmed by future studies then it will be imperative to reduce Sydney's already low air pollution levels even further.

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BACKGROUND: The effect of individual pollutants and the period(s) during pregnancy when pollutant levels are likely to have most impact on preterm birth is not clear. We evaluated the effect of prenatal exposure to six common urban air pollutants in the Sydney metropolitan area on preterm birth. METHODS: We obtained information on all births in metropolitan Sydney between January 1, 1998 and December 31, 2000. For each birth, exposure to each air pollutant was estimated for the first trimester, the three months preceding birth, the first month after the estimated date of conception and the month prior to delivery. Gestational age was analysed as a categorical variable in logistic regression models. RESULTS: There were 123,840 singleton births in Sydney in 1998-2000 and 4.9% were preterm. Preterm birth was significantly associated with maternal age, maternal smoking, male infant, indigenous status and first pregnancy. Air pollutant levels in the month and three months preceding birth had no significant effect on preterm birth after adjusting for maternal and infant covariates. Ozone levels in the first trimester of pregnancy and spring months of conception and sulphur dioxide were associated with increased risks for preterm births. Nitrogen dioxide was associated with a decreased risk of preterm births. CONCLUSION: We found more protective than harmful associations between ambient air pollutants and preterm births with most associations non-significant. In view of these inconsistent associations, it is important to interpret the harmful effects with caution. If our results are confirmed by future studies then it will be imperative to reduce Sydney's already low air pollution levels even further.

# Jalaludin, B., et al. (2006). "Associations between ambient air pollution and daily emergency department attendances for cardiovascular disease in the elderly (65+ years), Sydney, Australia." Journal of Exposure Science and Environmental Epidemiology 16(3): 225-237.

There are no reported studies on the effects of ambient air pollution on emergency department (ED) attendances in Sydney, Australia. This study aimed to determine associations between ambient air pollutants and ED attendances for cardiovascular disease (CVD) in those aged 65+ years. We constructed daily time series of hospital ED attendances, air pollutants and meteorological factors for the Sydney metropolitan area from 1 January 1997 to 31 December 2001. We used generalised linear models to determine associations between daily air pollution and daily ED attendances and controlled for the effects of long-term trends, seasonality, weather and other potential confounders. Increased ED attendances for all CVD, cardiac disease and ischaemic heart disease were seen with 24-h particulate pollution, 1-h NO(2), 8-h CO and 24-h SO(2). Air pollutants were associated with decreased ED attendances for stroke. The effects of air pollutants on CVD, cardiac disease and stroke attendances were generally greater in the cool period compared to the warm period. The single-pollutant effects of CO, O(3), NO(2) and SO(2) were essentially unchanged in two-pollutant models. Although air pollution levels in Sydney are relatively low compared to similar cities, we have demonstrated associations between ambient air pollutants and ED attendances for CVD in people aged 65+ years. Our study adds to the growing evidence for the effects of ambient air pollution on CVD outcomes even at relatively low ambient concentrations.

# Jarvis, D. L., et al. (2005). "Indoor nitrous acid and respiratory symptoms and lung function in adults." Thorax 60(6): 474-479.

Background: Nitrogen dioxide (NO2) is an important pollutant of indoor and outdoor air, but epidemiological studies show inconsistent health effects. These inconsistencies may be due to failure to account for the health effects of nitrous acid (HONO) which is generated directly from gas combustion and indirectly from NO2. Methods: Two hundred and seventy six adults provided information on respiratory symptoms and lung function and had home levels of NO2 and HONO measured as well as outdoor levels of NO2. The association of indoor HONO levels with symptoms and lung function was examined. Results: The median indoor HONO level was 3.10 ppb (IQR 2.05–5.09), with higher levels in homes with gas hobs, gas ovens, and in those measured during the winter months. Non-significant increases in respiratory symptoms were observed in those living in homes with higher HONO levels. An increase of 1 ppb in indoor HONO was associated with a decrease in forced expiratory volume in 1 second (FEV1) percentage (−0.96%; 95% CI −0.09 to −1.82) and a decrease in percentage FEV1/forced vital capacity (FVC) (−0.45%; 95% CI −0.06 to −0.83) after adjustment for relevant confounders. Measures of indoor NO2 were correlated with HONO (r = 0.77), but no significant association of indoor NO2 with symptoms or lung function was observed. After adjustment for NO2 measures, the association of HONO with low lung function persisted. Conclusion: Indoor HONO levels are associated with decrements in lung function and possibly with more respiratory symptoms. Inconsistencies between studies examining health effects of NO2 and use of gas appliances may be related to failure to account for this association.

# Jerrett, M., et al. (2009). "Long-term ozone exposure and mortality." New England Journal of Medicine 360(11): 1085-1095.

Background: Although many studies have linked elevations in tropospheric ozone to adverse health outcomes, the effect of long-term exposure to ozone on air pollution–related mortality remains uncertain. We examined the potential contribution of exposure to ozone to the risk of death from cardiopulmonary causes and specifically to death from respiratory causes. Methods: Data from the study cohort of the American Cancer Society Cancer Prevention Study II were correlated with air-pollution data from 96 metropolitan statistical areas in the United States. Data were analyzed from 448,850 subjects, with 118,777 deaths in an 18-year follow-up period. Data on daily maximum ozone concentrations were obtained from April 1 to September 30 for the years 1977 through 2000. Data on concentrations of fine particulate matter (particles that are 2.5 µm in aerodynamic diameter [PM2.5]) were obtained for the years 1999 and 2000. Associations between ozone concentrations and the risk of death were evaluated with the use of standard and multilevel Cox regression models. Results: In single-pollutant models, increased concentrations of either PM2.5 or ozone were significantly associated with an increased risk of death from cardiopulmonary causes. In two-pollutant models, PM2.5 was associated with the risk of death from cardiovascular causes, whereas ozone was associated with the risk of death from respiratory causes. The estimated relative risk of death from respiratory causes that was associated with an increment in ozone concentration of 10 ppb was 1.040 (95% confidence interval, 1.010 to 1.067). The association of ozone with the risk of death from respiratory causes was insensitive to adjustment for confounders and to the type of statistical model used. Conclusions: In this large study, we were not able to detect an effect of ozone on the risk of death from cardiovascular causes when the concentration of PM2.5 was taken into account. We did, however, demonstrate a significant increase in the risk of death from respiratory causes in association with an increase in ozone concentration.

# Kanno, S. and Y. Yanagisawa (1992). "Passive ozone/oxidant sampler with coulometric determination using iodine/nylon-6 charge-transfer complex." Environmental Science and Technology 26(4): 744-749.

# Katanoda, K., et al. (2011). "An association between long-term exposure to ambient air pollution and mortality from lung cancer and respiratory diseases in Japan." Journal of Epidemiology 21(2): 132-143.

Background: Evidence for a link between long-term exposure to air pollution and lung cancer is limited to Western populations. In this prospective cohort study, we examined this association in a Japanese population. Methods: The study comprised 63 520 participants living in 6 areas in 3 Japanese prefectures who were enrolled between 1983 and 1985. Exposure to particulate matter less than 2.5 µm in aerodynamic diameter (PM(2.5)), sulfur dioxide (SO(2)), and nitrogen dioxide (NO(2)) was assessed using data from monitoring stations located in or nearby each area. The Cox proportional hazards model was used to calculate the hazard ratios associated with the average concentrations of these air pollutants. Results: The 10-year average concentrations of PM(2.5), SO(2), and NO(2) before recruitment (1974-1983) were 16.8 to 41.9 µg/m(3), 2.4 to 19.0 ppb, and 1.2 to 33.7 ppb, respectively (inter-area range). During an average follow-up of 8.7 years, there were 6687 deaths, including 518 deaths from lung cancer. The hazard ratios for lung cancer mortality associated with a 10-unit increase in PM(2.5) (µg/m(3)), SO(2) (ppb), and NO(2) (ppb) were 1.24 (95% confidence interval: 1.12-1.37), 1.26 (1.07-1.48), and 1.17 (1.10-1.26), respectively, after adjustment for tobacco smoking and other confounding factors. In addition, a significant increase in risk was observed for male smokers and female never smokers. Respiratory diseases, particularly pneumonia, were also significantly associated with all the air pollutants. Conclusions: Long-term exposure to air pollution is associated with lung cancer and respiratory diseases in Japan.

# Khoder, M. I. (2002). "Nitrous acid concentrations in homes and offices in residential areas in Greater Cairo." Journal of Environmental Monitoring 4(4): 573-578.

Indoor and outdoor measurements of nitrous acid and nitrogen dioxide were conducted at four homes and two offices in residential areas in Greater Cairo during winter (2000-2001) and summer (2001) seasons. Indoor nitrogen dioxide concentrations were higher than outdoor levels at the four homes, whereas indoor concentrations of nitrogen dioxide were lower than outdoor levels at the two offices, during both seasons. Indoor nitrous acid concentrations were higher than outdoor levels at all homes and offices during the period of study. The mean indoor nitrous acid concentrations were 6.8 ppb and 3.67 ppb in the four homes, whereas they were 1.42 ppb and 1.24 ppb in the two offices, during the winter and summer seasons, respectively. Indoor/outdoor ratios of nitrous acid concentration were 6.94 in the winter and 5.03 in the summer for all of the homes. However, the ratios were 1.31 and 1.61 during the winter and summer seasons, respectively, for the two offices. Insignificant positive correlation coefficients were found between indoor and outdoor concentrations of nitrous acid at homes and offices. The maximum outdoor nitrous acid concentrations were recorded during the winter season. Significant positive correlation coefficients were found between nitrous acid and nitrogen dioxide and relative humidity in homes and offices. The ratios of nitrous acid to nitrogen dioxide concentrations ranged from 0.045 to 0.16, with a mean of 0.1, in the four homes, whereas the ratios ranged from 0.026 to 0.09, with a mean of 0.059, in the two offices.

# Kim, D., et al. (2006). "Associations between personal exposures and fixed-site ambient measurements of fine particulate matter, nitrogen dioxide, and carbon monoxide in Toronto, Canada." Journal of Exposure Science and Environmental Epidemiology 16(2): 172-183.

A longitudinal study investigating personal exposures to PM2.5, nitrogen dioxide (NO2), and carbon monoxide (CO) for cardiac compromised individuals was conducted in Toronto, Canada. The aim of the study was (1) to examine the distribution of exposures to PM2.5, NO2, and CO; and (2) to investigate the relationship between personal exposures and fixed-site ambient measurements of PM2.5, NO2, and CO. In total, 28 subjects with coronary artery disease wore the Rupprecht & Patashnick ChemPass Personal Sampling System one day a week for a maximum of 10 weeks. The mean (SD) personal exposures were 22 microg m(-3) (42), 14 p.p.b. (6), and 1.4 p.p.m (0.5) for PM2.5, NO2, and CO, respectively. PM2.5 and CO personal exposures were greater than central fixed-site ambient measurements, while the reverse pattern was observed for NO2. Ambient PM2.5 and NO2 were correlated with personal exposures to PM2.5 and NO2 with median Spearman's correlation coefficients of 0.69 and 0.57, respectively. The correlations between personal exposures and ambient measurements made closest to the subjects' homes or the average of all stations within the study were not stronger than the correlation between personal exposures and central fixed-site measurements. Personal exposures to PM2.5 were correlated with personal exposures to NO2 (median Spearman's correlation coefficient of 0.43). This study suggests that central fixed-site measurements of PM2.5 and NO2 may be treated as surrogates for personal exposures to PM2.5 and NO2 in epidemiological studies, and that NO2 is a potential confounder of PM2.5.

# Kim, S. Y., et al. (2009). "Health effects of long-term air pollution: influence of exposure prediction methods." Epidemiology 20(3): 442-450.

BACKGROUND: Air pollution studies increasingly estimate individual-level exposures from area-based measurements by using exposure prediction methods such as nearest-monitor and kriging predictions. However, little is known about the properties of these methods for health effects estimation. This simulation study explores how 2 common prediction approaches for fine particulate matter (PM2.5) affect relative risk estimates for cardiovascular events in a single geographic area.

METHODS: We estimated 2 sets of parameters to define correlation structures from 2002 data on PM2.5 in the Los Angeles area, and selected additional parameters to evaluate various correlation features. For each structure, annual average PM2.5 was generated at 22 monitoring sites and 2000 preselected individual locations in Los Angeles. Associated survival time until cardiovascular event was simulated for 10,000 hypothetical subjects. Using PM2.5 generated at monitoring sites, we predicted PM2.5 at subject locations by nearest-monitor and kriging interpolation. Finally, we estimated relative risks of the effect of PM2.5 on time to cardiovascular event.

RESULTS: Health effect estimates for cardiovascular events had higher or similar coverage probability for kriging compared with nearest-monitor exposures. The lower mean square error of nearest monitor prediction resulted from more precise but biased health effect estimates. The difference between these approaches dramatically moderated when spatial correlation increased and geographic characteristics were included in the mean model.

CONCLUSIONS: When the underlying exposure distribution has a large amount of spatial dependence, both kriging and nearest-monitor predictions gave good health effect estimates. For exposure with little spatial dependence, kriging exposure was preferable but gave very uncertain estimates.

# Kimbrough, E. S., et al. (2013). "Seasonal and diurnal analysis of NO2 concentrations from a long-duration study conducted in Las Vegas, Nevada." Journal of the Air and Waste Management Association 63(8): 934-942.

A study, conducted in Las Vegas, NV from mid-December 2008 to mid-December 2009 along an interstate highway, collected continuous and integrated samples for a wide variety of air pollutant species including NO2 and NO(x) associated with roadway traffic. This study examined long-term trends of NO2 and NO(x) in a near-road environment compared with previous near-road studies typically lasting only a few days to months. Study results revealed concentration gradients for NO2 and NO(x) with highest absolute and average concentrations at distances closest to the roadway throughout the year. Diurnal ambient temperature changes also influenced concentrations due to atmospheric chemistry activity as well as concentration changes due to seasonal effects. These concentration gradients were observed for all wind conditions; however under downwind conditions (winds from highway), the concentration gradients are more pronounced. Higher pollutant concentrations are generally observed during low wind speed conditions especially when those winds were from the highway. Understanding long-term, seasonal variability and levels of pollutant concentrations in the near-road environment is important to researchers and decision-makers evaluating exposures and risks for near-road populations; identifying locations for future near-road monitoring sites; and determining the viability and effectiveness of mitigation strategies. Implications: Population exposures to traffic emissions near roads have led to heightened public health concerns and awareness of the long-term levels and variability of these air pollutants. Epidemiological studies have lead to improved understanding of the associated risks and health effects of near road air pollutant emissions. While short-term studies provide insights on near-road air quality, longer-term trends need to be understood, especially for reactive pollutants such as NO2.

# Kimbrough, S. u., et al. (2013). "Long-term continuous measurement of near-road air pollution in Las Vegas: seasonal variability in traffic emissions impact on local air quality." Air Quality, Atmosphere and Health 6(1): 295-305.

Excess air pollution along roadways is an issue of public health concern to Federal, State, and local government environmental agencies and the public. This concern was the motivation for a long-term study to measure levels of air pollutants at various distances from a roadway in Las Vegas, Nevada. This study represents a joint effort between the US Environmental Protection Agency and the US Department of Transportation's Federal Highway Administration. Measurements of air pollutants-including carbon monoxide (CO), oxides of nitrogen (NO, NO2, NOX), and black carbon (BC)-were conducted concurrently at four distances from a major interstate (206,000 vehicles per day) for an entire year. With prevailing winds from the west, concentrations of all measured species at 20 m from the highway were significantly higher (non-overlapping 95% confidence intervals) than levels 300 m from the road. In addition, CO, NOX, and BC measured at 100 m from the road on the prevailing downwind side of the road were significantly higher than 100 m on the opposite side of the road. The disproportionate impact of the roadway emissions on the eastern side of the highway points to the importance of local meteorology in determining the extent of near-road impact. When isolating only time periods with winds from due west (+/- 60A degrees), CO, NO2, NOX, and BC levels at 20 m east of the highway were 60%, 46%, 122%, and 127% higher, respectively, than the concurrent measurements at the upwind site. Monthly average traffic volume and frequency of downwind conditions are not enough to explain the trends in monthly average excess CO at 20 m east of the road; average wind speed appears to be an important explanatory factor. The year-long extensive dataset afforded some unique data mining analyses-the maximum near-road impact (top 10% of 20 m east site minus 300 m east site) is associated with winds from the southwest to northwest, higher traffic volumes, and low wind speeds; meanwhile, the apparent maximum spatial extent in near-road impact (top 10% of 300 m east site minus to 100 m west site) occurred during evening to presunrise periods in the winter under conditions of low speed winds from due west, with moderate to low traffic volumes. This research confirms that excess air pollution associated with proximity to roads is significant over a year-long time frame and that local meteorology is a critical factor determining the extent of near-road impact.

# Kleffmann, J., et al., Eds. (2013). NO2 measurement techniques: Pitfalls and new developments. NATO Science for Peace and Security Series C: Environmental Security. New York, NY, Springer.

Reliable measurements of atmospheric trace gases are necessary for both, a better understanding of the chemical processes occurring in the atmosphere, and for the validation of model predictions. Nitrogen dioxide (NO2) is a toxic gas and is thus a regulated air pollutant. Besides, it is of major importance for the oxidation capacity of the atmosphere and plays a pivotal role in the formation of ozone and acid precipitation. Detection of NO2 is a difficult task since many of the different commercial techniques used are affected by interferences. The chemiluminescence instruments that are used for indirect NO2 detection in monitoring networks and smog chambers use either molybdenum or photolytic converters and are affected by either positive (NOy) or negative interferences (radical formation in the photolytic converter). Erroneous conclusions on NO2 can be drawn if these interferences are not taken into consideration. In the present study, NO2 measurements in the urban atmosphere, in a road traffic tunnel and in a smog chamber using different commercial techniques, i.e. chemiluminescence instruments with molybdenum or photolytic converters, a luminol based instrument and a new NO2-LOPAP, were compared with spectroscopic techniques, i.e. DOAS and FTIR. Interferences of the different instruments observed during atmospheric measurements were partly characterised in more detail in the smog chamber experiments. Whereas all the commercial instruments showed strong interferences, excellent agreement was obtained between a new NO2-LOPAP instrument and the FTIR technique for the measurements performed in the smog chamber.

# Ko, F. W., et al. (2007). "Temporal relationship between air pollutants and hospital admissions for chronic obstructive pulmonary disease in Hong Kong." Thorax 62(9): 780-785.

AIMS: To assess any relationship between the levels of ambient air pollutants and hospital admissions for chronic obstructive pulmonary disease (COPD) in Hong Kong. METHODS: A retrospective ecological study was undertaken. Data of daily emergency hospital admissions to 15 major hospitals in Hong Kong for COPD and indices of air pollutants (sulphur dioxide (SO(2)), nitrogen dioxide (NO(2)), ozone (O(3)), particulates with an aerodynamic diameter of <10 microm (PM(10)) and 2.5 microm (PM(2.5))) and meteorological variables from January 2000 to December 2004 were obtained from several government departments. Analysis was performed using generalised additive models with Poisson distribution, adjusted for the effects of time trend, season, other cyclical factors, temperature and humidity. Autocorrelation and overdispersion were corrected. RESULTS: Significant associations were found between hospital admissions for COPD with all five air pollutants. Relative risks for admission for every 10 microg/m(3) increase in SO(2), NO(2), O(3), PM(10) and PM(2.5) were 1.007, 1.026, 1.034, 1.024 and 1.031, respectively, at a lag day ranging from lag 0 to cumulative lag 0-5. In a multipollutant model, O(3), SO(2) and PM(2.5) were significantly associated with increased admissions for COPD. SO(2), NO(2) and O(3) had a greater effect on COPD admissions in the cold season (December to March) than during the warm season. CONCLUSION: Ambient concentrations of air pollutants have an adverse effect on hospital admissions for COPD in Hong Kong, especially during the winter season. This might be due to indoor exposure to outdoor pollution through open windows as central heating is not required in the mild winter. Measures to improve air quality are urgently needed.

# Kousa, A., et al. (2001). "Personal exposures to NO2 in the EXPOLIS-study: Relation to residential indoor, outdoor and workplace concentrations in Basel, Helsinki and Prague." Atmospheric Environment 35(20): 3405-3412.

European Union (EU); ERB (Prague); Academy of Finland; Swiss Ministry for Education and Science; KTL, the National Public Health Institute of Finland. #Personal exposures, residential indoor, outdoor and workplace levels of nitrogen dioxide (NO2) were measured for 262 urban adult (25-55 years) participants in three EXPOLIS centres (Basel; Switzerland, Helsinki; Finland, and Prague; Czech Republic) using passive samplers for 48-h sampling periods during 1996-1997. The average residential outdoor and indoor NO2 levels were lowest in Helsinki (24 +/- 12 and 18 +/- 11 mug m-3, respectively), highest in Prague (61 +/- 20 and 43 +/- 23 mug m-3), with Basel in between (36 +/- 13 and 27 +/- 13 mug m-3). Average workplace NO2 levels, however, were highest in Basel (36 +/- 24 mug m-3), lowest in Helsinki (27 +/- 15 mug m-3), with Prague in between (30 +/- 18 mug m-3). A time-weighted microenvironmental exposure model explained 74% of the personal NO2 exposure variation in all centres and in average 88% of the exposures. Log-linear regression models, using residential outdoor measurements (fixed site monitoring) combined with residential and work characteristics (i.e. work location, using gas appliances and keeping windows open), explained 48% (37%) of the personal NO2 exposure variation. Regression models based on ambient fixed site concentrations alone explained only 11-19% of personal NO2 exposure variation. Thus, ambient fixed site monitoring alone was a poor predictor for personal NO2 exposure variation, but adding personal questionnaire information can significantly improve the predicting power.

# Koutrakis, P., et al. (2005). Characterization of particulate and gas exposures of sensitive subpopulations living in Baltimore and Boston. Boston, MA, Health Effects Institute: 1-65; discussion 67-75.

Personal exposures to particulate and gaseous pollutants and corresponding ambient concentrations were measured for 56 subjects living in Baltimore, Maryland, and 43 subjects living in Boston, Massachusetts. The 3 Baltimore cohorts consisted of 20 healthy older adults (seniors), 21 children, and 15 individuals with physician-diagnosed chronic obstructive pulmonary disease (COPD\*). The 2 Boston cohorts were 20 healthy seniors and 23 children. All children were 9 to 13 years of age; seniors were 65 years of age or older; and the COPD participants had moderate to severe physician-diagnosed COPD. Personal exposures to particulate matter with aerodynamic diameters less than 2.5 microm (PM2.5), sulfate (SO(4)2-), elemental carbon (EC), ozone (03), nitrogen dioxide (NO2), and sulfur dioxide (SO2) were measured simultaneously for 24 hours/day. All subjects were monitored for 8 to 12 consecutive days. The primary objectives of this study were (1) to characterize the personal particulate and gaseous exposures for individuals sensitive to PM health effects and (2) to assess the appropriateness of exposure assessment strategies for use in PM epidemiologic studies. Personal exposures to multiple pollutants and ambient concentrations were measured for subjects from each cohort from each location. Pollutant data were analyzed using correlation and mixed-model regression analyses. In Baltimore, personal PM2.5 exposures tended to be comparable to (and frequently lower than) corresponding ambient concentrations; in Boston, the personal exposures were frequently higher. Overall, personal exposures to the gaseous pollutants, especially O3 and SO2, were considerably lower than corresponding ambient concentrations because of the lack of indoor sources for these gases and their high removal rate on indoor surfaces. Further, the impact of ambient particles on personal exposure (the infiltration factor) and differences in infiltration factor by city, season, and cohort were investigated. No difference in infiltration factor was found among the cohorts, which suggests that all subjects were exposed to the same fraction of ambient PM2.5 for a given ambient concentration. In addition, the results show significant correlations between ambient PM2.5 concentrations and corresponding personal exposures over time and provide further indication that ambient gaseous pollutant concentrations may be better surrogates for personal PM2.5 exposures, especially personal exposures to PM2.5 of ambient origin, than their respective personal exposures. These results have important implications for PM health effects studies that use regression models including both ambient PM2.5 and gaseous pollutant concentrations as independent variables, because both parameters may be serving as surrogates for PM2.5 exposures.

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Koutrakis, P., et al. (1993). "Measurement of ambient ozone using a nitrite-coated filter." Analytical Chemistry 65(3): 209-214.

Standard ozone monitoring techniques utilize large, heavy, and expensive instruments that are not easily adapted for personal or microenvironmental monitoring. For large-scale monitoring projects, where spatial variations of a pollutant and human exposure assessments are of interest, passive sampling devices can provide the methodology to meet monitoring and statistical goals. Recently we developed a coated filter for ozone collection that we used in a commercially available passive sampling device. Results from the ozone sampler validation tests are presented. The passive ozone sampler used in field and laboratory experiments consists of a badge clip suorting a barrel-shaped body which contains two coated glass fiber filters. The principal component of the coating is nitrite ion, which in the presence of ozone is oxidized to nitrate ion on the filter medium, NO2- + O3 --> NO3- + O2. After sample collection, the filters are extracted with ultrapure water and analyzed for nitrate ion by ion chromatography. The results from laboratory and field validation tests indicate excellent agreement between the passive method and standard ozone monitoring techniques. We have determined that relative humidity (ranging from 10 to 80 %) and temperature (ranging from 0 to 40-degrees-C) at typical ambient ozone levels (40-100 ppb) do not influence sampler performance. Face velocity and sampler orientation with respect to wind direction affected the sampler's collection rate of ozone. By using a protective cup which acts as both a wind screen and a rain cover, we were able to obtain a constant collection rate over a wide range of wind speeds.

# Koutrakis, P., et al. (1988). "Evaluation of an annular denuder/filter pack system to collect acidic aerosols and gases." Environmental Science and Technology 22(12): 1463-1468.

A glass impactor was designed and evaluated along with an annular denuder/filter pack system. The glass impactor has a 50% aerodynamic cutoff of 2.1 .mu.m at a flow of 10 L min-1 and allows a quantitative transfer of gases and fine particles to the annular denuder and filter pack components. Fine particle and gas concentrations, determined by using the glass impactor along with the annular denuder/filter pack, were in good agreement with those obtained with colocated reference samplers. Measurements of SO2, HNO3, and HNO2 gases showed mean collection efficiencies of 0.993, 0.984, and 0.952, respectively, which compared well with predicted values. Additionally, it was found that artifact formation of nitrate and nitrite ions, representing about 5-10% of the concentrations of HNO3 and HNO2, occurs in the Na2CO3-coated annular denuder. Corrections for these artifacts were made with a second Na2CO3-coated annular denuder. The results of this pilot study suggest that the glass impactor/annular denuder/filter pack sampling system is suitable for measuring acidic aerosols and gases.

# Krewski, D., et al. (2000). Reanalysis of the Harvard Six Cities study and the American Cancer Society study of particulate air pollution and mortality. HEI Special Report. Cambridge, MA, Health Effects Institute.

A Special Report of the Institute's Particle Epidemiology Reanalysis Project. The overall objective of this project was to conduct a rigorous and independent assessment of the findings of the Harvard Six Cities and American Cancer Society Studies of air pollution and mortality. This objective was met in two parts. In Part I: Replication and Validation, the Reanalaysis Team led by Dr. Daniel Krewski sought to replicate the original studies via a quality assurance audit of a sample of the original data and to validate the original numeric results. In Part II: Sensitivity Analyses, they tested the robustness of the original analyses to alternate risk models and analytic approaches.

# Lahde, T., et al. (2014). "Mobile Particle and NOx Emission Characterization at Helsinki Downtown: Comparison of Different Traffic Flow Areas." Aerosol and Air Quality Research 14(5): 1372-1382.

A two weeks measurement campaign by a mobile laboratory van was performed at downtown Helsinki, Finland, in winter 2010. The characteristics of air pollutants such as fine particles in the size ranges of 7-40 nm (N-p40) and 40-1000 nm (N-p1000), black carbon (BC), fine particle mass (PM2.5), as well as gaseous compounds NO, NO2, NOx, CO and CO2 were studied. The statistical analysis showed that the air pollution conditions strongly depended on the traffic flow area; therefore, the street sections were classified as high traffic flow areas (HTF1-HTF4), low traffic flow areas (LTF1-LTF5), and urban background areas (BG1-BG3). Large variation of particle emissions was observed, and the momentary peak particle concentrations were 8 x 10(5) cm(-3). At the HTF areas exhaust emissions followed clearly daily average heavy duty vehicle counts rather than the average daily vehicle counts. Higher correlation coefficients were found between CO2 and NO than between CO2 and N-tot. The dispersion studies indicated that the air pollution conditions strongly improved from high traffic flow areas to low traffic flow areas. Therefore, proper city planning and locating, for example, cycle tracks, schools and hospitals farther from busy city streets might significantly reduce exposure risk for humans.

# Lane, K. J., et al. (2013). "Positional error and time-activity patterns in near-highway proximity studies: an exposure misclassification analysis." Environmental Health: A Global Access Science Source 12(1): 75.

BACKGROUND: The growing interest in research on the health effects of near-highway air pollutants requires an assessment of potential sources of error in exposure assignment techniques that rely on residential proximity to roadways.

METHODS: We compared the amount of positional error in the geocoding process for three different data sources (parcels, TIGER and StreetMap USA) to a “gold standard”; residential geocoding process that used ortho-photos, large multi-building parcel layouts or large multi-unit building floor plans. The potential effect of positional error for each geocoding method was assessed as part of a proximity to highway epidemiological study in the Boston area, using all participants with complete address information (N=703). Hourly time-activity data for the most recent workday/weekday and non-workday/weekend were collected to examine time spent in five different micro-environments (inside of home, outside of home, school/work, travel on highway, and other). Analysis included examination of whether time-activity patterns were differentially distributed either by proximity to highway or across demographic groups.

RESULTS: Median positional error was significantly higher in street network geocoding (StreetMap USA=23 m; TIGER=22 m) than parcel geocoding (8 m). When restricted to multi-building parcels and large multi-unit building parcels, all three geocoding methods had substantial positional error (parcels=24 m; StreetMap USA=28 m; TIGER=37 m). Street network geocoding also differentially introduced greater amounts of positional error in the proximity to highway study in the 0-50 m proximity category. Time spent inside home on workdays/weekdays differed significantly by demographic variables (age, employment status, educational attainment, income and race). Time-activity patterns were also significantly different when stratified by proximity to highway, with those participants residing in the 0-50 m proximity category reporting significantly more time in the school/work micro-environment on workdays/weekdays than all other distance groups

CONCLUSIONS: These findings indicate the potential for both differential and non-differential exposure misclassification due to geocoding error and time-activity patterns in studies of highway proximity. We also propose a multi-stage manual correction process to minimize positional error. Additional research is needed in other populations and geographic settings.

# Langstaff, J. E. (2007). Analysis of uncertainty in ozone population exposure modeling [technical memorandum]. Research Triangle Park, NC, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.

N/A.

# Laurent, O., et al. (2013). "Investigating the association between birth weight and complementary air pollution metrics: a cohort study." Environmental Health: A Global Access Science Source 12(1): 18.

BACKGROUND: Exposure to air pollution is frequently associated with reductions in birth weight but results of available studies vary widely, possibly in part because of differences in air pollution metrics. Further insight is needed to identify the air pollution metrics most strongly and consistently associated with birth weight.

METHODS: We used a hospital-based obstetric database of more than 70,000 births to study the relationships between air pollution and the risk of low birth weight (LBW, <2,500 g), as well as birth weight as a continuous variable, in term-born infants. Complementary metrics capturing different aspects of air pollution were used (measurements from ambient monitoring stations, predictions from land use regression models and from a Gaussian dispersion model, traffic density, and proximity to roads). Associations between air pollution metrics and birth outcomes were investigated using generalized additive models, adjusting for maternal age, parity, race/ethnicity, insurance status, poverty, gestational age and sex of the infants.

RESULTS: Increased risks of LBW were associated with ambient O3 concentrations as measured by monitoring stations, as well as traffic density and proximity to major roadways. LBW was not significantly associated with other air pollution metrics, except that a decreased risk was associated with ambient NO2 concentrations as measured by monitoring stations. When birth weight was analyzed as a continuous variable, small increases in mean birth weight were associated with most air pollution metrics (<40 g per inter-quartile range in air pollution metrics). No such increase was observed for traffic density or proximity to major roadways, and a significant decrease in mean birth weight was associated with ambient O3 concentrations.

CONCLUSIONS: We found contrasting results according to the different air pollution metrics examined. Unmeasured confounders and/or measurement errors might have produced spurious positive associations between birth weight and some air pollution metrics. Despite this, ambient O3 was associated with a decrement in mean birth weight and significant increases in the risk of LBW were associated with traffic density, proximity to roads and ambient O3. This suggests that in our study population, these air pollution metrics are more likely related to increased risks of LBW than the other metrics we studied. Further studies are necessary to assess the consistency of such patterns across populations.

# Le, H. Q., et al. (2012). "Air pollutant exposure and preterm and term small-for-gestational-age births in Detroit, Michigan: Long-term trends and associations." Environment International 44: 7-17.

Studies in a number of countries have reported associations between exposure to ambient air pollutants and adverse birth outcomes, including low birth weight, preterm birth (PTB) and, less commonly, small for gestational age (SGA). Despite their growing number, the available studies have significant limitations, e.g., incomplete control of temporal trends in exposure, modest sample sizes, and a lack of information regarding individual risk factors such as smoking. No study has yet examined large numbers of susceptible individuals. We investigated the association between ambient air pollutant concentrations and term SGA and PTB outcomes among 164,905 singleton births in Detroit, Michigan occurring between 1990 and 2001. SO(2), CO, NO(2), O(3) and PM(10) exposures were used in single and multiple pollutant logistic regression models to estimate odds ratios (OR) for these outcomes, adjusted for the infant's sex and gestational age, the mother's race, age group, education level, smoking status and prenatal care, birth season, site of residence, and long-term exposure trends. Term SGA was associated with CO levels exceeding 0.75ppm (OR=1.14, 95% confidence interval=1.02-1.27) and NO(2) exceeding 6.8ppb (1.11, 1.03-1.21) exposures in the first month, and with PM(10) exceeding 35μg/m(3) (1.22, 1.03-1.46) and O(3) (1.11, 1.02-1.20) exposure in the third trimester. PTB was associated with SO(2) (1.07, 1.01-1.14) exposure in the last month, and with (hourly) O(3) exceeding 92ppb (1.08, 1.02-1.14) exposure in the first month. Exposure to several air pollutants at modest concentrations was associated with adverse birth outcomes. This study, which included a large Black population, suggests the importance of the early period of pregnancy for associations between term SGA with CO and NO(2), and between O(3) with PTB; and the late pregnancy period for associations between term SGA and O(3) and PM(10), and between SO(2) with PTB. It also highlights the importance of accounting for individual risk factors such as maternal smoking, maternal race, and long-term trends in air pollutant levels and adverse birth outcomes in evaluating relationships between pollutant exposures and adverse birth outcomes.

# Leaderer, B. P., et al. (1999). "Indoor, outdoor, and regional summer and winter concentrations of PM10, PM25, SO42-, H+, NH4+, NO3-, NH3, and nitrous acid in homes with and without kerosene space heaters." Environmental Health Perspectives 107(3): 223-231.

Twenty-four-hour samples of PM10 (mass of particles with aerodynamic diameter <= 10 µm), PM2.5, (mass of particles with aerodynamic diameter <= 2.5 µm), particle strong acidity (H+), sulfate (SO42-), nitrate (NO3-), ammonia (NH3), nitrous acid (HONO), and sulfur dioxide were collected inside and outside of 281 homes during winter and summer periods. Measurements were also conducted during summer periods at a regional site. A total of 58 homes of nonsmokers were sampled during the summer periods and 223 homes were sampled during the winter periods. Seventy-four of the homes sampled during the winter reported the use of a kerosene heater. All homes sampled in the summer were located in southwest Virginia. All but 20 homes sampled in the winter were also located in southwest Virginia; the remainder of the homes were located in Connecticut. For homes without tobacco combustion, the regional air monitoring site (Vinton, VA) appeared to provide a reasonable estimate of concentrations of PM2.5 and SO4'2-' during summer months outside and inside homes within the region, even when a substantial number of the homes used air conditioning. Average indoor/outdoor ratios for PM2.5 and SO4'2-' during the summer period were 1.03: 0.71 and 0.74:0.53, respectively. The indoor/outdoor mean ratio for sulfate suggests that on average approximately 75% of the fine aerosol indoors during the summer is associated with outdoor sources. Kerosene heater use during the winter months, in the absence of tobacco combustion, results in substantial increases in indoor concentrations of PM2.5, SO4'2-', and possibly H+, as compared to homes without kerosene heaters. During their use, we estimated that kerosene heaters added, on average, approximately 40 µg/m3 of PM2.5 and 15 µg/m3 of SO4'2-' to background residential levels of 18 and 2 µg/m3, respectively. Results from using sulfuric acid-doped Teflon (E.I. Du Pont de Nemours & Co., Wilmington, DE) filters in homes with kerosene heaters suggest that acid particle concentrations may be substantially higher than those measured because of acid neutralization by ammonia. During the summer and winter periods indoor concentrations of ammonia are an order of magnitude higher indoors than outdoors and appear to result in lower indoor acid particle concentrations. Nitrous acid levels are higher indoors than outdoors during both winter and summer and are substantially higher in homes with unvented combustion sources. Key words: gas stoves, indoor/outdoor concentrations, kerosene heaters, particle air pollution.

# Lee, A., et al. (2015). "Impact of preferential sampling on exposure prediction and health effect inference in the context of air pollution epidemiology." Environmetrics 26(4): 255-267.

Preferential sampling has been defined in the context of geostatistical modeling as the dependence between the sampling locations and the process that describes the spatial structure of the data. It can occur when networks are designed to find high values. For example, in networks based on the US Clean Air Act, monitors are sited to determine whether air quality standards are exceeded. We study the impact of the design of monitor networks in the context of air pollution epidemiology studies. The effect of preferential sampling has been illustrated in the literature by highlighting its impact on spatial predictions. In this paper, we use these predictions as input in a second-stage analysis, and we assess how they affect health effect inference. Our work is motivated by data from two US regulatory networks and health data from the Multi-Ethnic Study of Atherosclerosis and Air Pollution. The two networks were designed to monitor air pollution in urban and rural areas, and we found that the health analysis results based on the two networks can lead to different scientific conclusions. We use preferential sampling to gain insight into these differences. We designed a simulation study and found that the validity and reliability of the health effect estimate can be greatly affected by how we sample the monitor locations. To better understand its effect on second-stage inference, we identify two components of preferential sampling that shed light on how preferential sampling alters the properties of the health effect estimate. Copyright (c) 2015 John Wiley & Sons, Ltd.

# Lee, B. E., et al. (2003). "Exposure to air pollution during different gestational phases contributes to risks of low birth weight." Human Reproduction 18(3): 638-643.

BACKGROUND: Although there have been growing concerns about the adverse effects of air pollution on birth outcomes, little is known about which specific exposure times of specific pollutants contribute to low birth weight (LBW). METHODS: We evaluated the relationships between LBW and air pollution exposure levels in Seoul, Korea. Using the air pollution data, we estimated the exposure during each trimester and also during each month of pregnancy on the basis of the gestational age and birth date of each newborn. Generalized additive logistic regression analyses were conducted considering infant sex, birth order, maternal age, parental education level, time trend, and gestational age. RESULTS: The monthly analyses suggested that the risks for LBW tended to increase with carbon monoxide (CO) exposure between months 2-5 of pregnancy, with exposure to particles <10 micro m (PM(10)) in months 2 and 4, and for sulphur dioxide (SO(2)) and nitrogen dioxide (NO(2)) exposure between months 3-5. CONCLUSIONS: This study suggests that exposure to CO, PM(10,) SO(2) and NO(2) during early to mid pregnancy contribute to risks for LBW.

# Lee, K., et al. (2004). "Outdoor/indoor/personal ozone exposures of children in Nashville, Tennessee." Journal of the Air and Waste Management Association 54(3): 352-359.

An ozone (O3) exposure study was conducted in Nashville, TN, using passive O3 samplers to measure six weekly outdoor, indoor, and personal O3 exposure estimates for a group of 10- to 12-yr-old elementary school children. Thirty-six children from two Nashville area communities (Inglewood and Hendersonville) participated in the O3 sampling program, and 99 children provided additional time activity information by telephone interview. By design, this study coincided with the 1994 Nashville/Middle Tennessee Ozone Study conducted by the Southern Oxidants Study, which provided enhanced continuous ambient O3 monitoring across the Nashville area. Passive sampling estimated weekly average outdoor O3 concentrations from 0.011 to 0.030 ppm in the urban Inglewood community and from 0.015 to 0.042 ppm in suburban Hendersonville. The maximum 1- and 8-hr ambient concentrations encountered at the Hendersonville continuous monitor exceeded the levels of the 1- and 8-hr metrics for the O3 National Ambient Air Quality Standard. Weekly average personal O3 exposures ranged from 0.0013 to 0.0064 ppm (7-31% of outdoor levels). Personal O3 exposures reflected the proportional amount of time spent in indoor and outdoor environments. Air-conditioned homes displayed very low indoor O3 concentrations, and homes using open windows and fans for ventilation displayed much higher concentrations. Implications: This study demonstrates the usefulness of passive O3 sampling technology in measuring long-term outdoor/indoor/personal exposures. The test subjects did well in following simple directions concerning accurate exposure assessment and in keeping time-activity diaries. Personal O3 exposure, in between the extremes of higher outdoor and lower indoor exposures, is a function of time spent outdoors. Clearly, those children spending more time outdoors are subject to higher O3 exposures than are their more housebound peers. Continuous State and Local Air Monitoring System O3 monitoring results substantially overestimate weeklong indoor and personal O3 exposure. Centrally air-conditioned indoor environments confer a substantial degree of protection from ambient O3 levels.

# Lee, K., et al. (2002). "Nitrous acid, nitrogen dioxide, and ozone concentrations in residential environments." Environmental Health Perspectives 110(2): 145-150.

Nitrous acid (HONO) may be generated by heterogeneous reactions of nitrogen dioxide and direct emission from combustion sources. Interactions among nitrogen oxides and ozone are important for outdoor photochemical reactions. However, little is known of indoor HONO levels or the relationship between residential HONO, NO2, and O3 concentrations in occupied houses. Six-day integrated indoor and outdoor concentrations of the three pollutants were simultaneously measured in two communities in Southern California using passive samplers. The average indoor HONO concentration was 4.6 ppb, compared to 0.9 ppb for outdoor HONO. Average indoor and outdoor NO2 concentrations were 28 and 20.1 ppb, respectively. Indoor O3 concentrations were low (average 14.9 ppb) in comparison to the outdoor levels (average 56.5 ppb). Housing characteristics, including community and presence of a gas range, were significantly associated with indoor NO2 and HONO concentrations. Indoor HONO levels were closely correlated with indoor NO2 levels and were about 17% of indoor NO2 concentrations. Indoor HONO levels were inversely correlated with indoor O3 levels. The measurements demonstrated the occurrence of substantial residential indoor HONO concentrations and associations among the three indoor air pollutants.

# Lee, K., et al. (2013). "Seasonal and geographic effects on predicting personal exposure to nitrogen dioxide by time-weighted microenvironmental model." Atmospheric Environment 67: 143-148.

The purposes of this study were to investigate the impact of microenvironment concentrations on personal exposure by season and city, and to develop statistical models to predict personal exposure to nitrogen dioxide (NO2). Personal exposures, residential indoor, residential outdoor and workplace indoor levels of NO2 were measured in four cities in Korea (Seoul, Daegu, Asan and Suncheon) using a passive sampler for five weekdays. The measurements were conducted in summer and winter during 2008 -2009. Average personal NO2 exposures were 20.5 ppb in summer and 18.6 ppb in winter. The average personal exposures of NO2 and residential indoor levels were the highest in Seoul and the lowest in Suncheon both summer and winter. Personal exposure was significantly different by season. Personal exposure was significantly correlated with residential indoor concentration in all cities. The personal exposure estimated by residential indoor, workplace indoor and outdoor levels explained 38% and 41% of the measured personal exposure variance in summer and winter, respectively. The low correlation may be due to the longer time spent in other microenvironments in the Korean population. Personal exposure was significantly correlated with working day and city. Correlation between the estimated personal exposure and measured personal exposure was significantly associated with the season and city. The model can provide reasonable estimation of population exposure with appropriate microenvironmental concentrations and time activity data. However, season- and city-specific models should be considered. (C) 2012 Elsevier Ltd. All rights reserved.

# Lee, P. C., et al. (2012). "Ambient air pollution exposure and blood pressure changes during pregnancy." Environmental Research 117: 46-53.

BACKGROUND: Maternal exposure to ambient air pollution has been associated with adverse birth outcomes such as preterm delivery. However, only one study to date has linked air pollution to blood pressure changes during pregnancy, a period of dramatic cardiovascular function changes. Objectives: We examined whether maternal exposures to criteria air pollutants, including particles of less than 10 μm(PM(10)) or 2.5 μm diameter (PM(2.5)), carbon monoxide (CO), nitrogen dioxide (NO(2)), sulfur dioxide (SO(2)), and ozone (O(3)), in each trimester of pregnancy are associated with magnitude of rise of blood pressure between the first 20 weeks of gestation and late pregnancy in a prospectively followed cohort of 1684 pregnant women in Allegheny County, PA.

METHODS: Air pollution measures for maternal ZIP code areas were derived using Kriging interpolation. Using logistic regression analysis, we evaluated the associations between air pollution exposures and blood pressure changes between the first 20 weeks of gestation and late pregnancy.

RESULTS: First trimester PM(10) and ozone exposures were associated with blood pressure changes between the first 20 weeks of gestation and late pregnancy, most strongly in non-smokers. Per interquartile increases in first trimester PM(10) and O(3) concentrations were associated with mean increases in systolic blood pressure of 1.88mmHg (95% CI=0.84 to 2.93) and 1.84 (95% CI=1.05 to 4.63), respectively, and in diastolic blood pressure of 0.63mmHg (95% CI=-0.50 to 1.76) and 1.13 (95% CI=-0.46 to 2.71) in non-smokers.

CONCLUSIONS: Our novel finding suggests that first trimester PM(10) and O(3) air pollution exposures increase blood pressure in the later stages of pregnancy. These changes may play a role in mediating the relationships between air pollution and adverse birth outcomes.

# Lee, P. C., et al. (2011). "Particulate air pollution exposure and C-reactive protein during early pregnancy." Epidemiology 22(4): 524-531.

BACKGROUND: It is not well understood how air pollution leads to adverse pregnancy outcomes. One pathway may be through C-reactive protein, a biomarker of systemic inflammation that has been reported to increase the risk of preterm delivery. We examined whether air pollution influences serum concentrations of C-reactive protein in early pregnancy. METHODS: We studied 1696 pregnant women in Allegheny County, PA, from 1997 through 2001. C-reactive protein concentrations were assayed in blood collected before the 22nd week of gestation. We estimated levels of particles of less than 10 μm (PM10) and less than 2.5 μm diameter (PM2.5), carbon monoxide, nitrogen dioxide, sulfur dioxide, and ozone at the maternal zip code using Kriging interpolation for measurements obtained from ambient stations. Associations between air pollution and high C-reactive protein concentrations (≥ 8 ng/mL) were evaluated using logistic regression. RESULTS: Among nonsmokers, an observed 9.2 μg/m increase in PM10 (averaged over 28 days prior to the blood sample) was associated with an odds ratios of 1.41 for high C-reactive protein concentrations (95% confidence interval = 0.99-2.00). Similarly, a 4.6 μg/m increase in PM2.5 was associated with an odds ratio of 1.47 (1.05-2.06). The odds ratio was 1.49 (0.75-2.96) per 7.9 ppb increase in ozone during summer. There were no associations in smokers or for other air pollutants, and there was no evidence for effect-measure modification by obesity. CONCLUSIONS: PM10, PM2.5, and ozone exposures were associated with increased C-reactive protein concentrations in early pregnancy, suggesting that these air pollutants contribute to inflammation and thereby possibly to adverse pregnancy outcomes.

# Leem, J. H., et al. (2006). "Exposures to air pollutants during pregnancy and preterm delivery." Environmental Health Perspectives 114(6): 905-910.

The association between preterm delivery (PTD) and exposure to air pollutants has recently become a major concern. We investigated this relationship in Incheon, Republic of Korea, using spatial and temporal modeling to better infer individual exposures. The birth cohort consisted of 52,113 singleton births in 2001-2002, and data included residential address, gestational age, sex, birth date and order, and parental age and education. We used a geographic information system and kriging methods to construct spatial and temporal exposure models. Associations between exposure and PTD were evaluated using univariate and multivariate log-binomial regressions. Given the gestational age, birth date, and the mother's residential address, we estimated each mother's potential exposure to air pollutants during critical periods of the pregnancy. The adjusted risk ratios for PTD in the highest quartiles of the first trimester exposure were 1.26 [95% confidence interval (CI), 1.11-1.44] for carbon monoxide, 1.27 (95% CI, 1.04-1.56) for particulate matter with aerodynamic diameter < or = 10 microm, 1.24 (95% CI, 1.09-1.41) for nitrogen dioxide, and 1.21 (95% CI, 1.04-1.42) for sulfur dioxide. The relationships between PTD and exposures to CO, NO2, and SO2 were dose dependent (p < 0.001, p < 0.02, p < 0.02, respectively). In addition, the results of our study indicated a significant association between air pollution and PTD during the third trimester of pregnancy. In conclusion, our study showed that relatively low concentrations of air pollution under current air quality standards during pregnancy may contribute to an increased risk of PTD. A biologic mechanism through increased prostaglandin levels that are triggered by inflammatory mediators during exposure periods is discussed.

# Lepeule, J., et al. (2010). "Maternal exposure to nitrogen dioxide during pregnancy and offspring birth weight: Comparison of two exposure models." Environmental Health Perspectives 118(10): 1483-1489.

Background: Studies of the effects of air pollutants on birth weight often assess exposure with networks of permanent air quality monitoring stations (AQMSs), which have a poor spatial resolution. Objective: We aimed to compare the exposure model based on the nearest AQMS and a temporally adjusted geostatistical (TAG) model with a finer spatial resolution, for use in pregnancy studies. Methods: The AQMS and TAG exposure models were implemented in two areas surrounding medium-size cities in which 776 pregnant women were followed as part of the EDEN mother-child cohort. The exposure models were compared in terms of estimated nitrogen dioxide (NO2) levels and of their association with birth weight. Results: The correlations between the two estimates of exposure during the first trimester of pregnancy were r = 0.67, 0.70, and 0.83 for women living within 5, 2, and 1 km of an AQMS, respectively. Exposure patterns displayed greater spatial than temporal variations. Exposure during the first trimester of pregnancy was most strongly associated with birth weight for women living < 2 km away from an AQMS: a 10-µg/m3 increase in NO2 exposure was associated with an adjusted difference in birth weight of -37 g [95% confidence interval (CI), -75 to 1 g] for the nearest-AQMS model and of -51 g (95% CI, -128 to 26 g) for the TAG model. The association was less strong (higher p-value) for women living within 5 or 1 km of an AQMS. Conclusions: The two exposure models tended to give consistent results in terms of association with birth weight, despite the moderate concordance between exposure estimates. Editor's Summary Studies of the effects of air pollutants on birth weight often assess exposure with permanent air quality monitoring station (AQMS) networks, which are known to have poor spatial resolution. Lepeule et al. (p. 1483) compared two exposure models: one based on the nearest AQMS, and one temporally adjusted geostatistical (TAG) model, which has a finer spatial resolution. The authors compared the models in terms of both exposure estimates and associations with birth weight. Variations in exposure were mostly due to spatial rather than temporal considerations in both models; temporal variation was greater in the TAG model than in the nearest-AQMS model. The concordance between nitrogen dioxide (NO2) exposure estimates in the two models was modest when a 5-km buffer was considered. This concordance was stronger if the analysis was restricted to women living closer (≤ 2 km) to an AQMS. When exposure was coded as a continuous term, associations with birth weight for the TAG model were consistent with those obtained in analyses based on exposure estimated from the nearest-AQMS model. The authors conclude that models of exposure to background NO2 concentrations based on data from the nearest AQMS may contain large errors in estimated exposure, but in some instances, these errors have little impact on the relationship between exposure and birth weight.

# Levy, I., et al. (2014). "Elucidating multipollutant exposure across a complex metropolitan area by systematic deployment of a mobile laboratory." Atmospheric Chemistry and Physics 14(14): 7173-7193.

This study evaluates a deployment strategy of a heavily instrumented mobile lab for characterizing multipollutant spatial patterns based upon a limited number of measurement days spread over different seasons. The measurements obtained through this deployment strategy are used to gain insight into average pollutant levels between routine monitoring sites and in relation to emission sources in the region, as well as to assess correlations between pollutant patterns to better understand the nature of urban air pollutant mixtures. A wide range of locations were part of the deployment in order to characterize the distribution of chronic exposures potentially allowing development of exposure models. Comparison of the mobile lab averages to the available adjacent air quality monitoring network stations to evaluate their representativeness showed that they were in reasonable agreement with the annual averages at the monitoring sites, thus providing some evidence that, through the deployment approach, the mobile lab is able to capture the main features of the average spatial patterns. The differences between mobile lab and network averages varied by pollutant with the best agreement for NO2 with a percentage difference of 20 %. Sharp differences in the average spatial distribution were found to exist between different pollutants on multiple scales, particularly on the sub-urban scale, i. e., the neighborhood to street scales. For example, NO2 was observed to be 210-265% higher by the main highway in the study region compared to the nearby urban background monitoring site, while black carbon was higher by 180-200% and particle number concentration was 300% higher. The repeated measurements of near-roadway gradients showed that the rate of change differed by pollutant with elevated concentrations detected up to 600-700m away for some pollutants. These results demonstrate that through systematic deployment mobile laboratory measurements can be used to characterize average or typical concentration patterns, thus providing data to assess monitoring site representativeness, spatial relationships between pollutants, and chronic multipollutant exposure patterns useful for evaluating and developing exposure models for outdoor concentrations in an urban environment.

# Li, S., et al. (2011). "Association of daily asthma emergency department visits and hospital admissions with ambient air pollutants among the pediatric Medicaid population in Detroit: Time-series and time-stratified case-crossover analyses with threshold effects." Environmental Research 111(8): 1137-1147.

Asthma morbidity has been associated with ambient air pollutants in time-series and case-crossover studies. In such study designs, threshold effects of air pollutants on asthma outcomes have been relatively unexplored, which are of potential interest for exploring concentration-response relationships.

This study analyzes daily data on the asthma morbidity experienced by the pediatric Medicaid population (ages 2-18 years) of Detroit, Michigan and concentrations of pollutants fine particles (PM(2.5)), CO, NO(2) and SO(2) for the 2004-2006 period, using both time-series and case-crossover designs. We use a simple, testable and readily implementable profile likelihood-based approach to estimate threshold parameters in both designs.

Evidence of significant increases in daily acute asthma events was found for SO(2) and PM(2.5), and a significant threshold effect was estimated for PM(2.5) at 13 and 11 μgm(-3) using generalized additive models and conditional logistic regression models, respectively. Stronger effect sizes above the threshold were typically noted compared to standard linear relationship, e.g., in the time series analysis, an interquartile range increase (9.2 μgm(-3)) in PM(2.5) (5-day-moving average) had a risk ratio of 1.030 (95% CI: 1.001, 1.061) in the generalized additive models, and 1.066 (95% CI: 1.031, 1.102) in the threshold generalized additive models. The corresponding estimates for the case-crossover design were 1.039 (95% CI: 1.013, 1.066) in the conditional logistic regression, and 1.054 (95% CI: 1.023, 1.086) in the threshold conditional logistic regression.

This study indicates that the associations of SO(2) and PM(2.5) concentrations with asthma emergency department visits and hospitalizations, as well as the estimated PM(2.5) threshold were fairly consistent across time-series and case-crossover analyses, and suggests that effect estimates based on linear models (without thresholds) may underestimate the true risk.

# Liao, C. M., et al. (2011). "Fluctuation analysis-based risk assessment for respiratory virus activity and air pollution associated asthma incidence." Science of the Total Environment 409(18): 3325-3333.

Asthma is a growing epidemic worldwide. Exacerbations of asthma have been associated with bacterial and viral respiratory tract infections and air pollution. We correlated the asthma admission rates with fluctuations in respiratory virus activity and traffic-related air pollution, namely particulate matter with an aerodynamic diameter ≤10μm (PM(10)), nitrogen dioxide (NO(2)), carbon monoxide (CO), sulfur dioxide (SO(2)), and ozone (O(3)). A probabilistic risk assessment framework was developed based on a detrended fluctuation analysis to predict future respiratory virus and air pollutant associated asthma incidence. Results indicated a strong association between asthma admission rate and influenza (r=0.80, <0.05) and SO(2) level (r=0.73, p<0.05) in Taiwan in the period 2001-2008. No significant correlation was found for asthma admission and PM(10), O(3), NO(2), and CO. The proposed fluctuation analysis provides a simple correlation exponent describing the complex interactions of respiratory viruses and air pollutants with asthma. This study revealed that there was a 95% probability of having exceeded 2987 asthma admissions per 100,000 population. It was unlikely (30% probability) that the asthma admission rate exceeded 3492 per 100,000 population. The probability of asthma admission risk can be limited to below 50% by keeping the correlation exponent of influenza to below 0.9. We concluded that fluctuation analysis based risk assessment provides a novel predictor of asthma incidence.

# Liard, R., et al. (1999). "Use of personal passive samplers for measurement of NO2, NO, and O3 levels in panel studies." Environmental Research 81(4): 339-348.

We measured personal exposure to nitrogen dioxide (NO2), nitrogen monoxide (NO), and ozone (O3), using personal passive samplers during three 4-day periods, in a panel study of asthmatics continuing the normal activities of everyday life. Fifty-five adults, mean age 42 years, 53% men, and 39 children, mean age 11 years, 67% boys, wore two Ogawa passive samplers simultaneously: one for O3, the other for NO2 and NO. Mean outdoor pollution was measured at a regional monitoring network. Personal exposure levels were scattered; they were (on average) higher than stationary-site levels for NO and lower for NO2 and O3. In adults, 41% of the variance of personal exposure to NO2 was explained by mean stationary-site measurement levels (P<0.0001). Twenty-one percent additional variance was explained by living near a main road, not having an extractor fan over the cooker, older age, and male sex. NO and O3 personal exposures correlated poorly with stationary-site measurements. In panel studies of the health effects of air pollution, personal exposure to NO2 and NO can be measured satisfactorily by passive samplers: such measurements are necessary for NO but not for NO2. For O3, accurate personal exposure measurement remains a challenge and further technical development is required.

# Lin, Y. T., et al. (2014). "Air pollution and limb defects: A matched-pairs case-control study in Taiwan." Environmental Research 132C: 273-280.

BACKGROUND: Air pollution influences the development of limb defects in animals. There is little epidemiologic evidence on the effect of prenatal air pollution exposure on the risk of limb defects.

OBJECTIVE: To assess the relations between exposure to ambient air pollutants and the risk of limb defects.

METHODS: We conducted a matched-pairs case-control study in Taiwan from 2001 through 2007. The case group consisted of 1687 limb defects and the control group was density-sampling matched one to ten based on the month and year of conception from 1510,064 live singleton newborns in 2001-2007. Adjusted conditional logistic regression models were used to estimate odds ratios per 10ppb change for O3, NO2, 1ppb change for SO2, 10 µg/m(3) change for PM10, and 100ppb change for CO during the first trimester and first three gestational months.

RESULTS: Of the specific limb defects, reduction deformities of limbs (adjusted OR=1.024, 95% CI: 1.000, 1.048) was associated with a 1ppb increase in SO2 during weeks of 9-12 of gestation as well as the first trimester. Reduction deformities of limbs was also associated with a 10ppb increase in O3 during weeks of 1-4 of gestation (adjusted OR=1.391, 95% CI: 1.064, 1.818) among preterm births.

CONCLUSION: The present study provides evidence that exposure to outdoor air SO2 during the first trimester of pregnancy may increase the risk of limb defects. Exposure to O3 was associated with reduction deformities of limbs among preterm births. Similar levels of SO2 and O3 are encountered globally by large numbers of pregnant women.

# Linn, W. S., et al. (1996). "Short-term air pollution exposures and responses in Los Angeles area schoolchildren." Journal of Exposure Analysis and Environmental Epidemiology 6(4): 449-472.

We studied 269 school children from three Southern California communities of contrasting air quality in two successive school years, to investigate short-term effects of ambient ozone (O3), nitrogen dioxide (NO2), or particulate matter (PM) on respiratory health. We measured lung function and symptoms twice daily for one week each in fall, winter and spring; and concurrently assessed time-activity patterns and personal exposures. Average daily personal exposures correlated with pollutant concentrations at central sites (r = 0.61 for O3, 0.63 for NO2, 0.48 for PM). Questionnaire-reported outdoor activity increased slightly in communities/seasons with higher pollution. Lung function differences between communities were explainable by age differences. Morning forced vital capacity (FVC) decreased significantly with increase in PM or NO2 measured over the preceding 24 hours. Morning-to-afternoon change of forced expired volume in one second (FEV1) became significantly more negative with increase in PM, NO2, or O3 on the same day. Predicted FVC or FEV1 loss on highest- vs lowest-pollution days was < 2%. Daily symptoms showed no association with current or prior 24-hour pollution, but increased with decreasing temperature. Parents' questionnaire responses suggested excess asthma and allergy in children from one polluted community while children in the other polluted community reported more symptoms, relative to the cleaner community. We conclude that Los Angeles area children may experience slight lung function changes in association with day-to-day air quality changes, reasonably similar to responses seen by others in less polluted areas. Although short-term pollution effects appear small, they should be assessed in longitudinal lung function studies when possible, to allow maximally accurate measurement of longer-term function changes.

# Linn, W. S., et al. (2000). "Air pollution and daily hospital admissions in metropolitan Los Angeles." Environmental Health Perspectives 108(5): 427-434.

American Heart Association; National Institute of Environmental Health Sciences (Southern California Environmental Health Sciences Center). #We used daily time-series analysis to evaluate associations between ambient carbon monoxide, nitrogen dioxide, particulate matter 10 "mu"m in aerodynamic diameter (PM10), or ozone concentrations, and hospital admissions for cardiopulmonary illnesses in metropolitan Los Angeles during 1992-1995. We performed Poisson regressions for the entire patient population and for subgroups defined by season, region, or personal characteristics, allowing for effects of temporal variation, weather, and autocorrelation. CO showed the most consistently significant (p < 0.05) relationships to cardiovascular admissions. A wintertime 25th-75th percentile increase in CO (1.1-2.2 ppm) predicted an increase of 4% in cardiovascular admissions. NO2, and, to a lesser extent, PM10 tracked CO and showed similar associations with cardiovascular disease, but O3 was negatively or nonsignificantly associated. No significant demographic differences were found, although increased cardiovascular effects were suggested in diabetics, in whites and blacks (relative to Hispanics and Asians), and in persons older than 65 years of age. Pulmonary disease admissions associated more with NO2 and PM10 than with CO. Pulmonary effects were generally smaller than cardiovascular effects and were more sensitive to the choice of model. We conclude that in Los Angeles, atmospheric stagnation with high primary (CO/NO2/PM10) pollution, most common in autumn/winter, increases the risk of hospitalization for cardiopulmonary illness. Summer photochemical pollution (high O3) apparently presents less risk.

# Lipfert, F. W., et al. (2006). "PM2.5 constituents and related air quality variables as predictors of survival in a cohort of U.S. military veterans." Inhalation Toxicology 18(9): 645-657.

Air quality data on trace metals, other constituents of PM2.5, and criteria air pollutants were used to examine relationships with long-term mortality in a cohort of male U.S. military veterans, along with data on vehicular traffic density (annual vehicle-miles traveled per unit of land area). The analysis used county-level environmental data for the period 1997-2002 and cohort mortality for 1997-2001. The proportional hazards model included individual data on age, race, smoking, body mass index, height, blood pressure, and selected interactions; contextual variables also controlled for climate, education, and income. In single-pollutant models, traffic density appears to be the most important predictor of survival, but potential contributions are also seen for NO2, NO3-, elemental carbon, nickel, and vanadium. The effects of the other main constituents of PM2.5, of crustal particles, and of peak levels of CO, O3, or SO2 appear to be less important. Traffic density is also consistently the most important environmental predictor in multiple-pollutant models, with combined relative risks up to about 1.2. However, from these findings it is not possible to discern which aspects of traffic (pollution, noise, stress) may be the most relevant to public health or whether an area-based predictor such as traffic density may have an inherent advantage over localized measures of ambient air quality. It is also possible that traffic density could be a marker for unmeasured pollutants or for geographic gradients per se. Pending resolution of these issues, including replication in other cohorts, it will be difficult to formulate additional cost-effective pollution control strategies that are likely to benefit public health.

# Lipfert, F. W. and R. E. Wyzga (1996). The effects of exposure error on environmental epidemiology.

Electric Power Research Institute. This paper outlines the important concepts of uncertainties in the independent variables that have been used to characterize exposure in environment epidemiology studies and some of their ramifications, with special attention to airborne particles. Sources and typical magnitudes of such errors are discussed and it is shown that these errors may be exerting profound influences on the results of epidemiological studies that are being considered as the basis for further regulation of air pollution. An important finding in this regard is that the coarse particle mass obtained from dichotomous samplers typically has much more uncertainty than the fine particle mass, which makes comparisons of these two quantities problematic.

# Lipfert, F. W., et al. (2009). "Air pollution and survival within the Washington University-EPRI veterans cohort: Risks based on modeled estimates of ambient levels of hazardous and criteria air pollutants." Journal of the Air and Waste Management Association 59(4): 473-489.

For this paper, we considered relationships between mortality, vehicular traffic density, and ambient levels of 12 hazardous air pollutants, elemental carbon (EC), oxides of nitrogen (NOx), sulfur dioxide (SO2), and sulfate (SO4(2-)). These pollutant species were selected as markers for specific types of emission sources, including vehicular traffic, coal combustion, smelters, and metal-working industries. Pollutant exposures were estimated using emissions inventories and atmospheric dispersion models. We analyzed associations between county ambient levels of these pollutants and survival patterns among approximately 70,000 U.S. male veterans by mortality period (1976-2001 and subsets), type of exposure model, and traffic density level. We found significant associations between all-cause mortality and traffic-related air quality indicators and with traffic density per se, with stronger associations for benzene, formaldehyde, diesel particulate, NOx, and EC. The maximum effect on mortality for all cohort subjects during the 26-yr follow-up period is approximately 10%, but most of the pollution-related deaths in this cohort occurred in the higher-traffic counties, where excess risks approach 20%. However, mortality associations with diesel particulates are similar in high- and low-traffic counties. Sensitivity analyses show risks decreasing slightly over time and minor differences between linear and logarithmic exposure models. Two-pollutant models show stronger risks associated with specific traffic-related pollutants than with traffic density per se, although traffic density retains statistical significance in most cases. We conclude that tailpipe emissions of both gases and particles are among the most significant and robust predictors of mortality in this cohort and that most of those associations have weakened over time. However, we have not evaluated possible contributions from road dust or traffic noise. Stratification by traffic density level suggests the presence of response thresholds, especially for gaseous pollutants. Because of their wider distributions of estimated exposures, risk estimates based on emissions and atmospheric dispersion models tend to be more precise than those based on local ambient measurements.

# Lipfert, F. W., et al. (2000). "Infant mortality and air pollution: a comprehensive analysis of US data for 1990." Journal of the Air and Waste Management Association (1990-1992) 50(8): 1350-1366.

This paper uses U.S. linked birth and death records to explore associations between infant mortality and environmental factors, based on spatial relationships. The analysis considers a range of infant mortality end points, regression models, and environmental and socioeconomic variables. The basic analysis involves logistic regression modeling of individuals; the cohort comprises all infants born in the United States in 1990 for whom the required data are available from the matched birth and death records. These individual data include sex, race, month of birth, and birth weight of the infant, and personal data on the mother, including age, adequacy of prenatal care, and smoking and education in most instances. Ecological variables from Census and other sources are matched on the county of usual residence and include ambient air quality, elevation above sea level, climate, number of physicians per capita, median income, racial and ethnic distribution, unemployment, and population density. The air quality variables considered were 1990 annual averages of PM10, CO, SO2, SO4(2-), and "non-sulfate PM10" (NSPM10--obtained by subtracting the estimated SO4(2-) mass from PM10). Because all variables were not available for all counties (especially maternal smoking), it was necessary to consider various subsets of the total cohort. We examined all infant deaths and deaths by age (neonatal and postneonatal), by birth weight (normal and low [< 2500 g]), and by specific causes within these categories. Special attention was given to sudden infant death syndrome (SIDS). For comparable modeling assumptions, the results for PM10 agreed with previously published estimates; however, the associations with PM10 were not specific to probable exposures or causes of death and were not robust to changes in the model and/or the locations considered. Significant negative mortality associations were found for SO4(2-). There was no indication of a role for outdoor PM2.5, but possible contributions from indoor air pollution sources cannot be ruled out, given higher SIDS rates in winter, in the north and west, and outside of large cities.

# Liu, F., et al. (2014). "Asthma and asthma related symptoms in 23,326 Chinese children in relation to indoor and outdoor environmental factors: The Seven Northeastern Cities (SNEC) Study." Science of the Total Environment 497-498: 10-17.

BACKGROUND: Both the levels and patterns of outdoor and indoor air pollutants have changed dramatically during the last decade in China. However, few studies have evaluated the effects of the present air pollution on the health of Chinese children. This study examines the association between outdoor and indoor air pollution and respiratory diseases among children living in Liaoning, a heavy industrial province of China.

METHODS: A cross-sectional study of 23,326 Chinese children aged 6 to 13years was conducted in 25 districts of 7 cities in Northeast China during 2009. Three-year (2006-2008) average concentrations of particles with an aerodynamic diameter of ≤10μm (PM10), sulfur dioxide (SO2), nitrogen dioxides (NO2), and ozone (O3) were calculated from monitoring stations in each of the 25 districts. We used two-level logistic regression models to examine the effects of yearly variations in exposure to each pollutant, controlling for important covariates.

RESULTS: The prevalence of respiratory symptoms was higher for those dwelling close to a busy road, those living near smokestacks or factories, those living with smokers, those living in one-story houses typically with small yards, and those with home renovation, bedroom carpet or pets. Ventilation device use was associated with decreased odds of asthma in children. The adjusted odds ratio for diagnosed-asthma was 1.34 (95% confidence interval [CI], 1.24-1.45) per 31 μg/m(3) increase in PM10, 1.23 (95%CI, 1.14-1.32) per 21 μg/m(3) increase in SO2, 1.25 (95%CI, 1.16-1.36) per 10 μg/m(3) increase in NO2, and 1.31 (95%CI, 1.21-1.41) per 23 μg/m(3) increase in O3, respectively.

CONCLUSION: Outdoor and indoor air pollution was associated with an increased likelihood of respiratory morbidity among Chinese children.

# Liu, L., et al. (2009). "Acute effects of air pollution on pulmonary function, airway inflammation, and oxidative stress in asthmatic children." Environmental Health Perspectives 117(4): 668-674.

Background Air pollution is associated with respiratory symptoms, lung function decrements, and hospitalizations. However, there is little information about the influence of air pollution on lung injury. Objective In this study we investigated acute effects of air pollution on pulmonary function and airway oxidative stress and inflammation in asthmatic children. Methods We studied 182 children with asthma, 9–14years of age, for 4 weeks. Daily ambient concentrations of sulfur dioxide, nitrogen dioxide, ozone, and particulate matter ≤ 2.5 μm in aerodynamic diameter (PM2.5) were monitored from two stations. Once a week we measured spirometry and fractional exhaled nitric oxide (FeNO), and determined thiobarbituric acid reactive substances (TBARS) and 8-isoprostane—two oxidative stress markers—and interleukin-6 (IL-6) in breath condensate. We tested associations using mixed-effects regression models, adjusting for confounding variables. Results Interquartile-range increases in 3-day average SO2 (5.4 ppb), NO2 (6.8 ppb), and PM2.5 (5.4 μg/m3 were associated with decreases in forced expiratory flow between 25% and 75% of forced vital capacity, with changes being -3.1% [95% confidence interval (CI), -5.8 to -0.3], -2.8% (95% CI, -4.8 to -0.8), and -3.0% (95% CI, -4.7 to -1.2), respectively. SO2, NO2, and PM2.5 were associated with increases in TBARS, with changes being 36.2% (95% CI, 15.7 to 57.2), 21.8% (95% CI, 8.2 to 36.0), and 24.8% (95% CI, 10.8 to 39.4), respectively. Risk estimates appear to be larger in children not taking corticosteroids than in children taking corticosteroids. O3 (5.3 ppb) was not associated with health end points. FeNO, 8-isoprostane, and IL-6 were not associated with air pollutants. Conclusion Air pollution may increase airway oxidative stress and decrease small airway function of asthmatic children. Inhaled corticosteroids may reduce oxidative stress and improve airway function.

# Liu, L. J. S., et al. (1995). "Assessment of ozone exposures in the greater metropolitan Toronto area." Journal of the Air and Waste Management Association (1990-1992) 45(4): 223-234.

An ozone (O-3) exposure assessment study was conducted in Toronto, Ontario, Canada during the winter and summer of 1992. A new passive O-3 sampler developed by Harvard was used to measure indoor, outdoor, and personal O-3 concentrations. Measurements were taken weekly and daily during the winter and summer, respectively. Indoor samples were collected at a total of 50 homes and workplaces of study participants. Outdoor O-3 concentrations were measured both at home sites using the passive sampler and at 20 ambient monitoring sites with continuous monitors. Personal O-3 measurements were collected from 123 participants, who also completed detailed time-activity diaries. A total of 2,274 O-3 samples were collected. In addition, weekly air exchange rates of homes were measured. This study demonstrates the performance of our O-3 sampler for exposure assessment. The data obtained are further used to examine the relationships between personal, indoor (home and workplace), and outdoor O-3 concentrations, and to investigate outdoor and indoor spatial variations in O-3 concentrations. Based on home outdoor and indoor, workplace, and ambient O-3 concentrations measured at the Ontario Ministry of the Environment (MOE) sites, the traditional microenvironmental model predicts 72% of the variability in measured personal exposures. An alternative personal O-3 exposure model based on outdoor measurements and time-activity information is able to predict the mean personal exposures in a large population, with the highest R(2) value of 0.41.

# Liu, S., et al. (2007). "Association between maternal exposure to ambient air pollutants during pregnancy and fetal growth restriction." Journal of Exposure Science and Environmental Epidemiology 17(5): 426-432.

Previous research demonstrated consistent associations between ambient air pollution and emergency room visits, hospitalizations, and mortality. Effect of air pollution on perinatal outcomes has recently drawn more attention. We examined the association between intrauterine growth restriction (IUGR) among singleton term live births and sulfur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO), ozone (O3), and fine particles (PM2.5) present in ambient air in the Canadian cities of Calgary, Edmonton, and Montreal for the period 1985-2000. Multiple logistic regression was used to estimate odds ratios (ORs) and 95% confidence intervals (CIs) for IUGR, based on average daily levels of individual pollutants over each month and trimester of pregnancy after adjustment for maternal age, parity, infant gender, season, and city of residence. A 1 ppm increase in CO was associated with an increased risk of IUGR in the first (OR=1.18; 95% CI 1.14-1.23), second (OR=1.15; 95% CI 1.10-1.19) and third (OR=1.19; 95% CI 1.14-1.24) trimesters of pregnancy, respectively. A 20 ppb increase in NO2 (OR=1.16; 95% CI 1.09-1.24; OR=1.14; 95% CI 1.06-1.21; and OR=1.16; 95% CI 1.09-1.24 in the first, second, and third trimesters) and a 10 g/m3 increase in PM2.5 (OR=1.07; 95% CI 1.03-1.10; OR=1.06; 95% CI 1.03-1.10; and OR=1.06; 95% CI 1.03-1.10) were also associated with an increased risk of IUGR. Consistent results were found when ORs were calculated by month rather than trimester of pregnancy. Our findings add to the emerging body of evidence that exposure to relatively low levels of ambient air pollutants in urban areas during pregnancy is associated with adverse effects on fetal growth.

# Liu, S., et al. (2003). "Association between gaseous ambient air pollutants and adverse pregnancy outcomes in Vancouver, Canada." Environmental Health Perspectives 111(14): 1773-1778.

The association between ambient air pollution and adverse health effects, such as emergency room visits, hospitalizations, and mortality from respiratory and cardiovascular diseases, has been studied extensively in many countries, including Canada. Recently, studies conducted in China, the Czech Republic, and the United States have related ambient air pollution to adverse pregnancy outcomes. In this study, we examined association between preterm birth, low birth weight, and intrauterine growth retardation (IUGR) among singleton live births and ambient concentrations of sulfur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO), and ozone in Vancouver, Canada, for 1985-1998. Multiple logistic regression was used to estimate odds ratios (ORs) and 95% confidence intervals (CIs) for such effects. Low birth weight was associated with exposure to SO2 during the first month of pregnancy (OR = 1.11, 95% CI, 1.01-1.22, for a 5.0 ppb increase). Preterm birth was associated with exposure to SO2 (OR = 1.09, 95% CI, 1.01-1.19, for a 5.0 ppb increase) and to CO (OR = 1.08, 95% CI, 1.01-1.15, for a 1.0 ppm increase) during the last month of pregnancy. IUGR was associated with exposure to SO2 (OR = 1.07, 95% CI, 1.01-1.13, for a 5.0 ppb increase), to NO2 (OR = 1.05, 95% CI, 1.01-1.10, for a 10.0 ppb increase), and to CO (OR = 1.06, 95% CI, 1.01-1.10, for a 1.0 ppm increase) during the first month of pregnancy. In conclusion, relatively low concentrations of gaseous air pollutants are associated with adverse effects on birth outcomes in populations experiencing diverse air pollution profiles.

# Liu, X., et al. (2012). "Association between residential proximity to fuel-fired power plants and hospitalization rate for respiratory diseases." Environmental Health Perspectives 120(6): 807-810.

Background: Air pollution is known to cause respiratory disease. Unlike motor vehicle sources, fuel-fired power plants are stationary. Objective: Using hospitalization data, we examined whether living near a fuel-fired power plant increases the likelihood of hospitalization for respiratory disease. Methods: Rates of hospitalization for asthma, acute respiratory infection (ARI), and chronic obstructive pulmonary disease (COPD) were estimated using hospitalization data for 1993-2008 from New York State in relation to data for residences near fuel-fired power plants. We also explored data for residential proximity to hazardous waste sites. Results: After adjusting for age, sex, race, median household income, and rural/urban residence, there were significant 11%, 15%, and 17% increases in estimated rates of hospitalization for asthma, ARI, and COPD, respectively, among individuals > 10 years of age living in a ZIP code containing a fuel-fired power plant compared with one that had no power plant. Living in a ZIP code with a fuel-fired power plant was not significantly associated with hospitalization for asthma or ARI among children < 10 years of age. Living in a ZIP code with a hazardous waste site was associated with hospitalization for all outcomes in both age groups, and joint effect estimates were approximately additive for living in a ZIP code that contained a fuel-fired power plant and a hazardous waste site. Conclusions: Our results are consistent with the hypothesis that exposure to air pollution from fuel-fired power plants and volatile compounds coming from hazardous waste sites increases the risk of hospitalization for respiratory diseases.

# Llorca, J., et al. (2005). "Nitrogen dioxide increases cardiorespiratory admissions in Torrelavega (Spain)." Journal of Environmental Health 68(2): 30-35.

The objective of the study reported here was to analyze relationships between levels of air pollutants and emergency admissions for cardiorespiratory disease. Admission data from January 1, 1992, to December 31, 1995, were obtained from the Marques de Valdecilla University Hospital Admission Service; meteorological data (rainfall, temperatures wind speed, wind direction) were obtained from the National Meteorology Institute in Santander. Pollutant data on sulfur dioxide (SO2), hydrogen sulfide (H2S), total suspended particles (TSP), nitrogen oxide (NO), and nitrogen dioxide (NO2) were provided by the secretary of environment for the Cantabrian Regional Government. Rate ratios were estimated for each pollutant by Poisson regression; they were adjusted for meteorological variables. It was found that elevated NO2 increased by 20 percent the risk of having an admission for cardiorespiratory diseases; this effect was mainly due to respiratory diseases (rate ratio = 1.7, p < .001) and was negligible for cardiac diseases (rate ratio = 1.1, p = .28). In the one-pollutant model, elevated particulates and nitrogen monoxide were also related to admissions, but this effect disappeared when a five-pollutant model was used (p = .21 and p = 0.36, respectively. SO2 and SH2 did not show any relationship with admissions. Thus, nitrogen dioxide was the only pollutant the authors found to be related to emergency admissions for cardiorespiratory diseases. It is difficult to generalize from these results because of the small number of daily admissions and the variability in pollutant levels; therefore, more studies are necessary to improve knowledge about the relationship between air pollution and health in small towns.

# Luke, W. T. (1997). "Evaluation of a commercial pulsed fluorescence detector for the measurement of low-level SO2 concentrations during the Gas-Phase Sulfur Intercomparison Experiment." Journal of Geophysical Research 102(D13): 16255-16265.

A modified pulsed fluorescence (PF) detector (Thermo Environmental Instruments, Model 43s) was used to measure low levels of SO2 in a rigorous, blind intercomparison experiment (Gas-Phase Intercomparison Experiment (GASIE)). The PF detector was able to detect as little as 30 pptv SO2 in a 25-min sampling interval. The coefficients of variation for measurements of approximately 30, 60, 200, 330, and 600 pptv were approximately 40, 9, 6.5, 3, and 3%, respectively. Overall uncertainty of the measurements at 30 pptv approaches 100%. As inferred from GASIE results, the response of the PF detector may be reduced (quenched) by approximately 7% and 15% at water vapor mixing ratios of 1 and 1.5 mole percent (relative humidities of 35-50% at 20-25 C and 1 atm), respectively. These results are uncertain, however, due to lack of extensive data. Post-GASIE tests point to moderate interferences from NO (rejection ratio of 35), CS2 (rejection ratio of 20), and a number of highly fluorescent aromatic hydrocarbons such as benzene, toluene, o-xylene, m-xylene, p-xylene, m-ethyltoluene, ethylbenzene, and 1 ,2,4-trimethylbenzene. Rejection ratios for these compounds increase from approximately 17-123 to circa 1200-3800 as the sample flow rate is decreased from 2000 to 300 standard cubic centimeters per minute (sccm), and the hydrocarbons are more efficiently removed by the instrument's proprietary hydrocarbon "kicker" membrane. At a flow rate of 300 sccm and a pressure drop of 645 torr across the kicker, the interference from ppmv levels of many aromatic hydrocarbon was eliminated entirely. None of the tested interferants were removed by the carbonate-impregnated paper filter used to zero the instrument during GASIE; thus they induced no net response in the PF detector. These results illustrate the importance of using a selective zeroing method to scrub SO2 without removing potential interferants from the sample flow, thus preserving the overall composition of the sampling matrix.

# Madsen, C., et al. (2010). "Ambient air pollution exposure, residential mobility and term birth weight in Oslo, Norway." Environmental Research 110(4): 363-371.

Environmental exposure during pregnancy may have lifelong health consequences for the offspring and some studies have association between maternal exposure to air pollution during pregnancy and offspring's birth weight. However, many of these studies do not take into account small-scale variations in exposure, residential mobility, and work addresses during pregnancy. We used information from the National Birth Registry of Norway to examine associations between ambient environmental exposure such as air pollution and temperature, and offspring's birth weight taking advantage of information on migration history and work address in a large population-based cohort. A dispersion model was used to estimate ambient air pollution levels at all residential addresses and work addresses for a total of 25,229 pregnancies between 1999 and 2002 in Oslo, Norway. Ambient exposure to traffic pollution for the entire pregnancy was associated with a reduction in term birth weight in crude analyzes when comparing children of the highest and lowest exposed mothers. No evidence for an association between exposure to traffic pollution at home and work addresses and term birth weight after adjustment for covariates known to influence birth weight during pregnancy. After stratification, small statistically non-significant reductions were present but only for multiparious mothers. This group also had less residential mobility and less employment during pregnancy. The overall findings suggest no clear association between term birth weight and traffic pollution exposure during pregnancy. However, mobility patterns could introduce possible confounding when examining small-scale variations in exposure by using addresses. This could be of importance in future studies.

# Mannes, T., et al. (2005). "Impact of ambient air pollution on birth weight in Sydney, Australia." Occupational and Environmental Medicine 62(8): 524-530.

BACKGROUND: Studies in Asia, Europe, and the Americas have provided evidence that ambient air pollution may have an adverse effect on birth weight, although results are not consistent. METHODS: Average exposure during pregnancy to five common air pollutants was estimated for births in metropolitan Sydney between 1998 and 2000. The effects of pollutant exposure in the first, second, and third trimesters of pregnancy on risk of "small for gestational age" (SGA), and of pollutant exposure during pregnancy on birth weight were examined. RESULTS: There were 138,056 singleton births in Sydney between 1998 and 2000; 9.7% of babies (13,402) were classified as SGA. Air pollution levels in Sydney were found to be quite low. In linear regression models carbon monoxide and nitrogen dioxide concentrations in the second and third trimesters had a statistically significant adverse effect on birth weight. For a 1 part per million increase in mean carbon monoxide levels a reduction of 7 (95% CI -5 to 19) to 29 (95% CI 7 to 51) grams in birth weight was estimated. For a 1 part per billion increase in mean nitrogen dioxide levels a reduction of 1 (95% CI 0 to 2) to 34 (95% CI 24 to 43) grams in birth weight was estimated. Particulate matter (diameter less than ten microns) in the second trimester had a small statistically significant adverse effect on birth weight. For a 1 microgram per cubic metre increase in mean particulate matter levels a reduction of 4 grams (95% CI 3 to 6) in birth weight was estimated. CONCLUSION: These findings of an association between carbon monoxide, nitrogen dioxide, and particulate matter, and reduction in birth weight should be corroborated by further study.

# Mansfield, C. A., et al. (2006). "The missing piece: Valuing averting behavior for children's ozone exposures." Resource and Energy Economics 28(3): 215-228.

Individuals can reduce their exposure to air pollution by reducing the amount of time they spend outdoors. Reducing outdoor time is an example of an averting behavior that should be measured as part of willingness to pay (WTP) for improvements in air quality. In this paper, we estimate parents’ WTP to prevent restrictions on a child's outdoor time from a stated-preference (SP) conjoint survey. We combine this WTP measure with an estimate of reductions in time spent outdoors on high-ozone days from an activity-diary study to estimate this averting behavior component of WTP for reductions in ozone pollution.

# Mar, T. F., et al. (2000). "Associations between air pollution and mortality in Phoenix, 1995-1997." Environmental Health Perspectives 108(4): 347-353.

National Institutes of Health; U.S. Environmental Protection Agency. #We evaluated the association between mortality outcomes in elderly individuals and particulate matter (PM) of varying aerodynamic diameters (in micrometers) [PM10, PM2.5, and PMCF (PM10 minus PM2.5)], and selected particulate and gaseous phase pollutants in Phoenix, Arizona, using 3 years of daily data (1995-1997). Although source apportionment and epidemiologic methods have been previously combined to investigate the effects of air pollution on mortality, this is the first study to usc detailed PM composition data in a time-series analysis of mortality. Phoenix is in the arid Southwest and has approximately 1 million residents (9.7% of the residents are > 65 years of age). PM data were obtained from the U.S. Environmental Protection Agency (EPA) National Exposure Research Laboratory Platform in central Phoenix. We obtained gaseous pollutant data, specifically carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide data, from the EPA Aerometric Information Retrieval System Database. We used Poisson regression analysis to evaluate the associations between air pollution and nonaccidental mortality and cardiovascular mortality. Total mortality was significantly associated with CO and NO2 (p < 0.05) and weakly associated with SO2, PM10, and PMCE (p < 0.10). Cardiovascular mortality was significantly associated with CO, NO2, SO2, PM2.5, PM10, PMCF (p < 0.05), and elemental carbon. Factor analysis revealed that both combustion-related pollutants and secondary aerosols (sulfates) were associated with cardiovascular mortality.

# Marshall, J. D., et al. (2008). "Within-urban variability in ambient air pollution: Comparison of estimation methods." Atmospheric Environment 42(6): 1359-1369.

An important component of air quality management and health risk assessment is improved understanding of spatial and temporal variability in pollutant concentrations. We compare, for Vancouver, Canada, three approaches for estimating within-urban spatiotemporal variability in ambient concentrations: spatial interpolation of monitoring data; an empirical/statistical model based on geographic analyses (“land-use regression”;LUR); and an Eulerian grid model (community multiscale air quality model, CMAQ). Four pollutants are considered—nitrogen oxide (NO), nitrogen dioxide (NO2), carbon monoxide, and ozone-represent varying levels of spatiotemporal heterogeneity. Among the methods, differences in central tendencies (mean, median) and variability (standard deviation) are modest. LUR and CMAQ perform well in predicting concentrations at monitoring sites (average absolute bias: <50% for NO; <20% for NO2). Monitors (LUR) offer the greatest (least) temporal resolution; LUR (monitors) offers the greatest (least) spatial resolution. Of note, the length scale of spatial variability is shorter for LUR (units: km; 0.3 for NO, 1 for NO2) than for the other approaches (3-6 for NO, 4-6 for NO2), indicating that the approaches offer different information about spatial attributes of air pollution. Results presented here suggest that for investigations incorporating spatiotemporal variability in ambient concentrations, the findings may depend on which estimation method is employed.

# McClenny, W. A., et al. (2002). "Preparing to measure the effects of the NOx SIP call--methods for ambient air monitoring of NO, NO2, NOy, and individual NOz species." Journal of the Air and Waste Management Association 52(5): 542-562.

The capping of stationary source emissions of NOx in 22 states and the District of Columbia is federally mandated by the NOx SIP Call legislation with the intended purpose of reducing downwind O3 concentrations. Monitors for NO, NO2, and the reactive oxides of nitrogen into which these two compounds are converted will record data to evaluate air quality model (AQM) predictions. Guidelines for testing these models indicate the need for semicontinuous measurements as close to real time as possible but no less frequently than once per hour. The measurement uncertainty required for AQM testing must be less than +/-20% (10% for NO2) at mixing ratios of 1 ppbv and higher for NO, individual NO z component compounds, and NOy. This article is a review and discussion of different monitoring methods, some currently used in research and others used for routine monitoring. The performance of these methods is compared with the monitoring guidelines. Recommendations for advancing speciated and total NOy monitoring technology and a listing of demonstrated monitoring approaches are also presented.

# McConnell, R., et al. (2003). "Prospective study of air pollution and bronchitic symptoms in children with asthma." American Journal of Respiratory and Critical Care Medicine 168(7): 790-797.

The relationship of bronchitic symptoms to ambient particulate matter and to particulate elemental and organic carbon (OC), nitrogen dioxide (NO2) and other gaseous pollutants was examined in a cohort of asthmatic children in 12 Southern California communities. Symptoms, assessed yearly by questionnaire from 1996-1999, were associated with the yearly variability of particulate matter with aerodynamic diameter less than 2.5 odds ratio (O.R.) 1.09/µg/m3; 95% confidence interval (C.I.) 1.01-1.17), OC(O.R. 1.41/µg/m3; 95% C.I. 1.12-1.78), NO2 (O.R. 1.07/part per billion (ppb); 95% C.I. 1.02-1.13) and ozone (O.R. 1.06/ppb; 95% C.I. 1.00-1.12). The odds ratios associated with yearly within-community variability in air pollution were larger than the effect of the between-community four-year average concentrations. In two pollutant models, the effects of yearly variation in OC and NO2 were only modestly reduced by adjusting for other pollutants, except in a model containing both OC and NO2; the effects of all other pollutants were reduced after adjusting for OC or NO2. We conclude that OC and NO2 deserve greater attention as potential causes of the chronic symptoms of bronchitis in asthmatic children and that previous cross-sectional studies may have underestimated the risks associated with air pollution.

# McConnell, R., et al. (2006). "Predicting residential ozone deficits from nearby traffic." Science of the Total Environment 363(1-3): 166-174.

Oxides of nitrogen in fresh traffic exhaust are known to scavenge ambient ozone. However, there has only been little study of local variation in ozone resulting from variation in vehicular traffic patterns within communities. Homes of 78 children were selected from a sample of participants in 3 communities in the southern California Children's Health Study. Twenty-four hour ozone measurements were made simultaneously at a home and at a community central site monitor on two occasions between February and November 1994. Homes were geo-coded, and local residential nitrogen oxides (NOx) above regional background due to nearby traffic at each participant's home were estimated using a line source dispersion model. Measured home ozone declined in a predictable manner as modeled residential NOx increased. NOx modeled from local traffic near homes accounted for variation in ozone concentrations of as much as 17 parts per billion. We conclude that residential ozone concentrations may be over- or underestimated by measurements at a community monitor, depending on the variation in local traffic in the community. These findings may have implications for studies of health effects of traffic-related pollutants.

# McConnell, R., et al. (2010). "Childhood incident asthma and traffic-related air pollution at home and school." Environmental Health Perspectives 118(7): 1021-1026.

Background: Traffic-related air pollution has been associated with adverse cardio-respiratory effects, including increased asthma prevalence. However, there has been little study of effects of traffic exposure at school on new onset asthma. Objectives: To evaluate the relationship of new onset asthma with traffic-related pollution near homes and schools. Methods: Parent-reported physician diagnosis of new onset asthma (N=120) was identified during three years of follow-up of a cohort of 2497 kindergarten and first grade children who were asthma- and wheezing-free at study entry into the southern California Children’s Health Study. Traffic-related pollution exposure was assessed based on a line source dispersion model of traffic volume, distance from home and school, and local meteorology. Regional ambient ozone, nitrogen dioxide (NO2), and particulate matter were measured continuously at one central site monitor in each of 13 study communities. Hazard ratios (HRs) for new onset asthma were scaled to the range of ambient central site pollutants and to the residential inter-quartile range for each traffic exposure metric. Results: Asthma risk increased with modeled traffic-related pollution exposure from roadways near homes (HR 1.51; 95% confidence interval 1.25-1.82) and near schools (HR 1.45;1.06-1.98). Ambient NO2 measured at a central site in each community was also associated with increased risk (HR 2.18;1.18-4.01). In models with both NO2 and modeled traffic exposures, there were independent associations of asthma with traffic-related pollution at school and home, while the estimate for NO2 was attenuated (HR 1.37;0.69,2.71). Conclusions: Traffic-related pollution exposure at school and homes may both contribute to the development of asthma.

# McDermott, M., et al. (2006). "Awareness of and compliance with air pollution advisories: A comparison of parents of asthmatics with other parents." Journal of Asthma 43(3): 235-239.

Objectives. To determine parents' awareness of and compliance with air pollution advisories, and to compare the awareness and compliance of parents' of asthmatics to that of other parents. Methods. Responses of 240 parents surveyed at pediatric clinic visits were compared. Results. A total of 88% of parents were aware of air pollution advisories; 71% reduced pollution and 55% restricted children's play

# McDonnell, W. F., et al. (1999). "Long-term ambient ozone concentration and the incidence of asthma in nonsmoking adults: the Ahsmog study." Environmental Research 80(2): 110-121.

U.S. Environmental Protection Agency; California Air Resources Board. #We conducted a prospective study of a cohort of 3091 nonsmokers, ages 27 to 87 years, to evaluate the association between long-term ambient ozone exposure and development of adult-onset asthma. Over a 15-year period, 3.2% of males and 4.3% of females reported new doctor diagnoses of asthma. For males, we observed a significant relationship between report of doctor diagnosis of asthma and 20-year mean 8-h average ambient ozone concentration (relative risk (RR) = 2.09 for a 27 ppb increase in ozone concentration, 95% CI = 1.03 to 4.16). We observed no such relationship for females. Other variables significantly related to development of asthma were a history of ever-smoking for males (HR = 237, 95% CI = 1.13 to 4.81), and for females, number of years worked with a smoker (RR 1.21 for a 7-year increment, 95% CI = 1.04 to 1.39), age (RH = 0.61 for a 16-year increment, 95% CI = 0.44 to 0.84), and a history of childhood pneumonia or bronchitis (RH = 2.96, 95% CI = 1.68 to 5.03). Addition of other pollutants (PM10, SO4, NO2, and SO2) to the models did not diminish the relationship between ozone and asthma for males. These data suggest that long-term exposure to ambient ozone is associated with development of asthma in adult males.

# Mehta, S., et al. (2013). "Air pollution and admissions for acute lower respiratory infections in young children of Ho Chi Minh City." Air Quality, Atmosphere and Health 6(1): 167-179.

This study assessed the effects of exposure to air pollution on hospitalization for acute lower respiratory infection (ALRI) among children under 5 years of age in Ho Chi Minh City (HCMC) from 2003 to 2005. Case-crossover analyses with time-stratified selection of control periods were conducted using daily admissions for pneumonia and bronchiolitis and daily, citywide averages of PM10, NO2, SO2, and O3 (8-h maximum average) estimated from the local air quality monitoring network. Increased concentrations of NO2 and SO2 were associated with increased admissions in the dry season (November to April), with excess risks of 8.50% (95%CI 0.80–16.79) and 5.85% (95%CI 0.44–11.55), respectively. PM10 could also be associated with increased admissions in the dry season, but high correlation between PM10 and NO2 (0.78) limits our ability to distinguish between PM10 and NO2 effects. In the rainy season (May-October), negative associations between pollutants and admissions were observed. Results of this first study of the health effects of air pollution in HCMC support the presence of an association between combustion-source pollution and increased ALRI admissions. ALRI admissions were generally positively associated with ambient levels of PM10, NO2, and SO2 during the dry season, but not the rainy season. Negative results in the rainy season could be driven by residual confounding present from May to October. Preliminary exploratory analyses suggested that seasonal differences in the prevalence of viral causes of ALRI could be driving the observed differences in effects by season.

# Meng, Q. Y., et al. (2012). "Associations between personal exposures and ambient concentrations of nitrogen dioxide: A quantitative research synthesis." Atmospheric Environment 57: 322-329.

Although positive associations between ambient NO2 concentrations and personal exposures have generally been found by exposure studies, the strength of the associations varied among studies. Differences in results could be related to differences in study design and in exposure factors. However, the effects of study design, exposure factors, and sampling and measurement errors on the strength of the personal-ambient associations have not been evaluated quantitatively in a systematic manner. A quantitative research synthesis was conducted to examine these issues based on peer-reviewed publications in the past 30 years. Factors affecting the strength of the personal-ambient associations across the studies were also examined with meta-regression. Ambient NO2 was found to be significantly associated with personal NO2 exposures, with estimates of 0.42, 0.16, and 0.72 for overall pooled, longitudinal and daily average correlation coefficients based on random-effects meta-analysis. This conclusion was robust after correction for publication bias with correlation coefficients of 0.37, 0.16 and 0.45. We found that season and some population characteristics, such as pre-existing disease, were significant factors affecting the strength of the personal-ambient associations. More meaningful and rigorous comparisons would be possible if greater detail were published on the study design (e.g. local and indoor sources, housing characteristics, etc.) and data quality (e.g., detection limits and percent of data above detection limits). Published by Elsevier Ltd.

# Metzger, K. B., et al. (2004). "Ambient air pollution and cardiovascular emergency department visits." Epidemiology 15(1): 46-56.

Background: Despite evidence supporting an association between ambient air pollutants and cardiovascular disease (CVD), the roles of the physicochemical components of particulate matter (PM) and copollutants are not fully understood. This time-series study examined the relation between ambient air pollution and cardiovascular conditions using ambient air quality data and emergency department visit data in Atlanta, Georgia, from January 1, 1993, to August 31,2000. Methods: Outcome data on 4,407,535 emergency department visits were compiled from 31 hospitals in Atlanta. The air quality data included measurements of criteria pollutants for the entire study period, as well as detailed measurements of mass concentrations for the fine and coarse fractions of PM and several physical and chemical characteristics of PM for the final 25 months of the study. Emergency department visits for CVD and for cardiovascular sub-groups were assessed in relation to daily measures of air pollutants using Poisson generalized linear models controlling for long-term temporal trends and meteorologic conditions with cubic splines. Results: Using an a priori 3-day moving average in single-pollutant models, CVD visits were associated with NO2, CO, PM2.5, organic carbon, elemental carbon, and oxygenated hydrocarbons. Secondary analyses suggested that these associations tended to be strongest with same-day pollution levels. Conclusions: These findings provide evidence for an association between CVD visits and several correlated pollutants, including gases, PM2.5 and PM2.5 components.

# Mortimer, K. M., et al. (2002). "The effect of air pollution on inner-city children with asthma." European Respiratory Journal 19(4): 699-705.

The effect of daily ambient air pollution was examined within a cohort of 846 asthmatic children residing in eight urban areas of the USA, using data from the National Cooperative Inner-City Asthma Study. Daily air pollution concentrations were extracted from the Aerometric Information Retrieval System database from the Environment Protection Agency in the USA. Mixed linear models and generalized estimating equation models were used to evaluate the effects of several air pollutants (ozone, sulphur dioxide (SO2), nitrogen dioxide (NO2) and particles with a 50% cut-off aerodynamic diameter of 10 microm (PM10) on peak expiratory flow rate (PEFR) and symptoms in 846 children with a history of asthma (ages 4-9 yrs). None of the pollutants were associated with evening PEFR or symptom reports. Only ozone was associated with declines in morning % PEFR (0.59% decline (95% confidence interval (CI) 0.13-1.05%) per interquartile range (IQR) increase in 5-day average ozone). In single pollutant models, each pollutant was associated with an increased incidence of morning symptoms: (odds ratio (OR)=1.16 (95% CI 1.02-1.30) per IQR increase in 4-day average ozone, OR=1.32 (95% CI 1.03-1.70) per IQR increase in 2-day average SO2, OR=1.48 (95% CI 1.02-2.16) per IQR increase in 6-day average NO2 and OR=1.26 (95% CI 1.0-1.59) per IQR increase in 2-day average PM10. This longitudinal analysis supports previous time-series findings that at levels below current USA air-quality standards, summer-air pollution is significantly related to symptoms and decreased pulmonary function among children with asthma.

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# Moshammer, H., et al. (2006). "Low levels of air pollution induce changes of lung function in a panel of schoolchildren." European Respiratory Journal 27(6): 1138-1143.

In search of sensitive screening parameters for assessing acute effects of ambient air pollutants in young schoolchildren, the impact of 8-h average air pollution before lung function testing was investigated by oscillatory measurements of resistance and spirometry with flow-volume loops. At a central elementary school in Linz, the capital of Upper Austria, 163 children aged 7-10 yrs underwent repeated examinations at the same time of day during 1 school year, yielding a total of 11-12 lung function tests per child. Associations to mass concentrations of particulate matter and nitrogen dioxide (NO2) measured continuously at a nearby monitoring station were tested, applying the Generalised Estimating Equations model. Reductions per 10 microg.m-3 (both for particles and for NO2) were in the magnitude of 1% for most lung function parameters. The most sensitive indicator for acute effects of combustion-related pollutants was a change in maximal expiratory flow in small airways. NO2 at concentrations below current standards reduced (in the multipollutant model) the forced expiratory volume in one second by 1.01%, maximal instantaneous forced flow when 50% of the forced vital capacity remains to be exhaled (MEF(50%)) by 1.99% and MEF(25%) by 1.96%. Peripheral resistance increased by 1.03% per 10 microg.m(-3) of particulate matter with a 50% cut-off aerodynamic diameter of 2.5 mum (PM2.5). Resistance is less influenced by the child's cooperation and should be utilised more often in environmental epidemiology when screening for early signs of small airway dysfunction from urban air pollution, but cannot replace the measurement of MEF(50%) and MEF(25%). In the basic model, the reduction of these parameters per 10 microg.m(-3) was highest for NO2, followed by PM1, PM2.5 and PM10, while exposure to coarse dust (PM10-PM2.5) did not change end-expiratory flow significantly. All acute effects of urban air pollution found on the lung function of healthy pupils were evident at levels below current European limit values for nitrogen dioxide. Thus, planned reduction of nitrogen dioxide emission (Euro 5; vehicles that comply with the emission limits as defined in Directive 99/96/EC) of 20% in 2010 would seem to be insufficient.

# Neidell, M. (2009). "Information, avoidance behavior, and health: The effect of ozone on asthma hospitalizations." Journal of Human Resources 44(2): 450-478.

This paper assesses whether responses to information about risk impact estimates of the relationship between ozone and asthma in Southern California. Using a regression discontinuity design, I find smog alerts significantly reduce daily attendance at two major outdoor facilities. Using daily time-series regression models that include year-month and small area fixed effects, I find estimates of the effect of ozone for children and the elderly that include information are significantly larger than estimates that do not. These results are consistent with the hypothesis that individuals take substantial action to reduce exposure to risk; estimates ignoring these actions are severely biased.

# Neidell, M. (2010). "Air quality warnings and outdoor activities: Evidence from Southern California using a regression discontinuity design." Journal of Epidemiology and Community Health 64(10): 921-926.

Background A study was undertaken to assess the impact of air quality warnings associated with ground-level ozone on outdoor activities in Southern California. Methods Data on aggregate daily attendance at two major outdoor facilities were collected and merged with observed and forecasted air quality and meteorology at the daily level. A quasi-experimental regression discontinuity design was used to estimate the impact of warnings. Results Attendance declined significantly when stage 1 air quality warnings (‘smog alerts’) were issued. Consistent with expectations, responses were greater for populations more likely to be considered susceptible and more likely to be local residents. Conclusions Air quality warnings are an important policy tool for protecting the public's health from high levels of ambient air pollution.

# Neidell, M. and P. L. Kinney (2010). "Estimates of the association between ozone and asthma hospitalizations that account for behavioral responses to air quality information." Environmental Science and Policy 13(2): 97-103.

Behavioral responses to information about forecasted air quality may introduce systematic measurement error in pollution exposure, leading to biased estimates of the impact of pollution exposure on health. This paper estimates the statistical association between ambient ozone concentrations and asthma hospitalizations in Southern California while accounting for potential avoidance behavior in response to forecasted air quality. Data on asthma hospital admissions were merged with observed and forecasted air quality and meteorological data at the daily level for the years 1989-1997. A distributed lag Poisson generalized linear model allowing for overdispersion was estimated. Accounting for potential responses to information about pollution leads to significantly larger estimates of the relationship between ozone concentrations and asthma hospital admissions, particularly for susceptible populations. Individuals take substantial actions to reduce exposure to ozone; estimates of the concentration-response function for ozone that ignore these actions are biased towards the null and may significantly understate the costs to society from ozone concentrations.

# Nishimura, K. K., et al. (2013). "Early-life air pollution and asthma risk in minority children: The GALA II and SAGE II studies." American Journal of Respiratory and Critical Care Medicine 188(3): 309-318.

Rationale: Air pollution is a known asthma trigger and has been associated with short-term asthma symptoms, airway inflammation, decreased lung function, and reduced response to asthma rescue medications. Objectives: To assess a causal relationship between air pollution and childhood asthma using data that address temporality by estimating air pollution exposures prior to the development of asthma and to establish the generalizability of the association by studying diverse racial/ethnic populations in different geographic regions. Methods: This study included Latino (n= 3,343) and African American (n= 977) participants with and without asthma from five urban regions in the mainland U.S. and Puerto Rico. Residential history and data from local ambient air monitoring stations were used to estimate average annual exposure to five air pollutants: ozone (O3), nitrogen dioxide (NO2), sulfur dioxide (SO2), particulate matter ≤ 10µm and ≤ 2.5µm (PM10 and PM2.5). Within each region, we performed logistic regression to determine the relationship between early life exposure to air pollutants and subsequent asthma diagnosis. A random-effects model was used to combine the region-specific effects and generate summary odds ratios (OR) for each pollutant. Results: After adjustment for confounders, a 5 ppb increase in average NO2 during the first year of life was associated with an OR of 1.17 for physician-diagnosed asthma (95% confidence interval, 1.04-1.31). Conclusions: Early life NO2 exposure is associated with childhood asthma in Latino and African Americans. These results add to a growing body of evidence that traffic-related pollutants may be causally related to childhood asthma.

# Nunnermacker, L. J., et al. (1998). "Characterization of the Nashville urban plume on July 3 and July 18, 1995." Journal of Geophysical Research 103(D21): 28129-28148.

The Southern Oxidants Study field campaign was designed to characterize the formation and distribution of ozone and related species in the Nashville urban region. Data from several airborne platforms as well as surface observations on July 3 and 18 are examined to gain insight into the factors that control O3 formation rates and concentrations in the regional plumes. On both days, well-defined urban and power plant plumes were sampled. Utilizing both aircraft and surface data, a detailed kinetic analysis of the chemical evolution of the urban plume is performed to derive: NOx lifetime, ozone production efficiency, OH concentration, HNO3 dry deposition rate, and the relative importance of natural and anthropogenic hydrocarbons to O3 production. Analysis of the urban plume data revealed a very active photochemical system that consumed 50 percent of the NOx within approximately two hours, at an ozone production efficiency of 2.5 to 4 molecules for each molecule of NOx. Anthropogenic hydrocarbons provided approximately 44 percent of the fuel for ozone production by the urban plume. The dry deposition rate for HNO3 in the urban plume was estimated to be on the order of 5 to 7 cm sec-1.

# O'Connor, G. T., et al. (2008). "Acute respiratory health effects of air pollution on children with asthma in US inner cities." Journal of Allergy and Clinical Immunology 121(5): 1133-1139.e1131.

Background Children with asthma in inner-city communities may be particularly vulnerable to adverse effects of air pollution because of their airways disease and exposure to relatively high levels of motor vehicle emissions. Objective To investigate the association between fluctuations in outdoor air pollution and asthma morbidity among inner-city children with asthma. Methods We analyzed data from 861 children with persistent asthma in 7 US urban communities who performed 2-week periods of twice-daily pulmonary function testing every 6 months for 2 years. Asthma symptom data were collected every 2 months. Daily pollution measurements were obtained from the Aerometric Information Retrieval System. The relationship of lung function and symptoms to fluctuations in pollutant concentrations was examined by using mixed models. Results Almost all pollutant concentrations measured were below the National Ambient Air Quality Standards. In single-pollutant models, higher 5-day average concentrations of NO2, sulfur dioxide, and particles smaller than 2.5 μm were associated with significantly lower pulmonary function. Higher pollutant levels were independently associated with reduced lung function in a 3-pollutant model. Higher concentrations of NO2 and particles smaller than 2.5 μm were associated with asthma-related missed school days, and higher NO2 concentrations were associated with asthma symptoms. Conclusion Among inner-city children with asthma, short-term increases in air pollutant concentrations below the National Ambient Air Quality Standards were associated with adverse respiratory health effects. The associations with NO2 suggest that motor vehicle emissions may be causing excess morbidity in this population.

# O'Neill, M. S., et al. (2003). "Ozone exposure among Mexico City outdoor workers." Journal of the Air and Waste Management Association 53(3): 339-346.

In researching health effects of air pollution, pollutant levels from fixed-site monitors are commonly assigned to the subjects. However, these concentrations may not reflect the exposure these individuals actually experience. A previous study of ozone (O3) exposure and lung function among shoe-cleaners working in central Mexico City used fixed-site measurements from a monitoring station near the outdoor work sites as surrogates for personal exposure. The present study assesses the degree to which these estimates represented individual exposures. In 1996, personal O3 exposures of 39 shoe-cleaners working outdoors were measured using an active integrated personal sampler. Using mixed models, we assessed the relationship between measured personal O3 exposure and ambient O3 measurements from the fixed-site monitoring station. Ambient concentrations were approximately 50 parts per billion higher, on average, than personal exposures. The association between personal and ambient O3 was highly significant (mixed model slope p < 0.0001). The personal/ambient ratio was not constant, so use of the outdoor monitor would not be appropriate to rank O3 exposure and evaluate health effects between workers. However, the strong within-worker longitudinal association validates previous findings associating day-to-day changes in fixed-site O3 levels with adverse health effects among these shoe-cleaners and suggests fixed-site O3 monitors may adequately estimate exposure for other repeated-measure health studies of outdoor workers.

# Paciorek, C. J. (2010). "The importance of scale for spatial-confounding bias and precision of spatial regression estimators." Statistical Science 25(1): 107-125.

Residuals in regression models are often spatially correlated. Prominent examples include studies in environmental epidemiology to understand the chronic health effects of pollutants. I consider the effects of residual spatial structure on the bias and precision of regression coefficients, developing a simple framework in which to understand the key issues and derive informative analytic results. When unmeasured confounding introduces spatial structure into the residuals, regression models with spatial random effects and closely-related models such as kriging and penalized splines are biased, even when the residual variance components are known. Analytic and simulation results show how the bias depends on the spatial scales of the covariate and the residual: one can reduce bias by fitting a spatial model only when there is variation in the covariate at a scale smaller than the scale of the unmeasured confounding. I also discuss how the scales of the residual and the covariate affect efficiency and uncertainty estimation when the residuals are independent of the covariate. In an application on the association between black carbon particulate matter air pollution and birth weight, controlling for large-scale spatial variation appears to reduce bias from unmeasured confounders, while increasing uncertainty in the estimated pollution effect.

# Padró-Martínez, L. T., et al. (2012). "Mobile monitoring of particle number concentration and other traffic-related air pollutants in a near-highway neighborhood over the course of a year." Atmospheric Environment 61: 253-264.

Accurate quantification of exposures to traffic-related air pollution in near-highway neighborhoods is challenging due to the high degree of spatial and temporal variation of pollutant levels. The objective of this study was to measure air pollutant levels in a near-highway urban area over a wide range of traffic and meteorological conditions using a mobile monitoring platform. The study was performed in a 2.3-km(2) area in Somerville, Massachusetts (USA), near Interstate I-93, a highway that carries 150,000 vehicles per day. The mobile platform was equipped with rapid-response instruments and was driven repeatedly along a 15.4-km route on 55 days between September 2009 and August 2010. Monitoring was performed in 4-6-hour shifts in the morning, afternoon and evening on both weekdays and weekends in winter, spring, summer and fall. Measurements were made of particle number concentration (PNC; 4-3,000 nm), particle size distribution, fine particle mass (PM(2.5)), particle-bound polycyclic aromatic hydrocarbons (pPAH), black carbon (BC), carbon monoxide (CO), and nitrogen oxides (NO and NO(x)). The highest pollutant concentrations were measured within 0-50 m of I-93 with distance-decay gradients varying depending on traffic and meteorology. The most pronounced variations were observed for PNC. Annual median PNC 0-50 m from I-93 was two-fold higher compared to the background area (>1 km from I-93). In general, PNC levels were highest in winter and lowest in summer and fall, higher on weekdays and Saturdays compared to Sundays, and higher during morning rush hour compared to later in the day. Similar spatial and temporal trends were observed for NO, CO and BC, but not for PM(2.5). Spatial variations in PNC distance-decay gradients were non-uniform largely due to contributions from local street traffic. Hour-to-hour, day-to-day and season-to-season variations in PNC were of the same magnitude as spatial variations. Datasets containing fine-scale temporal and spatial variation of air pollution levels near highways may help to inform exposure assessment efforts.

# Painter, K., et al. (2014). "Automatic document classification for environmental risk assessment." Peer Journal 2: e300v301.

Motivation: In environmental risk assessment, information about potential health risks of chemicals released into the environment is compiled and distilled for use in informing public policy. The U.S. Environmental Protection Agency (EPA) produces Integrated Science Assessments (ISA) that provide a review of literature on air pollutants, including nitrogen oxides (NOx). That review process currently requires much human labor to evaluate thousands of potentially-relevant documents published each year, a problem this study seeks to alleviate by using automated topic classification methods. Results: For this study, abstracts and titles of scientific documents about NOx were labeled by subject matter experts in four domains relevant to ISAs: toxicology, atmospheric science, epidemiology, and exposure science. In addition, documents not relevant to the four domains were included to simulate the background literature that we want to filter out of consideration. The labeled documents were used to train models using a Naive Bayes Multinomial classifier, via the Weka data mining platform. Separate tests were performed using multi-class or single-class models, and including background literature or not including it. For the multi-class models, recall (% of all documents in a class that are classified correctly) for scientific domains ranged between 74% and 94%, with precision (% of classified documents that are in the desired class) between 38% and 93%, with models created with background literature performing worse than models without the background documents. Single-class models had precision that ranged from 31% to 90%, and recall that ranged from 84% to 98%, with better precision for models not using background literature, but better overall recall for models using background literature. Single-class models generally performed better than multi-class models in recall, though multi-class models without the background screen tended to be best for precision.

# Pan, G., et al. (2010). "Air pollution and children's respiratory symptoms in six cities of Northern China." Respiratory Medicine 104(12): 1903-1911.

OBJECTIVE: The associations between air pollution and children's respiratory health in the high pollution range have not yet been clearly characterized. We evaluated the effects of outdoor air pollution on respiratory morbidity in children selected from multiple sites in a heavy industrial province of northeastern China.

METHODS: The study included 11,860 children aged 3-12 years, selected from 18 districts of 6 cities in Liaoning province, the participation rate is 89.9%. Informed consent and written responses to surveys about children's historic and current health status, personal and household characteristics, and other information were obtained from parents. A two-stage regression approach was applied in data analyses.

RESULTS: There were wide gradients for TSP (188-689 μg/m(3)), SO(2) (14-140 μg/m(3) and NO(2) (29-94 μg/m(3)) across the 18 districts of 6 cities. The three air pollutants significantly increased the prevalence of persistent cough (21-28%), persistent phlegm (21-30%) and current asthma (39-56%) for each interquartile range increment (172 μg/m(3) for TSP, 69 μg/m(3) for SO(2), 30 μg/m(3) for NO(2)), showing larger between-city effects than within-city. Rates of respiratory symptoms were significantly higher for children with younger age, atopy, respiratory disease in early age, family history of asthma or chronic bronchitis, and tobacco smoke exposure.

CONCLUSION: The high levels of outdoor air pollution in north China are positively associated with children's respiratory symptoms, the associations with TSP appear to be stronger than SO(2) and NO(2).

# Park, S. S., et al. (2008). "Investigation of nitrous acid concentration in an indoor environment using an in-situ monitoring system." Atmospheric Environment 42(27): 6586-6596.

An in-situ measurement system for the determination of nitrous acid (HONO) was developed and used at an indoor residential environment. The system uses a diffusion scrubber to sample gaseous HONO and the peroxynitrite-induced luminol chemiluminescent method to quantify the amount of HONO. In this system, the detection limit of HONO, estimated as three times the noise level of the scrubbing solution bank, was 120 pptv for a 2-min integrated sample. Indoor HONO and NO, concentrations were determined for 7 days in the living room of an apartment with a gas range for cooking in the kitchen. Close examination of the relationships among HONO, NO, and NO2 concentrations during both the background and combustion periods confirm that the observed HONO was formed not only by direct emission from gas combustion, but also from heterogeneous reactions of NO2 with H2O on indoor surfaces. The average ratio of HONO to NO2 over the study period was 0.12 +/- 0.05. The HONO/NO2 concentration ratio was 0.04-0.08 during the combustion period, whereas it was 0.10-0.25 after combustion had stopped. This Suggests that HONO was generated through different production processes, both during combustion and after the completion of combustion. Tile controlled combustion experiments indicate that the burning rate is an important factor to determine the peak HONO concentration. In darkness, HONO had a nearly constant removal rate for all of the combustion experiments, whereas the removal rates of NO and NO2 depended on the burning rates of the gas range. Combustion experiments conducted at the fixed burning rate setting show also that ventilation decreased HONO concentration. This indicates that the airflow rate of the range hood fan is an important factor to control the concentration of indoor air pollutants. (C) 2008 Elsevier Ltd. All rights reserved.

# Parrish, D. D. and F. C. Fehsenfeld (2000). "Methods for gas-phase measurements of ozone, ozone precursors and aerosol precursors." Atmospheric Environment 34(12-14): 1921-1957.

The techniques currently available to measure the ambient atmospheric concentrations of O3, O3-precursors (including the odd-hydrogen free radicals), the oxidation products of these compounds, and gas-phase aerosol precursors are outlined below. This critical review focuses on the recent developments, and, in particular those developments that have been reported in the published literature since 1990. In general, the techniques are described in terms of the results of formal and informal comparisons of the techniques in measuring the compounds of interest in the ambient atmosphere. The article concludes with a brief discussion of calibration methods and standards and tests that should be routinely performed when measurements in ambient atmosphere are undertaken.

# Peel, J. L., et al. (2011). "Ambient air pollution and apnea and bradycardia in high-risk infants on home monitors." Environmental Health Perspectives 119(9): 1321-1327.

Background: Evidence suggests that increased ambient air pollution concentrations are associated with health effects, although relatively few studies have specifically examined infants. Objective: We examined associations of daily ambient air pollution concentrations with central apnea (prolonged pauses in breathing) and bradycardia (low heart rate) events among infants prescribed home cardiorespiratory monitors. Methods: The home monitors record the electrocardiogram, heart rate, and respiratory effort for detected apnea and bradycardia events in high-risk infants [primarily premature and low birth weight (LBW) infants]. From August 1998 through December 2002, 4,277 infants had 8,960 apnea event-days and 29,450 bradycardia event-days in > 179,000 days of follow-up. We assessed the occurrence of apnea and bradycardia events in relation to speciated particulate matter and gaseous air pollution levels using a 2-day average of air pollution (same day and previous day), adjusting for temporal trends, temperature, and infant age. Results: We observed associations between bradycardia and 8-hr maximum ozone [odds ratio (OR) = 1.049 per 25-ppb increase; 95% confidence interval (CI), 1.021-1.078] and 1-hr maximum nitrogen dioxide (OR =1.025 per 20-ppb increase; 95% CI, 1.000-1.050). The association with ozone was robust to different methods of control for time trend and specified correlation structure. In secondary analyses, associations of apnea and bradycardia with pollution were generally stronger in infants who were full term and of normal birth weight than in infants who were both premature and LBW. Conclusions: These results suggest that higher air pollution concentrations may increase the occurrence of apnea and bradycardia in high-risk infants.

# Peel, J. L., et al. (2005). "Ambient air pollution and respiratory emergency department visits." Epidemiology 16(2): 164-174.

Background: A number of emergency department studies have corroborated findings from mortality and hospital admission studies regarding an association of ambient air pollution and respiratory outcomes. More refined assessment has been limited by study size and available air quality data. Methods: Measurements of 5 pollutants (particulate matter [PM10], ozone, nitrogen dioxide [NO2], carbon monoxide [CO], and sulfur dioxide [SO2]) were available for the entire study period (1 January 1993 to 31 August 2000); detailed measurements of particulate matter were available for 25 months. We obtained data on 4 million emergency department visits from 31 hospitals in Atlanta. Visits for asthma, chronic obstructive pulmonary disease, upper respiratory infection, and pneumonia were assessed in relation to air pollutants using Poisson generalized estimating equations. Results: In single-pollutant models examining 3-day moving averages of pollutants (lags 0, 1, and 2): standard deviation increases of ozone, NO2, CO, and PM10 were associated with 1–3% increases in URI visits; a 2 μg/m3 increase of PM2.5 organic carbon was associated with a 3% increase in pneumonia visits; and standard deviation increases of NO2 and CO were associated with 2-3% increases in chronic obstructive pulmonary disease visits. Positive associations persisted beyond 3 days for several of the outcomes, and over a week for asthma. Conclusions: The results of this study contribute to the evidence of an association of several correlated gaseous and particulate pollutants, including ozone, NO2, CO, PM, and organic carbon, with specific respiratory conditions.

# Penard-Morand, C., et al. (2010). "Long-term exposure to proximity air pollution and asthma and allergies in urban children." European Respiratory Journal 36(1): 33-40.

The aim of this study was to evaluate the impact of urban air pollution, assessed through reliable indicators of exposure, on asthma and allergies in school children. A validated dispersion model, combining data on traffic conditions, topography, meteorology and background pollution was used to relate three-years-averaged concentrations of major urban pollutants at the schools' address to skin prick test, exercise-induced asthma, and reported asthma and allergies in 6683 children (9-11 years), attending 108 schools randomly selected in six French communities. For the 4907 children having resided at their current address in the past three years, asthma (exercised-induced, past year and lifetime) was significantly positively associated with benzene, SO2, PM10, NOx and CO, eczema (lifetime and past year) with benzene, PM10, NO2, NOx and CO, lifetime allergic rhinitis with PM10 and sensitisation to pollens with benzene and PM10. Among the 2213 children residing at their current address since birth, the associations persisted for lifetime asthma with benzene (adjusted odds ratio per interquartile range (95% confidence interval)=1.3 (1.0-1.9)) and PM10 (1.4 (1.0-2.0)) and for sensitisation to pollens with VOC (1.3 (1.0-1.9)) and PM10 (1.2 (1.0-1.9)). Accurately modelled urban air pollution was associated with some measures of childhood asthma and allergies.

# Pereira, L. A. A., et al. (1998). "Association between air pollution and intrauterine mortality in Sao Paulo, Brazil." Environmental Health Perspectives 106(6): 325-329.

The associations among daily counts of intrauterine mortality and pollutant concentrations (NO2, SO2, CO, O3, and particulate matter (3/4)10 microm) were investigated for the period ranging from January 1991 to December 1992 in the city of São Paulo, Brazil. We used Poisson regression techniques, adjusted for season and weather. The association between intrauterine mortality and air pollution was strong for NO2 (coefficient = 0.0013/ microg/m3; p<0.01) but lesser for SO2 (coefficient = 0.0005/ microg/m3; p<0.10) and CO (coefficient = 0.0223/ppm; p<0.10). A significant association was observed when an index that combined these three pollutants was considered in the models instead of considering each pollutant individually (p<0.01). These associations exhibited a short time lag, not over 5 days. In addition, some evidence of fetal exposure to air pollution was obtained by disclosing a significant association between the levels of carboxyhemoglobin of blood sampled from the umbilical cord and ambient CO levels in children delivered by nonsmoking pregnant women in the period from May to July 1995. Our results suggest that air pollution in São Paulo may promote adverse health effects on fetuses.

# Perry, S. G., et al. (2005). "AERMOD: A dispersion model for industrial source applications. Part II: Model performance against 17 field study databases." Journal of Applied Meteorology 44(5): 694-708.

The performance of the American Meteorological Society (AMS) and U.S. Environmental Protection Agency (EPA) Regulatory Model (AERMOD) Improvement Committee’s applied air dispersion model against 17 field study databases is described. AERMOD is a steady-state plume model with significant improvements over commonly applied regulatory models. The databases are characterized, and the performance measures are described. Emphasis is placed on statistics that demonstrate the model’s abilities to reproduce the upper end of the concentration distribution. This is most important for applied regulatory modeling. The field measurements are characterized by flat and complex terrain, urban and rural conditions, and elevated and surface releases with and without building wake effects. As is indicated by comparisons of modeled and observed concentration distributions, with few exceptions AERMOD’s performance is superior to that of the other applied models tested. This is the second of two articles, with the first describing the model formulations.

# Peters, A., et al. (2009). The influence of improved air quality on mortality risks in Erfurt, Germany. HEI Research Reports. Boston, MA, Health Effects Institute.

Around the world, daily variations in ambient air pollution have been consistently associated with variations in daily mortality. The aim of the study presented here was to assess the effects of ambient air pollution on daily mortality during a period of tremendous changes in air quality in the city of Erfurt, in eastern Germany, from October 1991 to March 2002. Data on particle size distributions were obtained from September 1995 to March 2002 at a research monitoring station. For particles from 0.01 microm to 2.5 microm in diameter, number concentrations (NCs)\* and mass concentrations (MCs) were calculated. Particles with diameters less than or equal to 0.10 microm are defined as ultrafine particles (UFP). Data on the gaseous pollutants NO2, CO, SO2, and O3 and on PM10 (particulate matter [PM] with aerodynamic diameter less than or equal to 10 microm) were obtained from a government air-monitoring station. Data on changes in energy consumption, car fleet composition, and population were collected from local authorities. Death certificates of persons living in and dying in Erfurt were abstracted, and daily mortality counts were calculated. Poisson regression models were used to analyze the data, applying penalized splines (also known as P-splines) to model nonlinear relationships in the confounders. Model selection was done without air pollutants in the models, based on a combination of goodness-of-fit criteria and avoidance of autocorrelation in error terms. Final models included P-splines of time trend, meteorologic data, and influenza epidemics as well as day of the week with an indicator variable. Results are presented as change per interquartile range (IQR), i.e., change in the relative risk of mortality associated with a change in the concentration from the 25th to the 75th percentile of a given pollutant. Air pollutants were considered both as linear terms and as P-splines to assess the exposure-response functions. Changes in effect estimates over time were calculated using fully Bayesian time-varying coefficient models. This method was selected over four other approaches tested in simulation studies. Air-pollution concentrations decreased substantially in Erfurt during the decade under observation. The strongest changes were observed for SO2, for which annual concentrations decreased from 64 microg/m3 in 1992 to 4 microg/m3 in 2001. Concentrations of PM10, PM2.5 (particulate matter with aerodynamic diameter less than or equal to 2.5 microm), and CO decreased by more than 50%. NO2, O3, and ultrafine particles also decreased, though to a lesser extent. Based on visual inspection of the data on the changes in ambient air-pollution concentrations during the study period, we defined three study subperiods: A first subperiod from 1991 to 1995; a second, transitional subperiod from 1995 to 1998; and a third subperiod from 1998 to 2002. Generally, air-pollution concentrations decreased substantially from the first subperiod to the second, and some additional decreases occurred from the second subperiod to the third. During the second, transitional subperiod, natural gas replaced coal as the main energy source in Erfurt. In addition, the number of cars with catalytic converters increased over time, as did the number of cars in general. To facilitate the interpretation of the results, we organized the air pollutants into four groups: (1) NO2, CO, and ultrafine particles, (2) PM10 and PM2.5, (3) SO2, and (4) O3. We observed a 1.6% increased risk for daily mortality (CI, -0.4% to 3.5%) for an increase of 19.7 microg/m3 in NO2 (lag day 3), a 1.9% increased risk (CI, 0.2%-3.6%) for an increase of 0.48 mg/m3 in CO (lag day 4), and a 2.9% increased risk (CI, 0.3%-5.5%) for an increase of 9743/cm3 in ultrafine particles (lag day 4). No consistent associations were observed for PM10, PM2.5, or SO2. For O3, a 4.6% increased risk for daily mortality (CI, 1.1%-8.3%) was associated with a 43.8 microg/m3 maximum 8-hr concentration of O3 per day (lag day 2). For all four pollutants, exposure-response functions suggested no deviation from linearity. However, in time-varying models the strongest associations were observed for NO2, CO, and ultrafine particles during the transition subperiod, from 1995 to 1998, when O3 concentrations were lowest. Changes in source characteristics or ambient air-pollution concentrations were not able to explain these observations in a straightforward manner. However, the observations suggested that changes such as the introduction of three-way catalytic converters in cars and the substitution natural gas for coal might have been beneficial. Overall we concluded that: 1. Economic and political changes and the adoption of new technologies in eastern Germany resulted in distinct improvements in ambient air quality; 2. Urban air pollution in Erfurt changed within one decade from the eastern mixture toward that of western Europe ("western mixture"), which is dominated by concentrations of NOx, O3, fine particles, and ultrafine particles with low concentrations of SO2; 3. There was an association between daily mortality and ultrafine particles and combustion-related gases (lag days 3 or 4); 4. Ultrafine particles seemed to be the best pollution indicator and to point to the role of local combustion in the pollution mixture; 5. Regression coefficients showed variation over time for NO2, CO, ultrafine particles, and O3 that could not be explained by nonlinearity in the exposure-response functions; 6. Mortality associated with pollution was lower at the end of the 1990s than during the 1990s, except for mortality associated with O3; and 7. Mortality associated with pollution was strongest in the second, transitional subperiod, from 1995 to 1998, when changes in source characteristics had taken place but the benefits of improved ambient air quality had not yet been completely achieved.

# Poddubny, V. A. and N. A. Yushketova (2013). "A physicochemical model of sorption processes in NO(2) passive sampling with air humidity effects." Environmental Monitoring and Assessment 185(5): 3819-3829.

Aqueous triethanolamine (TEA) solutions are widely used as sorption medium for passive sampling of ambient NO(2), with NO(2) trapped and accumulated as nitrite ion. The results of test measurements of ambient NO(2) concentrations using passive sampling method showed that the simple approach commonly used to describe passive sampling process might lead to substantial systematic errors. Presented in the article is a new physicochemical model of the process of passive sampling of gaseous NO(2), with aqueous TEA solution used as a trapping medium. The model is based on the available results of experimental studies of interaction of gaseous NO(2) with TEA/water solutions. The key principles underlying the model are: (1) when absorbed by a trapping solution, NO(2) forms nitrite ion only on the condition that TEA is hydrated; (2) coefficient of conversion of NO(2) to NO (2) (-) is equal to one when reacting with hydrated TEA; and (3) the fraction of hydrated TEA molecules depends on air humidity at the moment of measurement. Validation of the model was made using the data of the field measurements carried out in the Middle Urals in 2007-2009. The new model was used to calculate average NO(2) concentrations. Concentrations calculated agreed well with the results obtained by reference methods. The difference between the datasets was statistically insignificant.

# Polidori, A. and P. M. Fine (2012). Ambient concentrations of criteria and air toxic pollutants in close proximity to a freeway with heavy-duty diesel traffic, South Coast Air Quality Management District.

# Portnov, B. A., et al. (2012). "High prevalence of childhood asthma in Northern Israel is linked to air pollution by particulate matter: evidence from GIS analysis and Bayesian Model Averaging." International Journal of Environmental Health Research 22(3): 249-269.

The medical records of 3922 school children residing in the Greater Haifa Metropolitan Area in Northern Israel were analyzed. Individual exposure to ambient air pollution (SO(2) and PM(10)) for each child was estimated using Geographic Information Systems tools. Factors affecting childhood asthma risk were then investigated using logistic regression and the more recently developed Bayesian Model Averaging (BMA) tools. The analysis reveals that childhood asthma in the study area appears to be significantly associated with particulate matter of less than 10 μm in aerodynamic diameter (PM(10)) (Odds Ratio (OR) = .11; P<0.001). However, no significant association with asthma prevalence was found for SO(2) (P > 0.2), when PM(10) and SO(2) were introduced into the models simultaneously. When considering a change in PM(10) between the least and the most polluted parts of the study area (9.4 μg/m (3)), the corresponding OR, calculated using the BMA analysis, is 2.58 (with 95% posterior probability limits of OR ranging from 1.52 to 4.41), controlled for gender, age, proximity to main roads, the town of a child's residence, and family's socio-economic status. Thus, it is concluded that exposure to airborne particular matter, even at relatively low concentrations (40-50 μg/m(3)), generally below international air pollution standards (55-70 μg/m(3)), appears to be a considerable risk factor for childhood asthma in urban areas. This should be a cause of concern for public health authorities and environmental decision-makers.

# Qiu, H., et al. (2013). "Season and humidity dependence of the effects of air pollution on COPD hospitalizations in Hong Kong." Atmospheric Environment 76: 74-80.

Associations between ambient pollution and respiratory morbidity including chronic obstructive pulmonary disease (COPD) have been confirmed. Weather factors, such as temperature, season and relative humidity (RH), may modify the effects of air pollution. This time series study was conducted to examine whether the effects of air pollution on emergency COPD hospital admissions in Hong Kong varied across seasons and RH levels, and explore the possible joint modification of season and RH on the effects of pollution. Data of daily air pollution concentrations mean temperature and RH, and COPD hospital admissions from 1998 to 2007 were collected. Generalized additive Poisson models with interaction terms were used to estimate the effects of pollution across seasons and RH levels. We observed an increase in the detrimental effects of air pollution in the cool season and on low humidity days. On the cool and dry days, a 10 mu g m(-3) increment of lag(03) exposure was associated with an increase in emergency COPD admissions by 1.76% (95%CI: 1.19-2.34%), 3.43% (95%CI: 2.80-4.07%), and 1.99% (95% CI: 0.90-3.09%) for nitrogen dioxide (NO2), ozone (O-3), and sulfur dioxide (SO2), respectively, all of which were statistically significantly higher than those on the other days. No consistent modification of weather factors was found for the effects of particles with an aerodynamic diameter less than 10 mu m (PM10). The results suggested that season and RH jointly modified the effects of gaseous pollutants, resulting in increased emergency COPD hospitalizations on the cool and dry days. (C) 2012 Elsevier Ltd. All rights reserved.

# Ramírez-Aguilar, M., et al. (2008). "Assessment of personal exposure to ozone in asthmatic children residing in Mexico City." Salud Publica de Mexico 50(1): 67-75.

OBJECTIVE: A study was conducted to evaluate personal ozone exposure (O3p) among asthmatic children residing in Mexico City. MATERIAL AND METHODS: A total of 158 children were recruited from December 1998 to April 2000. On average, three O3p measurements were obtained per child using passive badges. Time-activity patterns were recorded in a diary. Daily ambient ozone measurements (O3a) were obtained from the fixed station, according to children's residence. Levels of O3a and ozone, weighted by time spent in different micro-environments (O3w), were used as independent variables in order to model O3p concentrations using a mixed-effects model. RESULTS: Mean O3p was 7.8 ppb. The main variables in the model were: time spent indoors, distance between residence and fixed station, follow-up group, and two interaction terms (overall R(2)=0.50, p<0.05). CONCLUSIONS: The O3w concentrations can be used as a proxy for O3p, taking into account time-activity patterns and the place of residence of asthmatic Mexican children.

# Reeves, G. K., et al. (1998). "Some aspects of measurement error in explanatory variables for continuous and binary regression models." Statistics in Medicine 17(19): 2157-2177.

A simple form of measurement error model for explanatory variables is studied incorporating classical and Berkson cases as particular forms, and allowing for either additive or multiplicative errors. The work is motivated by epidemiological problems, and therefore consideration is given not only to continuous response variables but also to logistic regression models. The possibility that different individuals in a study have errors of different types is also considered. The relatively simple estimation procedures proposed for use with cohort data and case-control data are checked by simulation, under the assumption of various error structures. The results show that even in situations where conventional analysis yields slope estimates that are on average attenuated by a factor of approximately 50 per cent, estimates obtained using the proposed amended likelihood functions are within 5 per cent of their true values. The work was carried out to provide a method for the analysis of lung cancer risk following residential radon exposure, but it should be applicable to a wide variety of situations.

# Reiss, R., et al. (1995). "Ozone reactive chemistry on interior latex paint." Environmental Science and Technology 29(8): 1906-1912.

#The heterogeneous chemistry of ozone on interior latex paint was investigated in a tube flow reactor. The emissions of several polar volatile organic compounds(VOCs) including organic acids and carbonyls (aldehydes and ketones) were measured while a glass tube coated with latex paint was exposed to clean air and ozone. Four different commercial brands of latex paint were tested. Formic and acetic acids were not found to be generated via ozone reactions; however, both were found to off-gas from the latex paints, and the off-gasing increased with increasing relative humidity. The off-gasing rates are large enough, particularly for acetic acid, to impact residential concentrations significantly. Formaldehyde was found to be produced by reactions related to the ozone concentration. There was some evidence that acetaldehyde and acetone may also be produced by processes related to the ozone concentration. A steady-state model is presented that is used to extrapolate the chamber results to a representative indoor environment. The model is based on an experimentally derived parameter termed the VOC formation factor, which is defined as the number of VOC molecules of a particular species formed via an ozone reaction divided by the total number of ozone molecules sticking to the surface. Using this model, it was found that formaldehyde production via ozone reactions is significant enough to impact indoor concentrations of formaldehyde.

# Reiss, R., et al. (1995). "Measurement of organic acids, aldehydes, and ketones in residential environments and their relation to ozone." Journal of the Air and Waste Management Association 45(10): 811-822.

Ozone and several polar volatile organic compounds (VOCs) including organic acids and carbonyls (aldehydes and ketones) were measured over an approximately 24 hour period in four residences during the winter of 1993 and in nine residences during the summer of 1993. All residences were in the greater Boston, Massachusetts area. The relation of the polar VOCs to the ozone concentration was examined. Indoor carbonyl concentrations were similar between the summer and winter, with the total mean winter concentration being 31.7 ppb and the total mean summer concentration being 36.6 ppb. However, the average air exchange rate was 0.9 hr(-1) during the winter and 2.6 hr(-1) during the summer. Therefore, the estimated carbonyl emission rates were significantly higher during the summer. Indoor organic acid concentrations were about twice as high during the summer as during the winter. For formic acid, the indoor winter mean was 9.8 ppb, and the summer indoor mean was 17.8 ppb. For acetic acid, the indoor winter mean was 15.5 ppb, and the summer indoor mean was 28.7 ppb. The concentrations of the polar VOCs were found to be significantly correlated with one another. Also, the emission rates of the polar VOCs were found to be correlated with both the environmental variables such as temperature and relative humidity and the ozone removal rate; however, it was difficult to apportion the relative effects of the environmental variables and the ozone removal.

# Rich, D. Q., et al. (2009). "Ambient air pollutant concentrations during pregnancy and the risk of fetal growth restriction." Journal of Epidemiology and Community Health 63(6): 488-496.

BACKGROUND: Previous studies of air pollution and birth outcomes have not evaluated whether complicated pregnancies might be susceptible to the adverse effects of air pollution. It was hypothesised that trimester mean pollutant concentrations could be associated with fetal growth restriction, with larger risks among complicated pregnancies. METHODS: A multiyear linked birth certificate and maternal/newborn hospital discharge dataset of singleton, term births to mothers residing in New Jersey at the time of birth, who were white (non-Hispanic), African-American (non-Hispanic) or Hispanic was used. Very small for gestational age (VSGA) was defined as a fetal growth ratio <0.75, small for gestational age (SGA) as > or =0.75 and <0.85, and 'reference' births as > or =0.85. Using polytomous logistic regression, associations between mean pollutant concentrations during the first, second and third trimesters and the risks of SGA/VSGA were examined, as well as effect modification of these associations by several pregnancy complications. RESULTS: Significantly increased risk of SGA was associated with first and third trimester PM(2.5) (particulate matter <2.5 microm in aerodynamic diameter), and increased risk of VSGA associated with first, second and third trimester nitrogen dioxide (NO(2)) concentrations. Pregnancies complicated by placental abruption and premature rupture of the membrane had approximately two- to fivefold greater excess risks of SGA/VSGA than pregnancies not complicated by these conditions, although these estimates were not statistically significant. CONCLUSIONS: These findings suggest that ambient air pollution, perhaps specifically traffic emissions during early and late pregnancy and/or factors associated with residence near a roadway during pregnancy, may affect fetal growth. Further, pregnancy complications may increase susceptibility to these effects in late pregnancy.

# Riediker, M., et al. (2003). "Exposure to particulate matter, volatile organic compounds, and other air pollutants inside patrol cars." Environmental Science and Technology 37(10): 2084-2093.

People driving in a vehicle might receive an enhanced dose of mobile source pollutants that are considered a potential risk for cardiovascular diseases. The exposure to components of air pollution in highway patrol vehicles, at an ambient, and a roadside location was determined during 25 work shifts (3 p.m. to midnight) in the autumn of 2001, each day with two cars. A global positioning system and a diary provided location and activity information. Average pollutant levels inside the cars were low compared to ambient air quality standards: carbon monoxide 2.7 ppm, nitrogen dioxide 41.7 µg/m3, ozone 11.7 ppb, particulate matter smaller 2.5 µm (PM2.5) 24 µg/m3. Volatile organic compounds inside the cars were in the ppb-range and showed the fingerprint of gasoline. PM2.5 was 24% lower than ambient and roadside levels, probably due to depositions associated with the recirculating air conditioning. Levels of carbon monoxide, aldehydes, hydrocarbons, and some metals (Al, Ca, Ti, V, Cr, Mn, Fe, Cu, and Sr) were highest in the cars, and roadside levels were higher than ambient levels. Elevated pollutant levels were related to locations with high traffic volumes. Our results point to combustion engine emissions from other vehicles as important sources of air pollutants inside the car.

# Roberts, S. and M. A. Martin (2006). "Using supervised principal components analysis to assess multiple pollutant effects." Environmental Health Perspectives 114(12): 1877-1882.

Background: Many investigations of the adverse health effect of multiple air pollutants analyse the time series involved by simultaneously entering the multiple pollutants into a Poisson log-linear model. This method can yield unstable parameter estimates when the pollutants involved suffer high intercorrelation, and so traditional approaches to dealing with multicollinearity such as principal components (PC) have been promoted in this context. Objectives: A characteristic of PC is the fact that its construction takes no account of the relationship between the covariates and the adverse health outcome. A refined version of PC, supervised principal components (SPC) is proposed that specifically addresses this issue. Methods: Models controlling for long term trends and weather effects were used in conjunction with each of SPC and PC to estimate the association between multiple air pollutants and mortality for US cities. The methods were further compared via a simulation study. Results: Simulation studies demonstrated that SPC, unlike PC, was successful in identifying the correct subset of multiple pollutants associated with mortality. Because of this property, SPC and PC returned different estimates for the relationship between air pollution and mortality. Conclusions: While a number of methods for assessing the effects of multiple pollutants have been proposed, such methods can falter in the presence of high correlation amongst pollutants. Both PC and SPC methods address this issue. By allowing the exclusion of pollutants that are not associated with the adverse health outcome from the mixture of pollutants selected, SPC offers a critical improvement over PC.

# Rodes, C. E., et al. (2010). "DEARS particulate matter relationships for personal, indoor, outdoor, and central site settings for a general population." Atmospheric Environment 44(11): 1386-1399.

This analysis provides the initial summary of PM2.5 mass concentrations relationships for all seasons and participants for a general population in the Detroit Exposure and Aerosol Research Study (DEARS). The summary presented highlights the utility of the new methodologies applied, in addition to summarizing the particulate matter (PM) data. Results include the requirement to adjust the exposure data for monitor wearing compliance and measured environmental tobacco smoke (ETS) levels, even though the study design specified a non-smoking household. A 40% wearing compliance acceptance level was suggested as necessary to balance minimizing exposure misclassification (from poor compliance) and having sufficient data to conduct robust statistical analyses. An ETS threshold level equivalent to adding more than 1.5 μg m−3 to the collected sample was found to be necessary to detect changes in the personal exposure factor (Fpex). It is not completely clear why such a large threshold level was necessary. Statistically significant spatial PM2.5 gradients were identified in three of the six DEARS neighborhoods in Wayne County. These were expected, given the number of strong, localized PM sources in the Detroit (Michigan) metro area. Some residential outdoor bias levels compared with the central site at Allen Park exceeded 15%. After adjusting for ETS biases, the outdoor contributions to the personal exposure were typically larger by factors from 1.75 to 2.2 compared with those of the non-outdoor sources. The outdoor contribution was larger in the summer than in the winter, which is consistent with the fractions of time spent outdoors in the summer vs. the winter (6.7% vs. 1.1% of the time). Mean personal PM2.5 cloud levels for the general population DEARS cohort ranged from 1.5 to 3.8 (after ETS adjustment) and were comparable to those reported previously. The personal exposure collections indoors were typically at least 13 times greater than those contributed outdoors.

# Rodgers, M. O. and D. D. Davis (1989). "A UV-photofragmentation/laser-induced fluorescence sensor for the atmospheric detection of HONO." Environmental Science and Technology 23(9): 1106-1112.

An in situ laser-based detection system for measuring atmospheric HONO has been built and tested. This spectroscopic selective system has been tested for numerous chemical interferences. The results from these tests indicate that down to the tens of parts per trillion HONO concentration range no significant problems were detected. Sampling losses were also evaluated under varying atmospheric conditions and were found to be negligible at ambient levels of HONO amenable to controlled testing, e.g., the low ppbv range. The PF-LIF system as currently configured has a detection limit in the low tens of parts per trillion concentration range for typical integration times of 15 min in duration. This sensitivity is roughly equivalent to that achieved by the long-path differential absorption technique, but the PF-LIF has the added feature of being fully mobile and capable of in situ HONO measurements.

# Rojas-Martinez, R., et al. (2007). "Lung function growth in children with long-term exposure to air pollutants in Mexico City." American Journal of Respiratory and Critical Care Medicine 176(4): 377-384.

Rationale: Although short-term exposure to air pollution has been associated with acute, reversible lung function decrements, the impact of long-term exposure has not been well established. Objectives: To evaluate the association between long-term exposure to ozone (O3), particulate matter less than 10 µm in diameter (PM10), and nitrogen dioxide (NO2) and lung function growth in Mexico City schoolchildren. Methods: A dynamic cohort of 3,170 children aged 8 years at baseline was followed from April 23, 1996, through May 19, 1999. The children attended 39 randomly selected elementary schools located near 10 air quality monitoring stations and were visited every 6 months. Statistical analyses were performed using general linear mixed models. Measurements and Main Results: After adjusting for acute exposure and other potential confounding factors, deficits in FVC and FEV1 growth over the 3-year follow-up period were significantly associated with exposure to O3, PM10, and NO2. In multipollutant models, an interquartile range (IQR) increase in mean O3 concentration (IQR, 11.3 ppb) was associated with an annual deficit in FEV1 of 12 ml in girls and 4 ml in boys, an IQR range (IQR, 36.4 µg/m3) increase in PM10 with an annual deficit in FEV1 of 11 ml in girls and 15 ml in boys, and an IQR range (IQR, 12.0 ppb) increase in NO2 with an annual deficit in FEV1 of 30 ml in girls and 25 ml in boys. Conclusions: We conclude that long-term exposure to O3, PM10, and NO2 is associated with a deficit in FVC and FEV1 growth among schoolchildren living in Mexico City.

# Romieu, I., et al. (1998). "Evaluation of indoor ozone concentration and predictors of indoor-outdoor ratio in Mexico City." Journal of the Air and Waste Management Association 48(4): 327-335.

Mexican Health Ministry; National Council of Science and Technology, Mexico; U.S. Centers for Disease Control and Prevention. As part of a study on the potential adverse health effects of ozone exposure on the respiratory health of young children residing in Mexico City, we used passive ozone monitoring devices to determine microenvironmental ozone concentrations. Indoor and outdoor ozone concentrations were measured at 145 homes and at the schools of participating children. In addition, outdoor concentrations were also measured with continuous monitors at the schools and at stationary outdoor monitoring sites. At the children's homes, indoor ozone levels were 10-30% of the outdoor ozone concentrations. The mean indoor-to-outdoor (I/O) ratio was 0.20 (SD = 0.18). The highest I/O ratios were observed in homes where windows were usually open during the day, and where there was carpeting or air filters. At school during class hours, the I/O ratio was higher (0.3 to 0.4) than at the children's homes, due to periodic opening of the doors and windows. Given the large disparity in ozone concentrations between different microenvironments, we concluded that, in epidemiological studies conducted in Mexico City, microenvironmental ozone concentrations and time spent in these microenvironments needed to be considered to adequately estimate personal ozone exposure.

# Sagiv, S. K., et al. (2005). "A time-series analysis of air pollution and preterm birth in Pennsylvania, 1997-2001." Environmental Health Perspectives 113(5): 602-606.

#Preterm delivery can lead to serious infant health outcomes, including death and lifelong disability. Small increases in preterm delivery risk in relation to spatial gradients of air pollution have been reported, but previous studies may have controlled inadequately for individual factors. Using a time-series analysis, which eliminates potential confounding by individual risk factors that do not change over short periods of time, we investigated the effect of ambient outdoor particulate matter with diameter = 10 µm (PM10) and sulfur dioxide on risk for preterm delivery. Daily counts of preterm births were obtained from birth records in four Pennsylvania counties from 1997 through 2001. We observed increased risk for preterm delivery with exposure to average PM10 and SO2 in the 6 weeks before birth [respectively, relative risk (RR) = 1.07; 95% confidence interval (CI), 0.98-1.18 per 50 µg/m3 increase; RR = 1.15; 95% CI, 1.00-1. 32 per 15 ppb increase], adjusting for long-term preterm delivery trends, co-pollutants, and offsetting by the number of gestations at risk. We also examined lags up to 7 days before the birth and found an acute effect of exposure to PM10 2 days and 5 days before birth (respectively, RR = 1.10; 95% CI, 1.00-1.21; RR = 1.07; 95% CI, 0.98-1.18) and SO2 3 days before birth (RR = 1.07; 95% CI, 0.99-1.15), adjusting for covariates, including temperature, dew point temperature, and day of the week. The results from this time-series analysis, which provides evidence of an increase in preterm birth risk with exposure to PM10 and SO2, are consistent with prior investigations of spatial contrasts.

# Sahsuvaroglu, T., et al. (2009). "Spatial analysis of air pollution and childhood asthma in Hamilton, Canada: comparing exposure methods in sensitive subgroups." Environmental Health: A Global Access Science Source 8: Z.

Variations in air pollution exposure within a community may be associated with asthma prevalence. However, studies conducted to date have produced inconsistent results, possibly due to errors in measurement of the exposures.

A standardized asthma survey was administered to children in grades one and eight in Hamilton, Canada, in 1994-95 (N approximately 1467). Exposure to air pollution was estimated in four ways: (1) distance from roadways; (2) interpolated surfaces for ozone, sulfur dioxide, particulate matter and nitrous oxides from seven to nine governmental monitoring stations; (3) a kriged nitrogen dioxide (NO2) surface based on a network of 100 passive NO2 monitors; and (4) a land use regression (LUR) model derived from the same monitoring network. Logistic regressions were used to test associations between asthma and air pollution, controlling for variables including neighbourhood income, dwelling value, state of housing, a deprivation index and smoking.

There were no significant associations between any of the exposure estimates and asthma in the whole population, but large effects were detected the subgroup of children without hayfever (predominately in girls). The most robust effects were observed for the association of asthma without hayfever and NO2LUR OR = 1.86 (95%CI, 1.59-2.16) in all girls and OR = 2.98 (95%CI, 0.98-9.06) for older girls, over an interquartile range increase and controlling for confounders.

Our findings indicate that traffic-related pollutants, such as NO2, are associated with asthma without overt evidence of other atopic disorders among female children living in a medium-sized Canadian city. The effects were sensitive to the method of exposure estimation. More refined exposure models produced the most robust associations.

# Sahsuvaroglu, T., et al. (2009). "Predicting personal nitrogen dioxide exposure in an elderly population: Integrating residential indoor and outdoor measurements, fixed-site ambient pollution concentrations, modeled pollutant levels, and time-activity patterns." Journal of Toxicology and Environmental Health, Part A: Current Issues 72(23): 1520-1533.

Predicting chronic exposure to air pollution at the intra-urban scale has been recognized as a priority area of research for environmental epidemiology. Exposure assessment models attempt to predict and proxy for individuals' personal exposure to ambient air pollution, and there are no studies to date that explicitly attempt to compare and cross-validate personal exposure concentrations with pollutants modeled at the intra-urban level using methods such as interpolated surfaces and land-use regression (LUR) models. This study aimed to identify how well personal exposure to NO2 (nitrogen dioxide) can be predicted from ambient exposure measurements and intra-urban exposure estimates using LUR and what other factors contribute to predicting variations in personal exposure beyond measured pollutant levels within home. Personal, indoor and outdoor NO2 were measured in a population of older adults (>65 yr old) living in Hamilton, Canada. Our results show that personal NO2 was most strongly associated with contemporaneously collected indoor and outdoor concentrations of NO2. Predicted NO2 exposures from intra-urban LUR models were not associated with personal NO2, whereas interpolated surfaces of particulates and ozone were modestly associated. Combinations of variables that best predicted personal NO2 variability were derived from time-activity diaries, interpolated surfaces of ambient particulate pollutants, and a citywide temporally matched average of NO2. The nonsignificant associations between personal NO2 and the modeled ambient NO2 concentrations suggest that observed associations between NO2 generated by LUR models and health effects are probably not produced by NO2, but by other pollutants that follow a similar spatial pattern.

# Sajani, S. Z., et al. (2011). "Comparison of different exposure settings in a case-crossover study on air pollution and daily mortality: Counterintuitive results." Journal of Exposure Science and Environmental Epidemiology 21(4): 385-394.

Because of practical problems associated with measurement of personal exposures to air pollutants in larger populations, almost all epidemiological studies assign exposures based on fixed-site ambient air monitoring stations. In the presence of multiple monitoring stations at different locations, the selection of them may affect the observed epidemiological concentration-response (C-R) relationships. In this paper, we quantify these impacts in an observational ecologic case-crossover study of air pollution and mortality. The associations of daily concentrations of PM10, O-3, and NO2 with daily all-cause non-violent mortality were investigated using conditional logistic regression to estimate percent increase in the risk of dying for an increase of 10 mu g/m(3) in the previous day air pollutant concentrations (lag 1). The study area covers the six main cities in the central-western part of Emilia-Romagna region (population of 1.1 million). We used four approaches to assign exposure to air pollutants for each individual considered in the study: nearest background station; city average of all stations available; average of all stations in a macro-area covering three cities and average of all six cities in the study area (50 x 150 km(2)). Odds ratios generally increased enlarging the spatial dimension of the exposure definition and were highest for six city-average exposure definition. The effect is especially evident for PM10, and similar for NO2, whereas for ozone, we did not find any change in the C-R estimates. Within a geographically homogeneous region, the spatial aggregation of monitoring station data leads to higher and more robust risk estimates for PM10 and NO2, even if monitor-to-monitor correlations showed a slight decrease with distance. We suggest that the larger aggregation improves the representativity of the exposure estimates by decreasing exposure misclassification, which is more profound when using individual stations vs regional averages. Journal of Exposure Science and Environmental Epidemiology (2011) 21, 385-394; doi: 10.1038/jes.2010.27; published online 23 June 2010

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# Samoli, E., et al. (2011). "Acute effects of air pollution on pediatric asthma exacerbation: Evidence of association and effect modification." Environmental Research 111(3): 418-424.

We investigated the short-term effects of particulate matter with aerodynamic diameter <10 μg/m3 (PM10), sulfur dioxide (SO2), nitrogen dioxide (NO2) and ozone (O3) on pediatric asthma emergency admissions in Athens, Greece over the period 2001-2004. We explored effect modification patterns by season, sex, age and by the presence of desert dust transported mainly from the Sahara area.

We used daily time-series data provided by the children's hospitals and the fixed monitoring stations. The associations were investigated using Poisson regression models controlling for seasonality, weather, influenza episodes, day of the week and holiday effects.

A 10 μg/m3 increase in PM10 was associated with a 2.54% increase (95% confidence interval (CI): 0.06%, 5.08%) in the number of pediatric asthma hospital admissions, while the same increase in SO2 was associated with a 5.98% (95% CI: 0.88%, 11.33%) increase. O3 was associated with a statistically significant increase in asthma term admissions among older children in the summer. Our findings provide limited evidence of an association between NO2 exposure and asthma exacerbation. Statistically significant PM10 effects were higher during winter and during desert dust days, while SO2 effects occurred mainly during spring. Our study confirms previously reported PM10 effects on emergency hospital admissions for effects and further provides evidence of stronger effects during desert dust days. We additionally report severe effects of SO2, even at today's low concentration levels.

# Sánchez Jiménez, A., et al. (2011). "Intercomparison study of NOx passive diffusion tubes with chemiluminescence analysers and evaluation of bias factors." Atmospheric Environment 45(18): 3062-3068.

Passive diffusion tubes (PDTs) are an inexpensive and simple method to monitor air pollutants. Numerous studies have investigated the performance of PDTs for NO(2) but little attention has been paid to PDTs for NO(x). The aim of this study was to evaluate the performance of NO(x) PDTs in three different urban environments. Duplicate NO(x) and NO(2) PDTs were co-located with chemiluminescence analysers at kerbside, urban centre and background sites in the city of Glasgow for twelve 1-week exposures. PDT measurements generally showed good temporal correlations with NO(x) and NO(2) determined by the continuous analysers. However detailed evaluation showed PDT measurements were variously influenced by factors causing bias, according to individual site characteristics: positive bias in both NO(x) and NO(2) PDTs due to wind-associated shortening of diffusion path; positive bias in NO(2) PDTs due to within-tube chemical reaction between NO and O(3); and, where NO concentrations were high, negative bias in NO(x) PDTs assumed due to incomplete oxidation of NO by the in-cap oxidising granules. In conclusion, where ambient NO(x) is low (less than a few tens of mu g m(-3)), and PDTs are in sheltered locations, NO(x) PDTs should perform well over 1-week exposures; however substantial negative bias for NO(x) PDTs is expected in polluted roadside environments for exposures of several weeks as is usually the case in ambient air quality deployment. Observations from this study suggest that sheltering PDTs from high wind is important to minimise positive bias due to wind-associated shortening of the diffusion path. (C) 2011 Elsevier Ltd. All rights reserved.

# Sánchez Jiménez, A., et al. (2012). "Correlations of particle number concentrations and metals with nitrogen oxides and other traffic-related air pollutants in Glasgow and London." Atmospheric Environment 54: 667-678.

Particle number concentration (PNC) and transition metal content are implicated in the health effects of airborne particulate matter (PM) but they are difficult to measure so consequently their temporal and spatial variations are not well characterized. Daily concentrations of PNC and particle-bound water-soluble metals (V, Cr, Mn, Fe, Ni, Cu, As, Cd and Pb) were measured at background and kerbside sites in Glasgow and London to examine if other metrics of air pollution such as optical darkness (absorbance) of collected filter samples of PM, gravimetric PM, and NO, NO2 and CO gas concentrations, can be used as surrogates for the temporal and spatial variations of the former. NO2 and NOx exhibited a high degree of within-site correlation and with PNC and water-soluble metals (Fe, Cu, As, Cd, Pb) at background sites in both cities. There is therefore potential to use NO2 and NOx as surrogates for PNC and water-soluble metal at background sites. However, correlation was weaker in complex street canyon environments where pollutant concentrations are strongly affected by local sources and the small-scale variations in pollutant dispersion induced by the wind regimes within street canyons. The corollary of the high correlation between NO2 and PNC and water-soluble metals at the background sites is that the latter pollutants may act as confounders for health effects attributed to NO2 from such sites. Concentrations of CO cannot be used as a surrogate for PNC. Increments in daily NOx and NO2 concentrations between trafficked and background sites were shown to be a simple and novel surrogate for daily spatial variation of PNC; for example, increments in NOx explained 78-79% of the variance in PNC at the paired sites in both Glasgow and London, but relationships were city specific. The increments in NOx also explained 70% of the spatial variation in Cu and Ni in Glasgow but not in London. Weekly NO2 measurements derived from passive diffusion tubes were also shown to correlate well with increments in PNC. A high temporal correlation between PNC and 1,3-butadiene and benzene (which can also be measured by passive sampler) implies that passive sampler measurements may be a straightforward tool for deriving long-term spatial patterns in PNC.

# Sarnat, J. A., et al. (2005). "Ambient gas concentrations and personal particulate matter exposures: Implications for studying the health effects of particles." Epidemiology 16(3): 385-395.

BACKGROUND: Data from a previous study conducted in Baltimore, MD, showed that ambient fine particulate matter less than 2.5 mum in diameter (PM2.5) concentrations were strongly correlated with corresponding personal PM2.5 exposures, whereas ambient O3, NO2, and SO2 concentrations were weakly correlated with their personal exposures to these gases. In contrast, many of the ambient gas concentrations were reasonable surrogates of personal PM2.5 exposures. METHODS: Personal multipollutant exposures and corresponding ambient air pollution concentrations were measured for 43 subjects living in Boston, MA. The cohort consisted of 20 healthy senior citizens and 23 schoolchildren. Simultaneous 24-hour integrated PM2.5, O3, NO2, and SO2 personal exposures and ambient concentrations were measured. All PM2.5 samples were also analyzed for SO4 (sulfate). We analyzed personal exposure and ambient concentration data using correlation and mixed model regression analyses to examine relationships among (1) ambient PM2.5 concentrations and corresponding ambient gas concentrations; (2) ambient PM2.5 and gas concentrations and their respective personal exposures; (3) ambient gas concentrations and corresponding personal PM2.5 exposures; and (4) personal PM2.5 exposures and corresponding personal gas exposures. RESULTS: We found substantial correlations between ambient PM2.5 concentrations and corresponding personal exposures over the course of time. Additionally, our results support the earlier finding that summertime gaseous pollutant concentrations may be better surrogates of personal PM2.5 exposures (especially personal exposures to PM2.5 of ambient origin) than they are surrogates of personal exposures to the gases themselves. CONCLUSIONS: Particle health effects studies that include both ambient PM2.5 and gaseous concentrations as independent variables must be analyzed carefully and interpreted cautiously, since both parameters may be serving as surrogates for PM2.5 exposures.

# Sarnat, J. A., et al. (2000). "Assessing the relationship between personal particulate and gaseous exposures of senior citizens living in Baltimore, MD." Journal of the Air and Waste Management Association 50(7): 1184-1198.

We conducted a multi-pollutant exposure study in Baltimore, MD, in which 15 non-smoking older adult subjects (>64 years old) wore a multi-pollutant sampler for 12 days during the summer of 1998 and the winter of 1999. The sampler measured simultaneous 24-hr integrated personal exposures to PM25, PM10, SO4 2-, O3, NO2, SO2, and exhaust-related VOCs. Results of this study showed that longitudinal associations between ambient PM2.5 concentrations and corresponding personal exposures tended to be high in the summer (median Spearman's r = 0.74) and low in the winter (median Spearman's r = 0.25). Indoor ventilation was an important determinant of personal PM2.5 exposures and resulting personal-ambient associations. Associations between personal PM25 exposures and corresponding ambient concentrations were strongest for well-ventilated indoor environments and decreased with ventilation. This decrease was attributed to the increasing influence of indoor PM2 5 sources. Evidence for this was provided by SO4 2-measurements, which can be thought of as a tracer for ambient PM25. For SO4 2-, personal-ambient associations were strong even in poorly ventilated indoor environments, suggesting that personal exposures to PM2.5 of ambient origin are strongly associated with corresponding ambient concentrations. The results also indicated that the contribution of indoor PM2.5 sources to personal PM2.5 exposures was lowest when individuals spent the majority of their time in well-ventilated indoor environments. Results also indicate that the potential for confounding by PM2.5 co-pollutants is limited, despite significant correlations among ambient pollutant concentrations. In contrast to ambient concentrations, PM2.5 exposures were not significantly correlated with personal exposures to PM2.5-10, PM2.5 of non-ambient origin, O3, NO2, and SO2. Since a confounder must be associated with the exposure of interest, these results provide evidence that the effects observed in the PM2.5 epidemiologic studies are unlikely to be due to confounding by the PM2.5 co-pollutants measured in this study.

# Sarnat, J. A., et al. (2001). "Gaseous pollutants in particulate matter epidemiology: Confounders or surrogates?" Environmental Health Perspectives 109(10): 1053-1061.

Health Effects Institute; Harvard-EPA Center on Particle Health Effects; Electric Power Research Institute; American Petroleum Institute. #Air pollution epidemiologic studies use ambient pollutant concentrations as surrogates of personal exposure. Strong correlations among numerous ambient pollutant concentrations, however, have made it difficult to determine the relative contribution of each pollutant to a given health outcome and have led to criticism that health effect estimates for particulate matter may be biased due to confounding. In the current study we used data collected from a multipollutant exposure study conducted in Baltimore, Maryland, during both the summer and winter to address the potential for confounding further. Twenty-four-hour personal exposures and corresponding ambient concentrations to fine particulate matter (PM2.5), ozone, nitrogen dioxide, sulfur dioxide, and carbon monoxide were measured for 56 subjects. Results from correlation and regression analyses showed that personal PM2.5 and gaseous air pollutant exposures were generally not correlated, as only 9 of the 178 individual-specific pairwise correlations were significant. Similarly, ambient concentrations were not associated with their corresponding personal exposures for any of the pollutants, except for PM2.5, which had significant associations during both seasons (p < 0.0001). Ambient gaseous concentrations were, however, strongly associated with personal PM2.5 exposures. The strongest associations were shown between ambient O3 and personal PM2.5 (p < 0.0001 during both seasons). These results indicate that ambient PM2.5 concentrations are suitable surrogates for personal PM2.5 exposures and that ambient gaseous concentrations are surrogates, as opposed to confounders, of PM2.5. These findings suggest that the use of multiple pollutant models in epidemiologic studies of PM2.5 may not be suitable and that health effects attributed to the ambient gases may actually be a result of exposures to PM2.5.

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Health Effects Institute; Harvard-EPA Center on Particle Health Effects; Electric Power Research Institute; American Petroleum Institute. #Air pollution epidemiologic studies use ambient pollutant concentrations as surrogates of personal exposure. Strong correlations among numerous ambient pollutant concentrations, however, have made it difficult to determine the relative contribution of each pollutant to a given health outcome and have led to criticism that health effect estimates for particulate matter may be biased due to confounding. In the current study we used data collected from a multipollutant exposure study conducted in Baltimore, Maryland, during both the summer and winter to address the potential for confounding further. Twenty-four-hour personal exposures and corresponding ambient concentrations to fine particulate matter (PM2.5), ozone, nitrogen dioxide, sulfur dioxide, and carbon monoxide were measured for 56 subjects. Results from correlation and regression analyses showed that personal PM2.5 and gaseous air pollutant exposures were generally not correlated, as only 9 of the 178 individual-specific pairwise correlations were significant. Similarly, ambient concentrations were not associated with their corresponding personal exposures for any of the pollutants, except for PM2.5, which had significant associations during both seasons (p < 0.0001). Ambient gaseous concentrations were, however, strongly associated with personal PM2.5 exposures. The strongest associations were shown between ambient O3 and personal PM2.5 (p < 0.0001 during both seasons). These results indicate that ambient PM2.5 concentrations are suitable surrogates for personal PM2.5 exposures and that ambient gaseous concentrations are surrogates, as opposed to confounders, of PM2.5. These findings suggest that the use of multiple pollutant models in epidemiologic studies of PM2.5 may not be suitable and that health effects attributed to the ambient gases may actually be a result of exposures to PM2.5.

# Sarnat, J. A., et al. (2007). "Panel discussion review: session one - exposure assessment and related errors in air pollution epidemiologic studies." Journal of Exposure Science and Environmental Epidemiology 17: S75-S82.

Examining the validity of exposure metrics used in air pollution epidemiologic models has been a key focus of recent exposure assessment studies. The objective of this work has been, largely, to determine what a given exposure metric represents and to quantify and reduce any potential errors resulting from using these metrics in lieu of true exposure measurements. The current manuscript summarizes the presentations of the co-authors from a recent EPA workshop, held in December 2006, dealing with the role and contributions of exposure assessment in addressing these issues. Results are presented from US and Canadian exposure and pollutant measurement studies as well as theoretical simulations to investigate what both particulate and gaseous pollutant concentrations represent and the potential errors resulting from their use in air pollution epidemiologic studies. Quantifying the association between ambient pollutant concentrations and corresponding personal exposures has led to the concept of defining attenuation factors, or a. Specifically, characterizing pollutant-specific estimates for a was shown to be useful in developing regression calibration methods involving PM epidemiologic risk estimates. For some gaseous pollutants such as NO2 and SO2, the associations between ambient concentrations and personal exposures were shown to be complex and still poorly understood. Results from recent panel studies suggest that ambient NO2 measurements may, in some locations, be serving as surrogates to traffic pollutants, including traffic-related PM2.5, hopanes, steranes, and oxidized nitrogen compounds (rather than NO2).

# Sarnat, S. E., et al. (2006). "Factors affecting the association between ambient concentrations and personal exposures to particles and gases." Environmental Health Perspectives 114(5): 649-654.

Results from air pollution exposure assessment studies suggest that ambient fine particles [particulate matter with aerodynamic diameter<or=2.5 microg (PM2.5)], but not ambient gases, are strong proxies of corresponding personal exposures. For particles, the strength of the personal-ambient association can differ by particle component and level of home ventilation. For gases, however, such as ozone (O3), nitrogen dioxide (NO2), and sulfur dioxide (SO2), the impact of home ventilation on personal-ambient associations is untested. We measured 24-hr personal exposures and corresponding ambient concentrations to PM2.5, sulfate (SO2-(4)), elemental carbon, O3, NO2, and SO2 for 10 nonsmoking older adults in Steubenville, Ohio. We found strong associations between ambient particle concentrations and corresponding personal exposures. In contrast, although significant, most associations between ambient gases and their corresponding exposures had low slopes and R2 values; the personal-ambient NO2 association in the fall season was moderate. For both particles and gases, personal-ambient associations were highest for individuals spending most of their time in high- compared with low-ventilated environments. Cross-pollutant models indicated that ambient particle concentrations were much better surrogates for exposure to particles than to gases. With the exception of ambient NO2 in the fall, which showed moderate associations with personal exposures, ambient gases were poor proxies for both gas and particle exposures. In combination, our results suggest that a) ventilation may be an important modifier of the magnitude of effect in time-series health studies, and b) results from time-series health studies based on 24-hr ambient concentrations are more readily interpretable for particles than for gases.

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# Sarnat, S. E., et al. (2010). "An examination of exposure measurement error from air pollutant spatial variability in time-series studies." Journal of Exposure Science and Environmental Epidemiology 20(2): 135-146.

Relatively few studies have evaluated the effects of heterogeneous spatiotemporal pollutant distributions on health risk estimates in time-series analyses that use data from a central monitor to assign exposures. We present a method for examining the effects of exposure measurement error relating to spatiotemporal variability in ambient air pollutant concentrations on air pollution health risk estimates in a daily time-series analysis of emergency department visits in Atlanta, Georgia. We used Poisson generalized linear models to estimate associations between current-day pollutant concentrations and circulatory emergency department visits for the 1998-2004 time period. Data from monitoring sites located in different geographical regions of the study area and at different distances from several urban geographical subpopulations served as alternative measures of exposure. We observed associations for spatially heterogeneous pollutants (CO and NO(2)) using data from several different urban monitoring sites. These associations were not observed when using data from the most rural site, located 38 miles from the city center. In contrast, associations for spatially homogeneous pollutants (O(3) and PM(2.5)) were similar, regardless of the monitoring site location. We found that monitoring site location and the distance of a monitoring site to a population of interest did not meaningfully affect estimated associations for any pollutant when using data from urban sites located within 20 miles from the population center under study. However, for CO and NO(2), these factors were important when using data from rural sites located > or = 30 miles from the population center, most likely owing to exposure measurement error. Overall, our findings lend support to the use of pollutant data from urban central sites to assess population exposures within geographically dispersed study populations in Atlanta and similar cities.

# Sarnat, S. E., et al. (2012). "Air pollution and acute respiratory response in a panel of asthmatic children along the U.S.-Mexico border." Environmental Health Perspectives 120(3): 437-444.

Background. Concerns regarding the health impact of urban air pollution on asthmatic children are pronounced along the US-Mexico border due to rapid population growth near busy border highways and roads. Objectives. We conducted the first binational study of the impacts of air pollution on asthmatic children in Ciudad Juarez, Mexico and El Paso, TX, and compared different exposure metrics to assess acute respiratory response. Methods. We recruited 58 asthmatic children from two schools in Ciudad Juarez and two schools in El Paso. A marker of airway inflammation (exhaled nitric oxide [eNO]), respiratory symptoms surveys, and pollutant measurements (indoor and outdoor 48-hr size-fractionated particulate matter, 48-hr black carbon, and 96-hr nitrogen dioxide) were collected at each school for 16 weeks. We examined associations between the pollutants and respiratory response using generalized linear mixed models. Results. We observed small but consistent associations between eNO and numerous pollutant metrics, with estimated increases in eNO ranging from 1 to 3% per interquartile range increase in pollutant concentrations. Effect estimates from models using school-based concentrations were generally stronger than corresponding estimates based on concentrations from ambient air monitors. Particles, both traffic- and non-traffic-related, were typically more robust predictors of eNO than nitrogen dioxide, for which associations were highly sensitive to model specification. Associations differed significantly across the four school-based cohorts, consistent with heterogeneity in pollutant concentrations and cohort characteristics. Models examining respiratory symptoms were consistent with the null. Conclusions. The results indicate adverse effects of air pollution on the subclinical respiratory health of asthmatic children in this region, and provide preliminary support for the use of air pollution monitors close to schools to track exposure and potential health risk in this population.

# Schembari, A., et al. (2013). "Personal, indoor and outdoor air pollution levels among pregnant women." Atmospheric Environment 64: 287-295.

Aim: The aims of this study were to investigate the relationship between pregnant women's personal exposures to NOx, NO2, PM2.5 concentration and absorbance as a marker for black carbon and their indoor and outdoor concentration levels at their residence, and also to identify predictors of personal exposure and indoor levels using questionnaire and time activity data.

Method: We recruited 54 pregnant women in Barcelona who carried a personal PM2.5 sampler for two days and NOx/NO2 passive badges for one week, while indoor and outdoor PM2.5 and NOx/NO2 levels at their residence were simultaneously measured. Time activity and house characteristics were recorded. Gravimetry determinations for PM2.5 concentration and absorbance measurements were carried out on the PM2.5 filter samples.

Results: Levels of personal exposure to NOx, PM2.5 and absorbance were slightly higher than indoor and outdoor levels (geometric mean of personal NOx = 61.9 vs indoor NOx = 60.6 mu g m(-3)), while for NO2 the indoor levels were slightly higher than the personal ones. Generally, there was a high statistically significant correlation between personal exposure and indoor levels (Spearman's r between 0.78 and 0.84). Women spent more than 60% of their time indoors at home. Ventilation of the house by opening the windows, the time spent cooking and indicators for traffic intensity were re-occurring statistically significant determinants of the personal and indoor pollutants levels with models for NOx explaining the 55% and 60% of the variability respectively, and models for NO2 explaining the 39% and 16% of the variability respectively. Models for PM2.5 and absorbance explained the least of the variability.

Conclusion: Our findings improve the current understanding of the characterization and inter-associations between personal, indoor and outdoor pollution levels among pregnant women. Variability in personal and indoor NOx and to a lesser extent NO2 levels could be explained well, but not the variability in PM2.5 could be explained. (C) 2012 Elsevier Ltd. All rights reserved.

# Schildcrout, J. S., et al. (2006). "Ambient air pollution and asthma exacerbations in children: An eight-city analysis." American Journal of Epidemiology 164(6): 505-517.

The authors investigated the relation between ambient concentrations of five of the Environmental Protection Agency's criteria pollutants and asthma exacerbations (daily symptoms and use of rescue inhalers) among 990 children in eight North American cities during the 22-month prerandomization phase (November 1993-September 1995) of the Childhood Asthma Management Program. Short-term effects of carbon monoxide, nitrogen dioxide, particulate matter less than 10 mum in aerodynamic diameter (PM10), sulfur dioxide, and warm-season ozone were examined in both one-pollutant and two-pollutant models, using lags of up to 2 days. Lags in carbon monoxide and nitrogen dioxide were positively associated with both measures of asthma exacerbation, and the 3-day moving sum of sulfur dioxide levels was marginally related to asthma symptoms. PM10 and ozone were unrelated to exacerbations. The strongest effects tended to be seen with 2-day lags, where a 1-parts-per-million change in carbon monoxide and a 20-parts-per-billion change in nitrogen dioxide were associated with symptom odds ratios of 1.08 (95% confidence interval (CI): 1.02, 1.15) and 1.09 (95% CI: 1.03, 1.15), respectively, and with rate ratios for rescue inhaler use of 1.06 (95% CI: 1.01, 1.10) and 1.05 (95% CI: 1.01, 1.09), respectively. The authors believe that the observed carbon monoxide and nitrogen dioxide associations can probably be attributed to mobile-source emissions, though more research is required.

# Schwartz, J. (1997). "Air pollution and hospital admissions for cardiovascular disease in Tucson." Epidemiology 8(4): 371-377.

John D. and Catherine T. MacArthur Fellowship; National Institute of Environmental Health Sciences. #Several recent studies have reported associations between short-term changes in both inhalable particles (PM10) and carbon monoxide and cardiovascular hospital admissions. Here, I seek to replicate those findings in a location where sulfur dioxide concentrations are low and poorly correlated with PM10, and where PM10 concentrations peak in the winter when ozone is lowest. This setting allows the opportunity to separate the effects of different air pollutants. I constructed daily counts of admissions to all hospitals in Tucson, AZ, for cardiovascular disease (International Classification of Diseases, 9th revision, codes 390-429) for persons age 65 years and older. I analyzed these admission counts in a Poisson regression, on temperature, humidity, day of the week indicators, and air pollution. I removed long wavelength patterns using a nonparametric smooth function of day of study. I used regression splines to model possible nonlinearities in the dependence of hospital admissions on weather. I then examined sensitivity analyses to control for weather. Both PM10 and carbon monoxide were associated with increased risk of cardiovascular hospital admissions. Admissions increased by 2.75% [95% confidence limits (CL) = 0.52%, 5.04%] for an interquartile range increase (23 µg per m) in PM10 and by 2.79% (95% CL = 0.51%, 5.41%) for an interquartile range increase (1.66 parts per million) in carbon monoxide. These associations were independent and additive. In contrast, I saw little association with sulfur dioxide [increase of 0.14% (95% CL = -1.3%, 1.6%) for an interquartile range increase in exposure], ozone [increase of 0.54% (95% CL = -2.3%, 3.45%)], or nitrogen dioxide [increase of 0.69% (95% CL = -2.3%, 3.8%)]. The air pollution associations were insensitive to control for a potential interaction between temperature and humidity and to control for temperature and humidity on more than 1 day.

# Ségala, C., et al. (2008). "Winter air pollution and infant bronchiolitis in Paris." Environmental Research 106(1): 96-100.

Respiratory syncytial virus (RSV) is one of the most common respiratory pathogens in infants and young children. It is not known why some previously healthy infants, when in contact with RSV, develop bronchiolitis whereas others have only mild symptoms. Our study aimed to evaluate the possible association between emergency hospital visits for bronchiolitis and air pollution in the Paris region during four winter seasons. We included children under the age of 3 years who attended emergency room services for bronchiolitis (following standardized definition) during the period 1997-2001. Two series of data from 34 hospitals, the daily number of emergency hospital consultations (n=50857) and the daily number of hospitalizations (n=16588) for bronchiolitis, were analyzed using alternative statistical methods; these were the generalized additive model (GAM) and case-crossover models. After adjustments for public holidays, holidays and meteorological variables the case-crossover model showed that PM10, BS, SO2 and NO2 were positively associated with both consultations and hospitalizations. GAM models, adjusting for long-term trend, seasonality, holiday, public holiday, weekday and meteorological variables, gave similar results for SO2 and PM10. This study shows that air pollution may act as a trigger for the occurrence of acute severe bronchiolitis cases.

# Sellier, Y., et al. (2014). "Health effects of ambient air pollution: Do different methods for estimating exposure lead to different results?" Environment International 66: 165-173.

BACKGROUND: Spatially resolved exposure models are increasingly used in epidemiology. We previously reported that, although exhibiting a moderate correlation, pregnancy nitrogen dioxide (NO2) levels estimated by the nearest air quality monitoring station (AQMS) model and a geostatistical model, showed similar associations with infant birth weight.

OBJECTIVES: We extended this study by comparing a total of four exposure models, including two highly spatially resolved models: a land-use regression (LUR) model and a dispersion model. Comparisons were made in terms of predicted NO2 and particle (aerodynamic diameter<10μm, PM10) exposure and adjusted association with birth weight.

METHODS: The four exposure models were implemented in two French metropolitan areas where 1026 pregnant women were followed as part of the EDEN mother-child cohort.

RESULTS: Correlations between model predictions were high (≥0.70), except for NO2 between the AQMS and both the LUR (r=0.54) and dispersion models (r=0.63). Spatial variations as estimated by the AQMS model were greater for NO2 (95%) than for PM10 (22%). The direction of effect estimates of NO2 on birth weight varied according to the exposure model, while PM10 effect estimates were more consistent across exposure models.

CONCLUSIONS: For PM10, highly spatially resolved exposure model agreed with the poor spatial resolution AQMS model in terms of estimated pollutant levels and health effects. For more spatially heterogeneous pollutants like NO2, although predicted levels from spatially resolved models (all but AQMS) agreed with each other, our results suggest that some may disagree with each other as well as with the AQMS regarding the direction of the estimated health effects.

# Semenza, J. C., et al. (2008). "Public perception and behavior change in relationship to hot weather and air pollution." Environmental Research 107(3): 401-411.

Background: Changes in climate systems are increasing heat wave frequency and air stagnation, both conditions associated with exacerbating poor air quality and of considerable public health concern. Objectives: Heat and air pollution advisory systems are in place in many cities for early detection and response to reduce health consequences, or severity of adverse conditions. Where as the ability to forecast heat waves and/or air pollution episodes has become increasingly sophisticated and accurate, little is known about the effectiveness of advisories in altering public behavior. Methods: Air quality and meteorological conditions were measured during advisory and control days in Portland, OR and Houston, TX in 2005 and 2006 and 1962 subjects were interviewed by telephone about their perception and response to these conditions. Results: Elevated ambient temperatures were accurately recognized regardless of air conditioning use; respondents resorted to active cooling behavior (AC, fan, etc.), while in Houston no such in Portland, change was observed. More heat-related symptoms were reported in Portland compared to Houston, probably due to low air conditioning use in the northwest. One-third of study participants were aware of air quality advisories but only similar to 10-15% claimed to have changed activities during such an episode. Not the advisory, however, drove their behavior change, but rather the perception of poor air quality, which was not related to PM2.5 or ozone measurements. Conclusions: Messages are not reaching the public during potentially hazardous weather and air quality conditions. Climatic forecasts are increasingly predictive but public agencies fail to mount an appropriate outreach response. (C) 2008 Elsevier Inc. All rights reserved.

# Šerevičienė—, V. and D. Paliulis (2012). "Influence of temperature and relative humidity on the performance of nitrogen dioxide diffusive sampler." Research Journal of Chemical Sciences 2(5): 89-92.

Passive diffusive samplers provide an excellent opportunity to perform indicative measurements or establish a dense network of measuring sites. This paper describe and present the results of experiments in exposure chamber to determine the effects of different ambient air temperature (T) and relatively humidity (RH) on the performances of passive diffusive samplers for measuring nitrogen dioxide (NO2) in the outdoor environment. In experimental studies were used passive diffusive samplers with stainless steel grids and impregnating solution of 10% (v/v) triethanolamine (TEA) with water. During these researches in laboratory chamber passive samplers was exposed at various conditions: temperature from 10°C to 40°C and relatively humidity from 30% to 80%. During these variations in conditions NO2 concentration was constant, approximately 40 μg/m3. Influence of temperature and relative humidity are weak on passive sampler performance when ambient temperature is 20°C and relatively humidity 60%. Changing environmental conditions (T > 30 °C and RH > 75 %) indicates accuracy of passive samplers 10-35% when compared to co-located continuous NOx analyzer.

# Setton, E., et al. (2011). "The impact of daily mobility on exposure to traffic-related air pollution and health effect estimates." Journal of Exposure Science and Environmental Epidemiology 21(1): 42-48.

Epidemiological studies of traffic-related air pollution typically estimate exposures at residential locations only; however, if study subjects spend time away from home, exposure measurement error, and therefore bias, may be introduced into epidemiological analyses. For two study areas (Vancouver, British Columbia, and Southern California), we use paired residence- and mobility-based estimates of individual exposure to ambient nitrogen dioxide, and apply error theory to calculate bias for scenarios when mobility is not considered. In Vancouver, the mean bias was 0.84 (range: 0.79-0.89; SD: 0.01), indicating potential bias of an effect estimate toward the null by ~16% when using residence-based exposure estimates. Bias was more strongly negative (mean: 0.70, range: 0.63-0.77, SD: 0.02) when the underlying pollution estimates had higher spatial variation (land-use regression versus monitor interpolation). In Southern California, bias was seen to become more strongly negative with increasing time and distance spent away from home (e.g., 0.99 for 0-2 h spent at least 10 km away, 0.66 for ≥ 10 h spent at least 40 km away). Our results suggest that ignoring daily mobility patterns can contribute to bias toward the null hypothesis in epidemiological studies using individual-level exposure estimates.

# Sheppard, L. (2003). Ambient air pollution and nonelderly asthma hospital admissions in Seattle, Washington, 1987-1994. Boston, MA, Health Effects Institute: 227-230.

# Sheppard, L. (2005). "Acute air pollution effects: Consequences of exposure distribution and measurements." Journal of Toxicology and Environmental Health, Part A: Current Issues 68(13-14): 1127-1135.

Acute effect air pollution studies estimate the effect of short-term change in exposure on a health outcome. The two designs most commonly used in air pollution epidemiology are panel studies and time-series studies. Typically, both designs rely on ambient concentration measurements and not the personal exposures of individuals. This article discusses how panel studies and time-series studies are related and reviews the use of ambient concentrations versus personal exposure measurements in the analyses. This work suggests that for estimating acute effects, ambient concentration measurements are quite adequate in time-series studies. In addition, time-series studies have ample power relative to panel studies, in spite of the ecologic nature of their design. Panel studies have the benefit of being able to use all the information from personal exposures in the analysis, but they are much more costly and difficult to conduct. Furthermore, nontraditional panel studies, where multiple repeat panels are followed over time, require additional considerations in the analysis.

Sheppard, L., et al. (2012). "Confounding and exposure measurement error in air pollution epidemiology." Air Quality, Atmosphere and Health 5(2): 203-216.

Studies in air pollution epidemiology may suffer from some specific forms of confounding and exposure measurement error. This contribution discusses these, mostly in the framework of cohort studies. Evaluation of potential confounding is critical in studies of the health effects of air pollution. The association between long-term exposure to ambient air pollution and mortality has been investigated using cohort studies in which subjects are followed over time with respect to their vital status. In such studies, control for individual-level confounders such as smoking is important, as is control for area-level confounders such as neighborhood socio-economic status. In addition, there may be spatial dependencies in the survival data that need to be addressed. These issues are illustrated using the American Cancer Society Cancer Prevention II cohort. Exposure measurement error is a challenge in epidemiology because inference about health effects can be incorrect when the measured or predicted exposure used in the analysis is different from the underlying true exposure. Air pollution epidemiology rarely if ever uses personal measurements of exposure for reasons of cost and feasibility. Exposure measurement error in air pollution epidemiology comes in various dominant forms, which are different for time-series and cohort studies. The challenges are reviewed and a number of suggested solutions are discussed for both study domains.

# Sheppard, L., et al. (1999). "Effects of ambient air pollution on nonelderly asthma hospital admissions in Seattle, Washington, 1987-1994." Epidemiology 10(1): 23-30.

U.S. Environmental Protection Agency. #As part of the Clean Air Act, Congress has directed EPA to set air quality standards to protect sensitive population groups from air pollutants in the ambient environment. People with asthma represent one such group. We undertook a study of the relation between measured ambient air pollutants in Seattle and nonelderly hospital admissions with a principal diagnosis of asthma. We regressed daily hospital admissions to local hospitals for area residents from 1987 through 1994 on particulate matter less than 10 and 2.5 microm in aerodynamic diameter (PM10 and PM2.5, respectively); coarse particulate mass; sulfur dioxide (SO2); ozone (O3); and carbon monoxide (CO) in a Poisson regression model with control for time trends, seasonal variations, and temperature-related weather effects. With the exception of seasonally monitored O3, we supplemented incomplete pollutant measures in a multiple imputation model to create a complete time series of exposure measures. We found an estimated 4-5% increase in the rate of asthma hospital admissions associated with an interquartile range change in PM (19 microg/m3 PM(10),11.8 microg/m3 PM2.5, and 9.3 microg/m3 coarse particulate mass) lagged 1 day; relative rates were as follows: for PM10, 1.05 [95% confidence interval (CI) = 1.02-1.08]; for PM2.5, 1.04 (95% CI = 1.02-1.07); and for coarse particulate mass, 1.04 (95% CI = 1.01-1.07). In single-pollutant models we also found that a 6% increase in the rate of admission was associated with an interquartile range change in CO (interquartile range, 924 parts per billion; 95% CI = 1.03-1.09) at a lag of 3 days and an interquartile range change in O3 (interquartile range, 20 parts per billion; 95% CI = 1.02-1.11) at a lag of 2 days. We did not observe an association for SO2. We found PM and CO to be jointly associated with asthma admissions. We estimated the highest increase in risk in the spring and fall seasons.

# Sheppard, L., et al. (2005). "Exposure and measurement contributions to estimates of acute air pollution effects." Journal of Exposure Analysis and Environmental Epidemiology 15(4): 366-376.

Air pollution health effect studies are intended to estimate the effect of a pollutant on a health outcome. The definition of this effect depends upon the study design, disease model parameterization, and the type of analysis. Further limitations are imposed by the nature of exposure and our ability to measure it. We define a plausible exposure model for air pollutants that are relatively nonreactive and discuss how exposure varies. We discuss plausible disease models and show how their parameterizations are affected by different exposure partitions and by different study designs. We then discuss a measurement model conditional on ambient concentrations and incorporate this into the disease model. We use simulation studies to show the impact of a range of exposure model assumptions on estimation of the health effect in the ecologic time series design. This design only uses information from the time-varying ambient source exposure. When ambient and nonambient sources are independent, exposure variation due to nonambient source exposures behaves like Berkson measurement error and does not bias the effect estimates. Variation in the population attenuation of ambient concentrations over time does bias the estimates with the bias being either positive or negative depending upon the association of this parameter with ambient pollution. It is not realistic to substitute measured average personal exposures into time series studies because so much of the variation in personal exposures comes from nonambient sources that do not contribute information in the time series design. We conclude that general statements about the implications of measurement error need to be conditioned on the health effect study design and the health effect parameter to be estimated.

# Simon, P. K. and P. K. Dasgupta (1995). "Continuous automated measurement of the soluble fraction of atmospheric particulate matter." Analytical Chemistry 67(1): 71-78.

State of Texas Advanced Research Program; U.S. Environmental Protection Agency. #A new approach is introduced for the quantitative collection of aerosol particles to submicrometer size. The design and construction of a continuously operating system is described. Particles are continuously transferred to a liquid stream utilizing condensation of super-saturated vapor to promote particle growth followed by collection that relies on impaction and the thermophoretic effect. The automated system is simple to construct and operate and provides quantitative collection of aerosol particulate matter even at a flow rate of 10 L/min. Individual measurements of aerosol particles and soluble gases are achieved by combining the system with a wetted wail parallel plate diffusion denuder. Interfaced to an inexpensive ion chromatograph for downstream analysis, the detection limits of the overall system for particulate sulfate, nitrite, and nitrate are 2.2, 0.6, and 5.1 ng/m3, respectively, for a 8 mm sample. The system has been used for the field measurement of gaseous and particulate components; results are presented.

# Singer, B. C., et al. (2004). "Passive measurement of nitrogen oxides to assess traffic-related pollutant exposure for the East Bay Children's Respiratory Health Study." Atmospheric Environment 38(3): 393-403.

The East Bay Children's Respiratory Health Study is examining associations between traffic-related pollutant exposures and respiratory health among children who reside and attend schools at varied proximity to northern California freeways. Chronic exposures are being inferred from outdoor pollutant concentrations at neighborhood schools. This paper reports primarily weeklong integrated NO2 and NOx concentrations measured with passive samplers placed outside at 10 elementary schools during 14 weeks in spring and 8 weeks in fall 2001. Measurements were also made outside selected student residences to examine spatial variability within three school neighborhoods. Regional concentrations of NO2 and NOx varied widely from week to week. School site data were normalized to measurements at a nearby regional monitoring station to facilitate analysis of relative pollutant exposures at the neighborhood schools. Normalized concentrations were consistent at each school throughout the study. Schools located upwind or far downwind of freeways were generally indistinguishable from one another and regional pollution levels. For school and neighborhood sites within 350 m downwind of a freeway, concentrations increased with decreasing downwind distance. The highest normalized concentrations occurred at a school located directly adjacent to a major freeway and a shopping center. In this case, normalized NO2 and NOx were ~60% and ~100% higher than regional background levels. At three schools within 130Ã»230 m downwind of a freeway, normalized NO2 and NOx were ~20-30% and ~50-80% higher than regional levels. Validation testing of the passive samplers indicated precision of better than 5% for both NO2 and NOx when samplers were deployed outside for 1-week periods. Passive sampler results agreed with co-located chemiluminescence measurements to within 8% for NO2 and 3% for NOx.

# Slama, R., et al. (2013). "Short-term impact of atmospheric pollution on fecundability." Epidemiology 24(6): 871-879.

BACKGROUND: Epidemiologic studies have reported associations between air pollution levels and semen characteristics, which might in turn affect a couple's ability to achieve a live birth. Our aim was to characterize short-term effects of atmospheric pollutants on fecundability (the month-specific probability of pregnancy among noncontracepting couples).

METHODS: For a cohort of births between 1994 and 1999 in Teplice (Czech Republic), we averaged fine particulate matter (PM2.5), carcinogenic polycyclic aromatic hydrocarbons, ozone, nitrogen dioxide (NO2), and sulfur dioxide levels estimated from a central measurement site over the 60-day period before the end of the first month of unprotected intercourse. We estimated changes in the probability of occurrence of a pregnancy during the first month of unprotected intercourse associated with exposure, using binomial regression and adjusting for maternal behaviors and time trends.

RESULTS: Among the 1,916 recruited couples, 486 (25%) conceived during the first month of unprotected intercourse. Each increase of 10 µg/m in PM2.5 levels was associated with an adjusted decrease in fecundability of 22% (95% confidence interval = 6%-35%). NO2 levels were also associated with decreased fecundability. There was no evidence of adverse effects with the other pollutants considered. Biases related to pregnancy planning or temporal trends in air pollution were unlikely to explain the observed associations.

CONCLUSIONS: In this polluted area, we highlighted short-term decreases in a couple's ability to conceive in association with PM2.5 and NO2 levels assessed in a central monitoring station.

# Smargiassi, A., et al. (2009). "Risk of asthmatic episodes in children exposed to sulfur dioxide stack emissions from a refinery point source in Montreal, Canada." Environmental Health Perspectives 117(4): 653-659.

BACKGROUND: Little is known about the respiratory effects of short-term exposures to petroleum refinery emissions in young children. This study is an extension of an ecologic study that found an increased rate of hospitalizations for respiratory conditions among children living near petroleum refineries in Montreal (Canada).

METHODS: We used a time-stratified case-crossover design to assess the risk of asthma episodes in relation to short-term variations in sulfur dioxide levels among children 2-4 years of age living within 0.5-7.5 km of the refinery stacks. Health data used to measure asthma episodes included emergency department (ED) visits and hospital admissions from 1996 to 2004. We estimated daily levels of SO2 at the residence of children using a) two fixed-site SO2 monitors located near the refineries and b) the AERMOD (American Meteorological Society/Environmental Protection Agency Regulatory Model) atmospheric dispersion model. We used conditional logistic regression to estimate odds ratios associated with an increase in the interquartile range of daily SO2 mean and peak exposures (31.2 ppb for AERMOD peaks). We adjusted for temperature, relative humidity, and regional/urban background air pollutant levels.

RESULTS: The risks of asthma ED visits and hospitalizations were more pronounced for same-day (lag 0) SO2 peak levels than for mean levels on the same day, or for other lags: the adjusted odds ratios estimated for same-day SO2 peak levels from AERMOD were 1.10 [95% confidence interval (CI), 1.00-1.22] and 1.42 (95% CI, 1.10-1.82), over the interquartile range, for ED visits and hospital admissions, respectively.

CONCLUSIONS: Short-term episodes of increased SO2 exposures from refinery stack emissions were associated with a higher number of asthma episodes in nearby children.

# Son, J. Y., et al. (2010). "Individual exposure to air pollution and lung function in Korea: Spatial analysis using multiple exposure approaches." Environmental Research 110(8): 739-749.

Interpolation methods can estimate individual-level exposures to air pollution from ambient monitors; however, few studies have evaluated how different approaches may affect health risk estimates. We applied multiple methods of estimating exposure for several air pollutants. We investigated how different methods of estimating exposure may influence health effect estimates in a case study of lung function data, forced expiratory volume in 1s (FEV1), and forced vital capacity (FVC), for 2102 cohort subjects in Ulsan, Korea, for 2003-2007. Measurements from 13 monitors for particulate matter <10μm (PM(10)), ozone, nitrogen dioxide, sulfur dioxide, and carbon monoxide were used to estimate individual-level exposures by averaging across values from all monitors, selecting the value from the nearest monitor, inverse distance weighting, and kriging. We assessed associations between pollutants and lung function in linear regression models, controlling for age, sex, and body mass index. Cross-validation indicated that kriging provided the most accurate estimated exposures. FVC was associated with all air pollutants under all methods of estimating exposure. Only ozone was associated with FEV1. An 11ppb increase in lag-0-2 8-h maximum ozone was associated with a 6.1% (95% confidence interval 5.0, 7.3%) decrease in FVC and a 0.50% (95% confidence interval 0.03, 0.96%) decrease in FEV1, based on kriged exposures. Central health effect estimates were generally higher using exposures based on averaging across all monitors or kriging. Results based on the nearest monitor approach had the lowest variance. Findings suggest that spatial interpolation methods may provide better estimates than monitoring values alone by reflecting the spatial variability of individual-level exposures and generating estimates for locations without monitors.

# Son, J. Y., et al. (2013). "Short-term effects of air pollution on hospital admissions in Korea." Epidemiology 24(4): 545-554.

BACKGROUND: Numerous studies have identified short-term effects of air pollution on morbidity in North America and Europe. The effects of air pollution may differ by region of the world. Evidence on air pollution and morbidity in Asia is limited.

METHODS: We investigated associations between ambient air pollution and hospital admissions in eight Korean cities for 2003-2008. We applied a two-stage Bayesian hierarchical model to estimate city-specific effects and the overall effects across the cities. We considered lagged effects of pollutants by cause (allergic disease, asthma, selected respiratory disease, and cardiovascular disease), sex, and age (0-14, 15-64, 65-74, and ≥75 years).

RESULTS: We found evidence of associations between hospital admissions and short-term exposure to air pollution. An interquartile range (IQR) increase in PM10 (30.7µg/m) was associated with an overall increase of 2.2% (95% posterior interval = 0.5%-3.9%), 2.8% (1.3%-4.4%), 1.7% (0.9%-2.6%), and 0.7% (0.0%-1.4%) in allergic, asthma, selected respiratory, and cardiovascular admissions, respectively. For NO2 (IQR 12.2 ppb), the corresponding figures were 2.3% (0.6%-4.0%), 2.2% (0.3%-4.1%), 2.2% (0.6%-3.7%), and 2.2% (1.1%-3.4%). For O3, we found positive associations for all the studied diagnoses except cardiovascular disease. SO2 was associated with hospital admissions for selected respiratory or cardiovascular causes, whereas O3 was negatively associated with cardiovascular admissions. We found suggestive evidence for stronger associations in younger and older age groups. Associations were similar for men and women.

CONCLUSIONS: Ambient air pollution was associated with increased risk of hospital admissions in Korea. Results suggest increased susceptibility among the young or the elderly for pollution effects on specific diseases.

# Spengler, J. D., et al. (1993). "Nitrous acid in Albuquerque, New Mexico, homes." Environmental Science and Technology 27(5): 841-845.

Experimental studies have shown that nitrogen acid species, particularly nitrous acid, are formed indoors during unvented combustion and by heterogeneous reactions of nitrogen dioxide. Limited measurements support the occurrence of nitrous acid production in occupied homes. We report additional measurements of HONO and NO2 in homes located in Albuquerque, NM, and assess the relationship with housing variables. Indoor HONO concentrations were found to be well correlated with indoor NO2 levels; HONO concentrations ranged from 5 % to 15 % of the measured NO2 concentrations. Given the correlation between HONO and NO2 in indoor environments, and the plausibility of HONO respiratory toxicity, investigations of respiratory health effects of unvented combustion should consider HONO, in addition to NO2, as a potentially hazardous indoor pollutant.

# Spengler, J. D., et al. (1979). "Sulfur dioxide and nitrogen dioxide levels inside and outside homes and the implications on health effects research." Environmental Science and Technology 13(10): 1276-1280.

This paper presents the results of 1 year's indoor and outdoor monitoring for SO2 and NO2 in six communities with widely varying outdoor levels. The representativeness of the monitoring in defining exposure is discussed for each city. In four of the communities, outdoor SO2 levels are less than 50% of the annual NAAQS, while violations are found in the other two. Annual average indoor levels of SO2 are never found to exceed the standard. In fact, indoor SO2 concentrations are 20 to 70% of the outdoor levels. Indoor NO2 levels, on the other hand, can exceed outdoor levels by a factor of two, depending on the type of cooking appliance used, but do not exceed the standard. The impact of various heating and cooking systems on the indoor concentrations of these gases, as well as the type of appliances used in the house, is evaluated.

# Spiegelman, D. (2013). "Regression calibration in air pollution epidemiology with exposure estimated by spatio-temporal modeling." Environmetrics 24(8): 521-524.

# Steinbacher, M., et al. (2007). "Nitrogen oxides measurements at rural sites in Switzerland: Bias of conventional measurement techniques." Journal of Geophysical Research: Atmospheres 112(D11): D11307.

Nitrogen oxides (NOx = NO + NO2) in the atmosphere are often measured using instruments equipped with molybdenum converters. NO2 is catalytically converted to NO on a heated molybdenum surface and subsequently measured by chemiluminescence after reaction with ozone. The drawback of this technique is that other oxidized nitrogen compounds such as peroxyacetyl nitrate and nitric acid are also partly converted to NO. Thus such NO2 measurements are really surrogate NO2 measurements because the resultant values systematically overestimate the true value because of interferences of these compounds, especially when sampling photochemically aged air masses. However, molybdenum converters are widely used, and a dense network of surrogate NO2 measurements exists. As an alternative with far less interference, photolytic converters using ultraviolet light are nowadays applicable also for long-term measurements. This work presents long-term collocated NO2 measurements using molybdenum and photolytic converters at two rural sites in Switzerland. On a relative scale, the molybdenum converter instruments overestimate the NO2 concentrations most during spring/summer because of prevalent photochemistry. On a monthly basis, only 70-83% of the “surrogate” NO2 can be attributed to “real” NO2 at the non-elevated site and even less (43-76%) at the elevated one. The observed interferences have to be taken into account for monitoring and regulatory issues and to be considered when using these data for ground-truthing of satellite data or for validation of chemical transport models. Alternatively, an increased availability of artifact-free data would also be beneficial for these issues.

# Steinvil, A., et al. (2009). "Environmental air pollution has decremental effects on pulmonary function test parameters up to one week after exposure." American Journal of the Medical Sciences 338(4): 273-279.

BACKGROUND: Recent exposure to air pollution has a decremental effect on pulmonary function. This short-term effect has only been studied for up to a few days postexposure. Our objective was to analyze the effect of air pollution on spirometric parameters in varying lag times of up to 1 week from the time of exposure. METHODS: Healthy subjects, never smokers, who were participants in the Tel Aviv Sourasky Medical Center Inflammation Survey held between 2002 and 2007, were included if residing within an 11-km range to the nearest air pollution monitoring station. Linear regression models were applied to each lung function variable [first second of exhalation (FEV(1)), forced vital capacity (FVC), FEV(1)/FVC] against air pollutant variables (particulate matter under 10 microns in diameter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and ozone) for increasing lag periods of up to 7 days, and they were adjusted for possible confounders that affect air pollution and spirometric measurements. RESULTS: The study population comprised 2380 individuals. We found a statistically significant negative correlation between air pollutants, mainly SO(2), and between FEV(1) and FVC. This effect was significant from days 3 to 6, with a maximal effect noted for the fifth day and for the 7-day average before pulmonary function measurement. No significant change was found for FEV(1)/FVC ratio. CONCLUSIONS: Air pollution has a decremental effect on lung function parameters for up to 6 days after exposure in healthy adults. SO(2) emerged as the most significant air pollutant affecting short-term lung function parameters.

# Steinvil, A., et al. (2008). "Short-term exposure to air pollution and inflammation-sensitive biomarkers." Environmental Research 106(1): 51-61.

To evaluate the effect of short-term exposure to air pollutants on inflammation-sensitive biomarkers in apparently healthy individuals.

We enrolled all participants from The Tel-Aviv Sourasky Medical Center inflammation survey held between 2003 and 2006, excluding participants with an acute or chronic inflammatory disease, pregnancy, steroidal or nonsteroidal treatment, or a recent invasive procedure. Additional subjects were excluded for living more than 11km from the nearest air pollution monitoring station. Analysis was performed separately for men and women. Linear regression models were fitted for each inflammatory variable against air pollutant variables (particulate matter under 10microm, sulfur dioxide, nitrogen dioxide, carbon monoxide, and ozone) for increasing lag times of up to 7 days, and adjusted for all possible and known confounding parameters.

The study population comprised 3659 individuals (2203 males and 1456 females). We found a statistically significant negative correlation in the male population between air pollutants, mainly NO2, SO2, and CO, and fibrinogen in several lag days. A positive correlation was found for PM10 at day 7. No such correlation was found for CRP and WBC, or for the female population.

Our findings do not support the potential link between short-term exposure to air pollution and enhanced inflammation as a possible explanation for increased cardiovascular morbidity. Additional large-scale population-based studies with good methodological design are needed in order to clarify this issue.

# Stieb, D. M., et al. (2009). "Air pollution and emergency department visits for cardiac and respiratory conditions: A multi-city time-series analysis." Environmental Health: A Global Access Science Source 8(25).

BACKGROUND: Relatively few studies have been conducted of the association between air pollution and emergency department (ED) visits, and most of these have been based on a small number of visits, for a limited number of health conditions and pollutants, and only daily measures of exposure and response. METHODS: A time-series analysis was conducted on nearly 400,000 ED visits to 14 hospitals in seven Canadian cities during the 1990 s and early 2000s. Associations were examined between carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3), sulfur dioxide (SO2), and particulate matter (PM 10 and PM2.5), and visits for angina/myocardial infarction, heart failure, dysrhythmia/conduction disturbance, asthma, chronic obstructive pulmonary disease (COPD), and respiratory infections. Daily and 3-hourly visit counts were modeled as quasi-Poisson and analyses controlled for effects of temporal cycles, weather, day of week and holidays. RESULTS: 24-hour average concentrations of CO and NO2 lag 0 days exhibited the most consistent associations with cardiac conditions (2.1% (95% CI, 0.0-4.2%) and 2.6% (95% CI, 0.2-5.0%) increase in visits for myocardial infarction/angina per 0.7 ppm CO and 18.4 ppb NO2 respectively; 3.8% (95% CI, 0.7-6.9%) and 4.7% (95% CI, 1.2-8.4%) increase in visits for heart failure). Ozone (lag 2 days) was most consistently associated with respiratory visits (3.2% (95% CI, 0.3-6.2%), and 3.7% (95% CI, -0.5-7.9%) increases in asthma and COPD visits respectively per 18.4 ppb). Associations tended to be of greater magnitude during the warm season (April - September). In particular, the associations of PM 10 and PM2.5 with asthma visits were respectively nearly three- and over fourfold larger vs. all year analyses (14.4% increase in visits, 95% CI, 0.2-30.7, per 20.6 microg/m3 PM 10 and 7.6% increase in visits, 95% CI, 5.1-10.1, per 8.2 microg/m3 PM2.5). No consistent associations were observed between three hour average pollutant concentrations and same-day three hour averages of ED visits. CONCLUSION: In this large multicenter analysis, daily average concentrations of CO and NO2 exhibited the most consistent associations with ED visits for cardiac conditions, while ozone exhibited the most consistent associations with visits for respiratory conditions. PM 10 and PM2.5 were strongly associated with asthma visits during the warm season.

# Strak, M., et al. (2013). "Composition of PM affects acute vascular inflammatory and coagulative markers - The RAPTES project." PLoS ONE 8(3): e58944.

BACKGROUND: Exposure to ambient particulate matter (PM) has been associated with adverse cardiovascular effects in epidemiological studies. Current knowledge of independent effects of individual PM characteristics remains limited.

METHODS: Using a semi-experimental design we investigated which PM characteristics were consistently associated with blood biomarkers believed to be predictive of the risk of cardiovascular events. We exposed healthy adult volunteers at 5 different locations chosen to provide PM exposure contrasts with reduced correlations among PM characteristics. Each of the 31 volunteers was exposed for 5 h, exercising intermittently, 3-7 times at different sites from March to October 2009. Extensive on-site exposure characterization included measurements of PM mass and number concentration, elemental- (EC) and organic carbon (OC), trace metals, sulfate, nitrate, and PM oxidative potential (OP). Before and 2 h and 18 h after exposure we measured acute vascular blood biomarkers - C-reactive protein, fibrinogen, platelet counts, von Willebrand Factor, and tissue plasminogen activator/plasminogen activator inhibitor-1 complex. We used two-pollutant models to assess which PM characteristics were most consistently associated with the measured biomarkers.

RESULTS AND CONCLUSION: We found OC, nitrate and sulfate to be most consistently associated with different biomarkers of acute cardiovascular risk. Associations with PM mass concentrations and OP were less consistent, whereas other measured components of the air pollution mixture, including PNC, EC, trace metals and NO2, were not associated with the biomarkers after adjusting for other pollutants.

# Strickland, M. J., et al. (2010). "Short-term associations between ambient air pollutants and pediatric asthma emergency department visits." American Journal of Respiratory and Critical Care Medicine 182(3): 307-316.

Rationale: Certain outdoor air pollutants cause asthma exacerbations in children. To advance understanding of these relationships, further characterization of the dose-response and pollutant lag effects are needed, as are investigations of pollutant species beyond the commonly measured criteria pollutants. Objectives: Investigate short-term associations between ambient air pollutant concentrations and emergency department visits for pediatric asthma. Methods: Daily counts of emergency department visits for asthma or wheeze among children age 5 to 17 were collected from 41 Metropolitan Atlanta hospitals during 1993-2004 (n = 91,386 visits). Ambient concentrations of gaseous pollutants and speciated particulate matter were available from stationary monitors during this time period. Rate ratios for the warm season (May-October) and cold season (November-April) were estimated using Poisson generalized linear models in the framework of a case-crossover analysis. Measurements and Main Results: Both ozone and primary pollutants from traffic sources were associated with emergency department visits for asthma or wheeze; evidence for independent effects of ozone and primary pollutants from traffic sources were observed in multipollutant models. These associations tended to be of the highest magnitude for concentrations on the day of the emergency department visit and were present at relatively low ambient concentrations. Conclusions: Even at relatively low ambient concentrations, ozone and primary pollutants from traffic sources independently contributed to the burden of emergency department visits for pediatric asthma.

# Strickland, M. J., et al. (2011). "Implications of different approaches for characterizing ambient air pollutant concentrations within the urban airshed for time-series studies and health benefits analyses." Environmental Health: A Global Access Science Source 10(1): 36.

BACKGROUND: In time-series studies of the health effects of urban air pollutants, decisions must be made about how to characterize pollutant levels within the airshed. METHODS: Emergency department visits for pediatric asthma exacerbations were collected from Atlanta hospitals. Concentrations of carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, particulate matter less than 10 microns in diameter (PM10), particulate matter less than 2.5 microns in diameter (PM2.5), and the PM2.5 components elemental carbon, organic carbon, and sulfate were obtained from networks of ambient air quality monitors. For each pollutant we created three different daily metrics. For one metric we used the measurements from a centrally-located monitor; for the second we averaged measurements across the network of monitors; and for the third we estimated the population-weighted average concentration using an isotropic spatial model. Rate ratios for each of the metrics were estimated from time-series models. RESULTS: For pollutants with relatively homogeneous spatial distributions we observed only small differences in the rate ratio across the three metrics. Conversely, for spatially heterogeneous pollutants we observed larger differences in the rate ratios. For a given pollutant, the strength of evidence for an association (i.e., chi-square statistics) tended to be similar across metrics. CONCLUSIONS: Given that the chi-square statistics were similar across the metrics, the differences in the rate ratios for the spatially heterogeneous pollutants may seem like a relatively small issue. However, these differences are important for health benefits analyses, where results from epidemiological studies on the health effects of pollutants (per unit change in concentration) are used to predict the health impacts of a reduction in pollutant concentrations. We discuss the relative merits of the different metrics as they pertain to time-series studies and health benefits analyses.

# Strickland, M. J., et al. (2013). "Effects of ambient air pollution measurement error on health effect estimates in time-series studies: a simulation-based analysis." Journal of Exposure Science and Environmental Epidemiology 25(2): 160-166.

In this study, we investigated bias caused by spatial variability and spatial heterogeneity in outdoor air-pollutant concentrations, instrument imprecision, and choice of daily pollutant metric on risk ratio (RR) estimates obtained from a Poisson time-series analysis. Daily concentrations for 12 pollutants were simulated for Atlanta, Georgia, at 5 km resolution during a 6-year period. Viewing these as being representative of the true concentrations, a population-level pollutant health effect (RR) was specified, and daily counts of health events were simulated. Error representative of instrument imprecision was added to the simulated concentrations at the locations of fixed site monitors in Atlanta, and these mismeasured values were combined to create three different city-wide daily metrics (central monitor, unweighted average, and population-weighted average). Given our assumptions, the median bias in the RR per unit increase in concentration was found to be lowest for the population-weighted average metric. Although the Berkson component of error caused bias away from the null in the log-linear models, the net bias due to measurement error tended to be towards the null. The relative differences in bias among the metrics were lessened, although not eliminated, by scaling results to interquartile range increases in concentration. Journal of Exposure Science and Environmental Epidemiology advance online publication, 10 April 2013; doi:10.1038/jes.2013.16.

# Strickland, M. J., et al. (2009). "Ambient air pollution and cardiovascular malformations in Atlanta, Georgia, 1986-2003." American Journal of Epidemiology 169(8): 1004-1014.

Associations between ambient air pollution levels during weeks 3-7 of pregnancy and risks of cardiovascular malformations were investigated among the cohort of pregnancies reaching at least 20 weeks' gestation that were conceived during January 1, 1986-March 12, 2003, in Atlanta, Georgia. Surveillance records obtained from the Metropolitan Atlanta Congenital Defects Program, which conducts active, population-based surveillance on this cohort, were reviewed to classify cardiovascular malformations. Ambient 8-hour maximum ozone and 24-hour average carbon monoxide, nitrogen dioxide, particulate matter with an average aerodynamic diameter of <10 microm (PM(10)), and sulfur dioxide measurements were obtained from centrally located stationary monitors. Temporal associations between these pollutants and daily risks of secundum atrial septal defect, aortic coarctation, hypoplastic left heart syndrome, patent ductus arteriosus, valvar pulmonary stenosis, tetralogy of Fallot, transposition of the great arteries, muscular ventricular septal defect, perimembranous ventricular septal defect, conotruncal defects, left ventricular outflow tract defect, and right ventricular outflow defect were modeled by using Poisson generalized linear models. A statistically significant association was observed between PM(10) and patent ductus arteriosus (for an interquartile range increase in PM(10) levels, risk ratio = 1.60, 95% confidence interval: 1.11, 2.31). Of the 60 associations examined in the primary analysis, no other significant associations were observed.

# Suh, H. H. and A. Zanobetti (2010). "Exposure error masks the relationship between traffic-related air pollution and heart rate variability." Journal of Occupational and Environmental Medicine 52(7): 685-692.

OBJECTIVE: We examined whether more precise exposure measures would better detect associations between traffic-related pollution, elemental carbon (EC), nitrogen dioxide (NO2), and heart rate variability (HRV). METHODS: Repeated 24-hour personal and ambient PM2.5, EC, and NO2 were measured for 30 people living in Atlanta, GA. The association between HRV and either ambient concentrations or personal exposures was examined using linear mixed effects models. RESULTS: Ambient PM2.5, EC, NO2, and personal PM2.5 were not associated with HRV. Personal EC and NO2 measured 24 hours before HRV were associated with decreased RMSSD, PNN50, and HF and with increased LF/HF. RMSSD decreased by 10.97% (95% confidence interval: -18.00 to -3.34) for an inter-quartile range change in personal EC (0.81 microg/m3). CONCLUSIONS: Results indicate decreased vagal tone in response to traffic pollutants, which can best be detected with precise personal exposure measures.

# Swaans, W., et al. (2007). "Laboratory and field validation of a combined NO2-SO2 Radiello passive sampler." Journal of Environmental Monitoring 9(11): 1231-1240.

A combined NO2-SO2 Radiello radial-type diffusive sampler was validated under controlled laboratory conditions and compared with NO2-SO2 results of 3 other type of samplers in a field comparison at two locations Ghent-Mariakerke and Borgerhout in Flanders. Laboratory exposures at different temperatures (-5, 10 and 30 degrees C) and relative humidities (0, 50 and 80% RH) in combination with varying concentration levels and exposure times were carried out, with a focus on extreme conditions. Concentration level and exposure time were changed together following suppliers linear working range of samplers and assuring absolute amounts of compounds on the sampler corresponding to those of environmental levels. The average uptake rate for NO2 for 24 hour exposures at 10 degrees C and 50% RH and tested concentration levels (+/-73, 146 and 293 ppb NO2) was 0.076 +/- 0.011 ng ppb(-1) min(-1). Uptake rates during all experiments were lower than the uptake rate given in the instruction manual of the sampler. A significant effect of temperature and relative humidity on NO2 uptake rate was observed. The temperature effect from 10 to 30 degrees C corresponds to the temperature effect given by the supplier of the samplers. High relative humidity (70 to 80%) caused a strong non-reproducible decrease of uptake rate for NO2 at 24 hour experiments but this effect was not observed at longer exposures except for the tests at -5 degrees C. At the tested temperature below zero in combination with high relative humidity the sampler showed anomalous behaviour for NO2. The possible effect of concentration level and exposure time for NO2 needs further research. The average uptake rate for SO2 calculated from all exposures is 0.478 +/- 0.075 ng of sulfate ion each ppb min of SO2 and accords to suppliers uptake rate. No clear effects of temperature, relative humidity or concentration level/exposure time on the uptake rate for SO2 were found, partly due to the large scatter of results. Although NO2 accuracy of Radiello samplers was better during field campaigns than during laboratory validation, IVL and OGAWA samplers gave better results for NO2. In the field, IVL samplers showed best agreement with the continuous analyzers for both NO2 and SO2.

# Szpiro, A. A. and C. J. Paciorek (2013). "Measurement error in two-stage analyses, with application to air pollution epidemiology." Environmetrics 24(8): 501-517.

Public health researchers often estimate health effects of exposures (e.g., pollution, diet, lifestyle) that cannot be directly measured for study subjects. A common strategy in environmental epidemiology is to use a first-stage (exposure) model to estimate the exposure based on covariates and/or spatio-temporal proximity and to use predictions from the exposure model as the covariate of interest in the second-stage (health) model. This induces a complex form of measurement error. We propose an analytical framework and methodology that is robust to misspecification of the first-stage model and provides valid inference for the second-stage model parameter of interest. We decompose the measurement error into components analogous to classical and Berkson error and characterize properties of the estimator in the second-stage model if the first-stage model predictions are plugged in without correction. Specifically, we derive conditions for compatibility between the first- and second-stage models that guarantee consistency (and have direct and important real-world design implications), and we derive an asymptotic estimate of finite-sample bias when the compatibility conditions are satisfied. We propose a methodology that (1) corrects for finite-sample bias and (2) correctly estimates standard errors. We demonstrate the utility of our methodology in simulations and an example from air pollution epidemiology.

# Szpiro, A. A. and C. J. Paciorek (2013). "Rejoinder." Environmetrics 24(8): 531-536.

# Szpiro, A. A., et al. (2011). "Does more accurate exposure prediction necessarily improve health effect estimates?" Epidemiology 22(5): 680-685.

A unique challenge in air pollution cohort studies and similar applications in environmental epidemiology is that exposure is not measured directly at subjects' locations. Instead, pollution data from monitoring stations at some distance from the study subjects are used to predict exposures, and these predicted exposures are used to estimate the health effect parameter of interest. It is usually assumed that minimizing the error in predicting the true exposure will improve health effect estimation. We show in a simulation study that this is not always the case. We interpret our results in light of recently developed statistical theory for measurement error, and we discuss implications for the design and analysis of epidemiologic research.

# Szpiro, A. A., et al. (2014). "Estimating acute air pollution health effects from cohort study data." Biometrics 70(1): 164-174.

Traditional studies of short-term air pollution health effects use time series data, while cohort studies generally focus on long-term effects. There is increasing interest in exploiting individual level cohort data to assess short-term health effects in order to understand the mechanisms and time scales of action. We extend semiparametric regression methods used to adjust for unmeasured confounding in time series studies to the cohort setting. Time series methods are not directly applicable since cohort data are typically collected over a prespecified time period and include exposure measurements on days without health observations. Therefore, long-time asymptotics are not appropriate, and it is possible to improve efficiency by exploiting the additional exposure data. We show that flexibility of the semiparametric adjustment model should match the complexity of the trend in the health outcome, in contrast to the time series setting where it suffices to match temporal structure in the exposure. We also demonstrate that pre-adjusting exposures concurrent with the health endpoints using trends in the complete exposure time series results in unbiased health effect estimation and can improve efficiency without additional confounding adjustment. A recently published article found evidence of an association between short-term exposure to ambient fine particulate matter (PM2.5) and retinal arteriolar diameter as measured by retinal photography in the Multi-Ethnic Study of Atherosclerosis (MESA). We reanalyze the data from this article in order to compare the methods described here, and we evaluate our methods in a simulation study based on the MESA data.

# Szpiro, A. A., et al. (2011). "Efficient measurement error correction with spatially misaligned data." Biostatistics 12(4): 610-623.

Association studies in environmental statistics often involve exposure and outcome data that are misaligned in space. A common strategy is to employ a spatial model such as universal kriging to predict exposures at locations with outcome data and then estimate a regression parameter of interest using the predicted exposures. This results in measurement error because the predicted exposures do not correspond exactly to the true values. We characterize the measurement error by decomposing it into Berkson-like and classical-like components. One correction approach is the parametric bootstrap, which is effective but computationally intensive since it requires solving a nonlinear optimization problem for the exposure model parameters in each bootstrap sample. We propose a less computationally intensive alternative termed the ‘parameter bootstrap’; that only requires solving one nonlinear optimization problem, and we also compare bootstrap methods to other recently proposed methods. We illustrate our methodology in simulations and with publicly available data from the Environmental Protection Agency.

# Tao, Y., et al. (2012). "Estimated acute effects of ambient ozone and nitrogen dioxide on mortality in the Pearl River Delta of Southern China." Environmental Health Perspectives 120(3): 393-398.

Background and objectives: Epidemiologic studies have attributed adverse health effects to air pollution; however, controversy remains regarding the relationship between ambient oxidants [ozone (O3) and nitrogen dioxide (NO2)] and mortality, especially in Asia. We conducted a four-city time-series study to investigate acute effects of O3 and NO2 in the Pearl River Delta (PRD) of southern China, using data from 2006 through 2008. Methods: We used generalized linear models with Poisson regression incorporating natural spline functions to analyze acute mortality in association with O3 and NO2, with PM10 (particulate matter ≤ 10 μm in diameter) included as a major confounder. Effect estimates were determined for individual cities and for the four cities as a whole. We stratified the analysis according to high- and low- exposure periods for O3. Results: We found consistent positive associations between ambient oxidants and daily mortality across the PRD cities. Overall, 10-Î¼g/m3 increases in average O3 and NO2 concentrations over the previous 2 days were associated with 0.81% [95% confidence interval (CI): 0.63%, 1.00%] and 1.95% (95% CI: 1.62%, 2.29%) increases in total mortality, respectively, with stronger estimated effects for cardiovascular and respiratory mortality. After adjusting for PM10, estimated effects of O3 on total and cardiovascular mortality were stronger for exposure during high-exposure months (September through November), whereas respiratory mortality was associated with O3 exposure during nonpeak exposure months only. Conclusions: Our findings suggest significant acute mortality effects of O3 and NO2 in the PRD and strengthen the rationale for further limiting the ambient pollution levels in the area.

# Timonen, K. L., et al. (2006). "Effects of ultrafine and fine particulate and gaseous air pollution on cardiac autonomic control in subjects with coronary artery disease: The ULTRA study." Journal of Exposure Science and Environmental Epidemiology 16(4): 332-341.

Previous studies have shown an association between elevated concentrations of particulate air pollution and cardiovascular morbidity and mortality. Therefore, the association between daily variation of ultrafine and fine particulate air pollution and cardiac autonomic control measured as heart rate variability (HRV) was studied in a large multicenter study in Amsterdam, the Netherlands, Erfurt, Germany, and Helsinki, Finland. Elderly subjects (n=37 in Amsterdam, n=47 in both Erfurt and Helsinki) with stable coronary artery disease were followed for 6 months with biweekly clinical visits. During the visits, ambulatory electrocardiogram was recorded during a standardized protocol including a 5-min period of paced breathing. Time and frequency domain analyses of HRV were performed. A statistical model was built for each center separately. The mean 24-h particle number concentration (NC) (1000/cm(3)) of ultrafine particles (diameter 0.01-0.1 mum) was 17.3 in Amsterdam, 21.1 in Erfurt, and 17.0 in Helsinki. The corresponding values for PM2.5 were 20.0, 23.1, and 12.7 mug/m(3). During paced breathing, ultrafine particles, NO(2), and CO were at lags of 0-2 days consistently and significantly associated with decreased low-to-high frequency ratio (LF/HF), a measure of sympathovagal balance. In a pooled analysis across the centers, LF/HF decreased by 13.5% (95% confidence interval: -20.1%, -7.0%) for each 10,000/cm(3) increase in the NC of ultrafine particles (2-day lag). PM2.5 was associated with reduced HF and increased LF/HF in Helsinki, whereas the opposite was true in Erfurt, and in Amsterdam, there were no clear associations between PM2.5 and HRV. The results suggest that the cardiovascular effects of ambient ultrafine and PM2.5 can differ from each other and that their effect may be modified by the characteristics of the exposed subjects and the sources of PM2.5.

# Tolbert, P. E., et al. (2007). "Multipollutant modeling issues in a study of ambient air quality and emergency department visits in Atlanta." Journal of Exposure Science and Environmental Epidemiology 17(Suppl 2): S29-S35.

Multipollutant models are frequently used to differentiate roles of multiple pollutants in epidemiologic studies of ambient air pollution. In the presence of differing levels of measurement error across pollutants under consideration, however, they can be biased and as misleading as single-pollutant models. Their appropriate interpretation depends on the relationships among the pollutant measurements and the outcomes in question. In situations where two or more pollutant variables may be acting as surrogates for the etiologic agent(s), multipollutant models can help identify the best surrogate, but the risk estimates may be influenced by inclusion of a second variable that is not itself an independent risk factor for the outcome in question. In this paper, these issues will be illustrated in the context of an ongoing study of emergency visits in Atlanta. Emergency department visits from 41 of 42 hospitals serving the twenty-county Atlanta metropolitan area for the period 1993-2004 (n=10,206,389 visits) were studied in relation to ambient pollutant levels, including speciated particle measurements from an intensive monitoring campaign at a downtown station starting in 1998. Relative to our earlier publications, reporting results through 2000, the period for which the speciated data are now available is now tripled (six years in length). Poisson generalized linear models were used to examine outcome counts in relation to three-day moving average concentrations of pollutants of a priori interest (ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide, oxygenated hydrocarbons, PM10, coarse PM, PM2.5, and the following components of PM2.5: elemental carbon, organic carbon, sulfate, water-soluble transition metals.) In the present analysis, we report results for two outcome groups: a respiratory outcomes group and a cardiovascular outcomes group. For cardiovascular visits, associations were observed with CO, 3 NO2, and PM2.5 elemental carbon and organic carbon. In multipollutant models, CO was the strongest predictor. For respiratory visits, associations were observed with ozone, PM10, CO and NO2 in single-pollutant models. In multipollutant models, PM10 and ozone persisted as predictors, with ozone the stronger predictor. Caveats and considerations in interpreting the multipollutant model results are discussed.

# Trasande, L., et al. (2013). "Exploring prenatal outdoor air pollution, birth outcomes and neonatal health care utilization in a nationally representative sample." Journal of Exposure Science and Environmental Epidemiology 23(3): 315-321.

The impact of air pollution on fetal growth remains controversial, in part, because studies have been limited to sub-regions of the United States with limited variability. No study has examined air pollution impacts on neonatal health care utilization. We performed descriptive, univariate and multivariable analyses on administrative hospital record data from 222,359 births in the 2000, 2003 and 2006 Kids Inpatient Database linked to air pollution data drawn from the US Environmental Protection Agency's Aerometric Information Retrieval System. In this study, air pollution exposure during the birth month was estimated based on birth hospital address. Although air pollutants were not individually associated with mean birth weight, a three-pollutant model controlling for hospital characteristics, demographics, and birth month identified 9.3% and 7.2% increases in odds of low birth weight and very low birth weight for each μg/m (3) increase in PM(2.5) (both P<0.0001). PM(2.5) and NO(2) were associated with -3.0% odds/p.p.m. and +2.5% odds/p.p.b. of preterm birth, respectively (both P<0.0001). A four-pollutant multivariable model indicated a 0.05 days/p.p.m. NO(2) decrease in length of the birth hospitalization (P=0.0061) and a 0.13 days increase/p.p.m. CO (P=0.0416). A $1166 increase in per child costs was estimated for the birth hospitalization per p.p.m. CO (P=0.0002) and $964 per unit increase in O(3) (P=0.0448). A reduction from the 75th to the 25th percentile in the highest CO quartile for births predicts annual savings of $134.7 million in direct health care costs. In a national, predominantly urban, sample, air pollutant exposures during the month of birth are associated with increased low birth weight and neonatal health care utilization. Further study of this database, with enhanced control for confounding, improved exposure assessment, examination of exposures across multiple time windows in pregnancy, and in the entire national sample, is supported by these initial investigations.

# Tsai, S. S., et al. (2012). "Air pollution and hospital admissions for myocardial infarction: Are there potentially sensitive groups?" Journal of Toxicology and Environmental Health, Part A: Current Issues 75(4): 242-251.

Recent studies showed that air pollution is a risk factor for hospitalization for myocardial infarction (MI). However, there is limited evidence to suggest which subpopulations are at higher risk for MI arising from air pollution. This study was undertaken to examine the modifying effects of specific secondary cardiovascular diagnosis (including hypertension, diabetes, congestive heart failure, and arrhythmias) on the relationship between hospital admissions for MI and exposure to ambient air pollutants. Hospital admissions for MI and ambient air pollution data for Taipei were obtained for the period 1999-2009. The relative risk of hospital admissions for MI was estimated using a case-crossover approach. None of the secondary diagnosis examined showed significant evidence of effect modification. It would appear that the correlation between air pollutant exposure and MI occurrence is not affected by predisposing factors present in other cardiovascular diseases.

# Turin, T. C., et al. (2012). "Short-term exposure to air pollution and incidence of stroke and acute myocardial infarction in a Japanese population." Neuroepidemiology 38(2): 84-92.

BACKGROUND: Exposure to high levels of air pollution can increase the risk of cardiovascular events. However, there is no clear information in Japan on the effect of pollution on the incidence of stroke and acute myocardial infarction (AMI). Therefore, we investigated the effects of air pollution on the incidence of stroke and AMI in a setting where pollutant levels are rather low.

METHODS: Data were obtained from the Takashima Stroke and AMI Registry, which covers a population of approximately 55,000 in Takashima County in central Japan. We applied a time-stratified, bidirectional, case-crossover design to estimate the effects of air pollutants, which included suspended particulate matter (SPM), sulfur dioxide (SO(2)), nitrogen dioxide (NO(2)) and photochemical oxidants (Ox). We used the distributed lag model to estimate the effect of pollutant exposure 0-3 days before the day of event onset and controlled for meteorological covariates in all of the models.

RESULTS: There were 2,038 first-ever strokes (1,083 men, 955 women) and 429 first-ever AMI cases (281 men, 148 women) during 1988-2004. The mean pollutant levels were as follows: SPM 26.9 μg/m (3); SO(2) 3.9 ppb; NO(2) 16.0 ppb, and Ox 28.4 ppb. In single-pollutant and two-pollutant models, SO(2) was associated with the risk of cerebral hemorrhage. Other stroke subtypes and AMI were not associated with air pollutant levels.

CONCLUSIONS: We observed an association between SO(2) and hemorrhagic stroke; however, we found inconclusive evidence for a short-term effect of air pollution on the incidence of other stroke types and AMI.

# U.S, E. P. A. (2009). Integrated science assessment for particulate matter. Research Triangle Park, NC, U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment- RTP Division.

EPA has released the final Integrated Science Assessment (ISA) for Particulate Matter (PM). This is EPA’s latest evaluation of the scientific literature on the potential human health and welfare effects associated with ambient exposures to particulate matter (PM). The development of this document is part of the Agency's periodic review of the national ambient air quality standards (NAAQS) for PM. The recently completed PM ISA and supplementary annexes, in conjunction with additional technical and policy assessments developed by EPA’s Office of Air and Radiation, will provide the scientific basis to inform EPA decisions related to the review of the current PM NAAQS.

# U.S, E. P. A. (2016). Integrated science assessment for oxides of nitrogen-Health Criteria (final report). Research Triangle Park, NC, U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment.

The Integrated Science Assessment (ISA) for Oxides of Nitrogen – Health Criteria document represents a concise synthesis and evaluation of the most policy-relevant science and will ultimately provide the scientific basis for EPA’s decision regarding whether the current standard for NO2 sufficiently protects public health.

# U.S, E. P. A. (2017). Integrated science assessment for sulfur oxides: Health criteria. Research Triangle Park, NC, U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment- RTP.

# Van Roosbroeck, S., et al. (2008). "Traffic-related outdoor air pollution and respiratory symptoms in children: The impact of adjustment for exposure measurement error." Epidemiology 19(3): 409-416.

BACKGROUND: Outdoor concentrations of soot and nitrogen dioxide (NO2) outside of schools have been associated with children's respiratory and eye symptoms. We assessed how adjustments for measurement error affect these associations. METHODS: Concentrations of air pollutants outside children's schools were validated by personal measurements of exposure to traffic-related air pollution. We estimated prevalence ratios of 4 health outcomes (current wheeze, conjunctivitis, phlegm, and elevated total serum immunoglobulin E) using school outdoor measurements, and then adjusted for measurement error using the personal exposure data and applying a regression calibration method. The analysis adjusting for measurement error was carried out using a main study/external validation design. RESULTS: Adjusting for measurement error produced effect estimates related to soot and NO2 that were 2 to 3 times higher than in the original study. The adjusted prevalence ratio for current phlegm was 5.3 (95% confidence interval = 1.2-23) for a 9.3 microg/m3 increase in soot, and 3.8 (1.0-14), for a 17.6 microg/m3 increase in NO2, compared with the original results of 2.2 (1.3-3.9) and 1.8 (1.1-2.8), respectively. Corrections were of similar magnitude for the prevalence of current wheeze, current conjunctivitis, and total elevated total immunoglobulin E. CONCLUSIONS: The estimated effects of outdoor air pollution on respiratory and other health effects in children may be substantially attenuated when based on exposure measurements outside schools instead of personal exposure.

# Vardoulakis, S., et al. (2009). "Comparative evaluation of nitrogen oxides and ozone passive diffusion tubes for exposure studies." Atmospheric Environment 43(16): 2509-2517.

Passive diffusion tubes are recognised as a cost-effective sampling method for characterising the spatial variability, as well as the seasonal and annual trends, of NO2 concentrations in urban areas. In addition, NOX and O3 passive diffusion tubes have been developed and deployed in urban and rural areas. Despite their many advantages (e.g. low operational and analysis cost, small size and no need for power supply), they have certain limitations mainly related to their accuracy and precision. In particular, the absorbent solution used, the length of the exposure period, the exact location and use of protective devices, and other environmental conditions (e.g. wind, ambient temperature and relative humidity) may have a significant impact on the performance of passive diffusion tubes. The aim of this study is to evaluate the performance of co-located NO2, NOX and O3 diffusion tubes in an urban environment. A one-year passive sampling campaign was carried out in Birmingham (UK) for this purpose. NO2, NOX and O3 diffusion tubes (including triplicate sets of each) were co-located at one urban background and two roadside permanent air quality monitoring stations equipped with standard gas analysers. In addition, meteorological data, such as wind speed and direction, ambient temperature and relative humidity, were obtained during the same period of time. A thorough QA/QC procedure, including storage and laboratory blanks was followed throughout the campaign. The analysis of results showed a very good agreement of NO2 passive samplers with co-located chemiluminescence analysers, but substantial underestimations of total NOX levels by the diffusion tubes. The O3 diffusion sampler appeared to marginally overestimate the automatic UV analyser results, especially during warm weather periods.

# Venkanna, R., et al. (2015). "Environmental monitoring of surface ozone and other trace gases over different time scales: chemistry, transport and modeling." International Journal of Environmental Science and Technology 12(5): 1749-1758.

Increasing concentration of tropospheric ozone (O-3) is a serious air pollution problem faced commonly by the urban people. The present study emphasizes on variations of air pollutant concentrations viz., O-3, nitrogen oxides (NOx), carbon monoxide (CO), sulfur dioxide (SO2) and black carbon (BC) at a tropical urban site located in the Deccan plateau region with semi-arid climate. The air monitoring site revealed typical diurnal/seasonal trends attributing to the complex chemistry of surface O-3 formation from its precursors. Role of SO2 in the formation of free radical () and its impact on O-3 concentration is distinguished part of the study. The results showed the highest mean O-3 in summer (57.5 +/- A 15.2 ppbv) followed by winter and monsoon. Observations of BC aerosols showed the highest mean value during winter (8.2 +/- A 2 mu g m(-3)) and the lowest in monsoon (4.2 +/- A 1 mu g m(-3)). Besides local influences, long-range transport of air masses were also studied by simulating back trajectories at different elevations during the study period. Furthermore, statistical analysis and modeling was performed with both linear (regression) and nonlinear (neural network) methods.

# Vieira, S. E., et al. (2012). "Urban air pollutants are significant risk factors for asthma and pneumonia in children: The influence of location on the measurement of pollutants." Archivos de Bronconeumología 48(11): 389-395.

BACKGROUND: Air pollution is associated with a substantial burden on human health; however, the most important pollutants may vary with location. Proper monitoring is necessary to determine the effect of these pollutants on respiratory health.

OBJECTIVES: This study was designed to evaluate the role of outdoor, indoor and personal exposure to combustion-related pollutants NO(2) and O(3) on respiratory health of children in a non-affluent urban area of São Paulo, Brazil.

METHODS: Levels of NO(2) and O(3) were continuously measured in outdoor and indoor air, as well as personal exposure, for 30 days using passive measurement monitors. Respiratory health was assessed with a Brazilian version of the ISAAC questionnaire.

RESULTS: Complete data were available from 64 children, aged 6-10 years. Respiratory morbidity was high, with 43 (67.2%) reporting having had wheezing at any time, 27 (42.2%) wheezing in the last month, 17 (26.6%) asthma at any time and 21 (32.8%) pneumonia at any time. Correlations between levels of NO(2) and O(3) measured in the three locations evaluated were poor. Levels of NO(2) in indoor air and personal exposure to O(3) were independently associated with asthma (both cases P=.02), pneumonia (O(3), P=.02) and wheezing at any time (both cases P<.01). No associations were seen between outdoor NO(2) and O(3) and respiratory health.

CONCLUSIONS: Exposure to higher levels of NO(2) and O(3) was associated with increased risk for asthma and pneumonia in children. Nonetheless, the place where the pollutants are measured influences the results. The measurements taken in indoor and personal exposure were the most accurate.

# Villena, G., et al. (2012). "Interferences of commercial NO2 instruments in the urban atmosphere and in a smog chamber." Atmospheric Measurement Techniques 5(1): 149-159.

Reliable measurements of atmospheric trace gases are necessary for both, a better understanding of the chemical processes occurring in the atmosphere, and for the validation of model predictions. Nitrogen dioxide (NO2) is a toxic gas and is thus a regulated air pollutant. Besides, it is of major importance for the oxidation capacity of the atmosphere and plays a pivotal role in the formation of ozone and acid precipitation. Detection of NO2 is a difficult task since many of the different commercial techniques used are affected by interferences. The chemiluminescence instruments that are used for indirect NO2 detection in monitoring networks and smog chambers use either molybdenum or photolytic converters and are affected by either positive (NOy) or negative interferences (radical formation in the photolytic converter). Erroneous conclusions on NO2 can be drawn if these interferences are not taken into consideration. In the present study, NO2 measurements in the urban atmosphere, in a road traffic tunnel and in a smog-chamber using different commercial techniques, i.e. chemiluminescence instruments with molybdenum or photolytic converters, a Luminol based instrument and a new NO2-LOPAP, were compared with spectroscopic techniques, i.e. DOAS and FTIR. Interferences of the different instruments observed during atmospheric measurements were partly characterised in more detail in the smog chamber experiments. Whereas all the commercial instruments showed strong interferences, excellent agreement was obtained between a new NO2-LOPAP instrument and the FTIR technique for the measurements performed in the smog chamber.

# Villeneuve, P. J., et al. (2007). "Outdoor air pollution and emergency department visits for asthma among children and adults: A case-crossover study in northern Alberta, Canada." Environmental Health: A Global Access Science Source 6: 40.

BACKGROUND: Recent studies have observed positive associations between outdoor air pollution and emergency department (ED) visits for asthma. However, few have examined the possible confounding influence of aeroallergens, or reported findings among very young children. METHODS: A time stratified case-crossover design was used to examine 57,912 ED asthma visits among individuals two years of age and older in the census metropolitan area of Edmonton, Canada between April 1, 1992 and March 31, 2002. Daily air pollution levels for the entire region were estimated from three fixed-site monitoring stations. Similarly, daily levels of aeroallergens were estimated using rotational impaction sampling methods for the period between 1996 and 2002. Odds ratios and their corresponding 95% confidence intervals were estimated using conditional logistic regression with adjustment for temperature, relative humidity and seasonal epidemics of viral related respiratory disease. RESULTS: Positive associations for asthma visits with outdoor air pollution levels were observed between April and September, but were absent during the remainder of the year. Effects were strongest among young children. Namely, an increase in the interquartile range of the 5-day average for NO2 and CO levels between April and September was associated with a 50% and 48% increase, respectively, in the number of ED visits among children 2 - 4 years of age (p < 0.05). Strong associations were also observed with these pollutants among those 75 years of age and older. Ozone and particulate matter were also associated with asthma visits. Air pollution risk estimates were largely unchanged after adjustment for aeroallergen levels. CONCLUSION: Our findings, taken together, suggest that exposure to ambient levels of air pollution is an important determinant of ED visits for asthma, particularly among young children and the elderly.

# Wang, M., et al. (2014). "Performance of multi-city land use regression models for nitrogen dioxide and fine particles." Environmental Health Perspectives 122(8): 843-849.

BACKGROUND: Land use regression (LUR) models have mostly been developed to explain intra-urban variations in air pollution based on often small local monitoring campaigns. Transferability of LUR models from city to city has been investigated, but little is known about the performance of models based on large numbers of monitoring sites covering a large area.

OBJECTIVES: To develop European and regional LUR models and to examine their transferability to areas not used for model development.

METHODS: We evaluated LUR models for nitrogen dioxide (NO2) and Particulate Matter (PM2.5, PM2.5 absorbance) by combining standardized measurement data from 17 (PM) and 23 (NO2) ESCAPE study areas across 14 European countries for PM and NO2. Models were evaluated with cross validation (CV) and hold-out validation (HV). We investigated the transferability of the models by successively excluding each study area from model building.

RESULTS: The European model explained 56% of the concentration variability across all sites for NO2, 86% for PM2.5 and 70% for PM2.5 absorbance. The HV R(2)s were only slightly lower than the model R(2) (NO2: 54%, PM2.5: 80%, absorbance: 70%). The European NO2, PM2.5 and PM2.5 absorbance models explained a median of 59%, 48% and 70% of within-area variability in individual areas. The transferred models predicted a modest to large fraction of variability in areas which were excluded from model building (median R(2): 59% NO2; 42% PM2.5; 67% PM2.5 absorbance).

CONCLUSIONS: Using a large dataset from 23 European study areas, we were able to develop LUR models for NO2 and PM metrics that predicted measurements made at independent sites and areas reasonably well. This finding is useful for assessing exposure in health studies conducted in areas where no measurements were conducted.

# Weil, J. C. (1992). Updating the ISC model through AERMIC. 85th Annual Meeting of Air and Waste Management Association.

# Weschler, C. J. and H. C. Shields (1997). "Potential reactions among indoor pollutants." Atmospheric Environment 31(21): 3487-3495.

#Reactions among indoor pollutants can produce products that, otherwise, might not be present in an indoor environment. To be relevant in an indoor setting, a chemical reaction must occur within a time interval shorter than or comparable to the residence time for a packet of indoor air. At typical air exchange rates, the reactions that meet this criterion include those of ozone with nitric oxide, nitrogen dioxide, and selected unsaturated hydrocarbons; thermal decomposition of peroxyacyl nitrates; numerous free radical reactions; and selected heterogeneous processes. Stable products include aldehydes, ketones, carboxylic acids and various organic nitrates. These reactions also generate free radicals, starting with the nitrate radical, Criegree biradicals, and peroxyacyl radicals, and leading to the hydroxyl, alkyl, alkylperoxy, hydroperoxy, and alkoxy radicals. Such radicals can react with other indoor species yielding additional aldehydes, ketones, carboxylic acids, dinitrates and peroxyacyl nitrates. Some of the potential products are known or suspected to be irritating (e.g. methacrolein, nonanoic acid, 1,2-propanediol dinitrate, peroxybenzoyl nitrate, and radical anions of the type (Cl ... NO-2)-). However, some of these same products are difficult to detect using the sampling and analysis techniques currently applied to indoor air.

# Wheeler, A. J., et al. (2008). "Intra-urban variability of air pollution in Windsor, Ontario - Measurement and modeling for human exposure assessment." Environmental Research 106(1): 7-16.

There are acknowledged difficulties in epidemiological studies to accurately assign exposure to air pollution for large populations, and large, long-term cohort studies have typically relied upon data from central monitoring stations. This approach has generally been adequate when populations span large areas or diverse cities. However, when the effects of intra-urban differences in exposure are being studied, the use of these existing central sites are likely to be inadequate for representing spatial variability that exists within an urban area. As part of the Border Air Quality Strategy (BAQS), an international agreement between the governments of Canada and the United States, a number of air health effects studies are being undertaken by Health Canada and the US EPA. Health Canada's research largely focuses on the chronic exposure of elementary school children to air pollution. The exposure characterization for this population to a variety of air pollutants has been assessed using land-use regression (LUR) models. This approach has been applied in several cities to nitrogen dioxide (NO2), as an assumed traffic exposure marker. However, the models have largely been developed from limited periods of saturation monitoring data and often only represent one or two seasons. Two key questions from these previous efforts, which are examined in this paper, are: If NO2 is a traffic marker, what other pollutants, potentially traffic related, might it actually represent? How well is the within city spatial variability of NO2, and other traffic-related pollutants, characterized by a single saturation monitoring campaign. Input data for the models developed in this paper were obtained across a network of 54 monitoring sites situated across Windsor, Ontario. The pollutants studied were NO2, sulfur dioxide (SO2) and volatile organic compounds, which were measured in all four seasons by deploying passive samplers for 2-week periods. Correlations among these pollutants were calculated to assess what other pollutants NO2 might represent, and correlations across seasons for a given pollutant were determined to assess how much the within-city spatial pattern varies with time. LUR models were then developed for NO2, SO2, benzene, and toluene. A multiple regression model including proximity to the Ambassador Bridge (the main Canada-US border crossing point), and proximity to highways and major roads, predicted NO2 concentrations with an R2=0.77. The SO2 model predictors included distance to the Ambassador Bridge, dwelling density within 1500m, and Detroit-based SO2 emitters within 3000m resulting in a model with an R2=0.69. Benzene and toluene LUR models included traffic predictors as well as point source emitters resulting in R2=0.73 and 0.46, respectively. Between season pollutant correlations were all significant although actual concentrations for each site varied by season. This suggests that if one season were to be selected to represent the annual concentrations for a specific site this may lead to a potential under or overestimation in exposure, which could be significant for health research. All pollutants had strong inter-pollutant correlations suggesting that NO2 could represent SO2, benzene, and toluene.

# Wichmann, J., et al. (2012). "Apparent temperature and acute myocardial infarction hospital admissions in Copenhagen, Denmark: A case-crossover study." Environmental Health: A Global Access Science Source 11(19).

BACKGROUND: The influence of temperature on acute myocardial infarction (AMI) has not been investigated as extensively as the effects of broader outcomes of morbidity and mortality. Sixteen studies reported inconsistent results and two considered confounding by air pollution. We addressed some of the methodological limitations of the previous studies in this study.

METHODS: This is the first study of the association between the daily 3-hour maximum apparent temperature (Tapp(max)) and AMI hospital admissions in Copenhagen. The study period covered 1 January 1999-31 December 2006, stratified in warm (April-September) and cold (October-March) periods. A case-crossover epidemiology study design was applied. Models were adjusted for public holidays and influenza, confounding by PM₁₀, NO₂ and CO was Investigated, the lag and non-linear effects of Tapp(max) was examined, effect modification by age, sex and SES was explored, and the results of the case-crossover models were compared to those of the generalised additive Poisson time-series and generalised estimating equation models.

RESULTS: 14,456 AMI hospital admissions (12,995 people) occurred during the study period. For an inter-quartile range (6 or 7°C) increase in the 5-day cumulative average of Tapp(max), a 4% (95% CI:-2%; 10%) and 9% (95% CI: 3%; 14%) decrease in the AMI admission rate was observed in the warm and cold periods, respectively. The 19-65 year old group, men and highest SES group seemed to be more susceptible in the cold period.

CONCLUSION: An increase in Tapp(max) is associated with a decrease in AMI admissions during the colder months.

# Williams, R., et al. (2012). "Impact of personal and ambient-level exposures to nitrogen dioxide and particulate matter on cardiovascular function." International Journal of Environmental Health Research 22(1): 71-91.

This work explored the association between nitrogen dioxide (NO(2)) and PM(2.5) components with changes in cardiovascular function in an adult non-smoking cohort. The cohort consisted of 65 volunteers participating in the US EPA's Detroit Exposure and Aerosol Research Study (DEARS) and a University of Michigan cardiovascular sub-study. Systolic and diastolic blood pressure (SBP, DBP), heart rate (HR), brachial artery diameter (BAD), brachial artery flow-mediated dilatation (FMD) and nitroglycerin-mediated arterial dilatation (NMD) were collected by in-home examinations. A maximum of 336 daily environmental and health effect observations were obtained. Daily potassium air concentrations were associated with significant decreases in DBP (-0.0447 mmHg/ng/m(3) ± 0.0132, p = 0.0016, lag day 0) among participants compliant with the personal monitoring protocol. Personal NO(2) exposures resulted in significant changes in BAD (e.g., 0.0041 mm/ppb ± 0.0019, p = 0.0353, lag day 1) and FMD (0.0612 ± 0.0235, p = 0.0103, lag day 0) among other findings.

# Williams, R., et al. (2012). "Multi-pollutant exposures in an asthmatic cohort." Atmospheric Environment 61: 244-252.

An investigation of personal fine and coarse particulate matter (PM2.5, PM10-2.5), nitrogen dioxide (NO2). and ozone (O-3) exposures was conducted with an adult asthmatic cohort as part of the U.S. Environmental Protection Agency's Moderate and Severe Asthmatics and their Environment Study (MASAES). The overall goal of the MASAES was to determine the association of particulate matter on the degree of resulting lung inflammation, with those having severe asthma hypothesized to be more highly susceptible to such outcomes. The primary exposure objective was to determine the spatial (personal versus ambient) and temporal relationships associated with the aforementioned air pollutants and establish the precision of a new dual PM2.5, PM10-2.5 monitor (CPEM) for personal exposure monitoring. A total of 16 non-smoking adults of various asthma severities were monitored over the course of a 14 month period during 2008-2009. Participants were monitored for 24 continuous hours each monitoring day with a maximum of five events per participant. Median personal PM2.5 and PM10-2.5 exposures were 16.5 and 10.1 mu g m(-3), respectively. Daily ambient mass concentrations accounted for less than 1% of the observed variability in personal PM2.5 or PM10-2.5 exposures. Duplicate personal measures yielded R-2 values of 0.92 PM2.5 and 0.77 PM10-2.5, respectively. Maximum daily personal exposures of 17.0 ppb NO2 and 21.7 ppb O-3 occurred with respective mean exposures of 5.8 and 3.4 ppb. Ambient NO2 and O-3 measures were observed to be poorly associated with personal exposures (R-2 < 0.08) when viewed independent of the participant. The poor correlation between personal and ambient concentrations of PM as well as the various gaseous copollutants indicates the complexity of the multi-pollutant environment and the impact of non-ambient sources on these pollutants relative to total personal exposures. (C) 2012 Elsevier Ltd. All rights reserved.

# Wilson, A. M., et al. (2005). "Air pollution, weather, and respiratory emergency room visits in two northern New England cities: an ecological time-series study." Environmental Research 97(3): 312-321.

Daily emergency room (ER) visits for all respiratory (ICD-9 460-519) and asthma (ICD-9 493) were compared with daily sulfur dioxide (SO2), ozone (O3), and weather variables over the period 1998-2000 in Portland, Maine (population 248,000), and 1996-2000 in Manchester, New Hampshire (population 176,000). Seasonal variability was removed from all variables using nonparametric smoothed function (LOESS) of day of study. Generalized additive models were used to estimate the effect of elevated levels of pollutants on ER visits. Relative risks of pollutants are reported over their interquartile range (IQR, the 75th -25th percentile pollutant values). In Portland, an IQR increase in SO2 was associated with a 5% (95% CI 2-7%) increase in all respiratory ER visits and a 6% (95% CI 1-12%) increase in asthma visits. An IQR increase in O3 was associated with a 5% (95% CI 1-10%) increase in Portland asthmatic ER visits. No significant associations were found in Manchester, New Hampshire, possibly due to statistical limitations of analyzing a smaller population. The absence of statistical evidence for a relationship should not be used as evidence of no relationship. This analysis reveals that, on a daily basis, elevated SO2 and O3 have a significant impact on public health in Portland, Maine.

# Wilson, K. L. and J. W. Birks (2006). "Mechanism and elimination of a water vapor interference in the measurement of ozone by UV absorbance." Environmental Science and Technology 40(20): 6361-6367.

Water vapor interference in ozone measurements by UV absorption was investigated using four different ozone monitors (TEI models 49 and 49C, Dasibi model 1003-AH, and a 2B Technologies model 202 prototype). In the extreme case of step changes between 0 and 90% relative humidity (RH), a large interference in the range of tens to hundreds of ppbv was found for all instruments tested, with the magnitude and sign depending on the manufacturer and model. Considering that water vapor does not absorb at the wavelength of the Hg lamp (253.7 nm) used in these instruments, another explanation is required. Based on experimental evidence and theoretical considerations, we conclude that the water vapor interference is caused by humidity effects on the transmission of uncollimated UV light through the detection cell. The ozone scrubber acts as a water reservoir, either adding or removing water from the air sample, thereby modulating the detector signal and producing a positive or negative offset. It was found for the 2B Technologies ozone monitor that use of a 1-m length of Nafion tubing just prior to the entrance to the detection cell reduces the water vapor interference to negligible levels (+/- 2 ppbv for step changes between 0 and 90% RH) while quantitatively passing ozone.

# Wilson, W. E., et al. (2000). "Estimating separately personal exposure to ambient and nonambient particulate matter for epidemiology and risk assessment: Why and how." Journal of the Air and Waste Management Association 50(7): 1167-1183.

U.S. Environmental Protection Agency. This paper discusses the legal and scientific reasons for separating personal exposure to PM into ambient and nonambient components. It then demonstrates by several examples how well-established models and data typically obtained in exposure field studies can be used to estimate both individual and community average expo-sure to ambient-generated PM (ambient PM outdoors plus ambient PM that has infiltrated indoors), indoor-generated PM, and personal activity PM. Ambient concentrations are not highly correlated with personal exposure to nonambient PM or total PM but are highly correlated with personal exposure to ambient-generated PM. Therefore, ambient concentrations may be used in epidemiology as an appropriate surrogate for personal exposure to ambient-generated PM. Suggestions are offered as to how exposure to ambient-generated PM may be obtained and used in epidemiology and risk assessment. Implications: Exposure analysts historically have sought to determine the total personal exposure to PM of all types in all environments. The lack of correlation between this parameter and ambient PM concentration has been considered an impediment to epidemiologic studies seeking to find an association between ambient PM concentrations and health outcomes. For community, time-series epidemiology, it is necessary only that the community average personal exposure to ambient-generated PM be correlated with the ambient PM concentration. If everyone spent the same amount of time outside and in each microenvironment each day, and the air exchange rate and any forced-air ventilation that resulted in particle removal was a constant, and PM concentrations were uniform across the community, a high correlation would be expected between the PM concentration measured by a community-based PM monitor and the personal exposure of each individual to ambient-generated PM. Also, a high correlation would be expected between ambient concentration and the exposure surrogate of interest in epidemiology, the community average personal exposure to ambient-generated PM. For short-term panel studies, time-series should be determined for all classes of PM. For cohort studies of long-term effects, consideration must be given to the influence of possible variations in exposures to nonambient-generated PM because of differences among cities in time-location patterns (fractions of time spent outdoors), average air exchange rates, and average concentrations of indoor-generated and personal activity PM.

# Wilson, W. E. and H. H. Suh (1997). "Fine particles and coarse particles: Concentration relationships relevant to epidemiologic studies." Journal of the Air and Waste Management Association 47(12): 1238-1249.

Fine particles and coarse particles are defined in terms of the modal structure of particle size distributions typically observed in the atmosphere. Differences between the various modes are discussed. The fractions of fine and coarse particles collected in specific size ranges, such as total suspended particulate matter (TSP), PM10, PM2.5, and PM(10-2.5), are shown. Correlations of 24-h concentrations of PM2.5, PM10, and PM(10-2.5) at the same site show that, in Philadelphia and St. Louis, PM2.5 is highly correlated with PM10 but poorly correlated with PM(10-2.5). Among sites distributed across these urban areas, the site-to-site correlations of 24-h PM concentrations are high for PM2.5 but not for PM(10-2.5). This indicates that a PM measurement at a central monitor can serve as a better indicator of the community-wide concentration of fine particles than of coarse particles. The fraction of ambient outdoor particles found suspended indoors is greater for fine particles than for coarse particles because of the difference in indoor lifetimes. Consideration of these relationships leads to the hypothesis that the statistical associations found between daily PM indicators and health outcomes may be the result of variations in the fine particle component of the atmospheric aerosol, not of variations in the coarse component. As a result, epidemiologic studies using PM10 or TSP may provide more useful information on the acute health effects of fine particles than coarse particles. Fine and coarse particles are separate classes of pollutants and should be measured separately in research and epidemiologic studies. PM2.5 and PM(10-2.5) are indicators or surrogates, but not measurements, of fine and coarse particles.

# Winer, A. M., et al. (1974). "Response of commercial chemiluminescent NO-NO2 analyzers to other nitrogen-containing compounds." Environmental Science and Technology 8(13): 1118-1121.

##Commercial chemiluminescent oxides of nitrogen analyzers employing carbon or molybdenum converters are nonspecific for determination of nitrogen dioxide (NO/sub 2/). The instruments not only measure NO/sub 2/, but also simultaneously respond nearly quantitatively to peroxyacetyl nitrate (PAN), and a variety of other organic nitrates and nitrites. Furthermore, they respond nonquantitatively to compounds such as nitroethane and nitric acid. The implications of these observations are not serious for most ambient air analyses where the concentrations of the interfering nitrogenous compounds are low relative to NO/sub 2/ levels. However, for highly quantitative ambient air or smog chamber measurements under circumstances where relatively low concentrations of NO/sub 2/ occur simultaneously with high concentrations of PAN and other nitrogen-containing compounds, corrections for interference by these compounds can be significant. In the absence of such corrections, the NO/sub x/ mode of commercial chemiluminescent analyzers must be viewed to the good approximation as measuring total gas phase 'oxides of nitrogen,' not simply the sum of NO and NO/sub 2/.

# Winquist, A., et al. (2014). "Joint effects of ambient air pollutants on pediatric asthma emergency department visits in Atlanta, 1998-2004." Epidemiology 25(5): 666-673.

BACKGROUND: Because ambient air pollution exposure occurs as mixtures, consideration of joint effects of multiple pollutants may advance our understanding of the health effects of air pollution.

METHODS: We assessed the joint effect of air pollutants on pediatric asthma emergency department visits in Atlanta during 1998-2004. We selected combinations of pollutants that were representative of oxidant gases and secondary, traffic, power plant, and criteria pollutants, constructed using combinations of criteria pollutants and fine particulate matter (PM2.5) components. Joint effects were assessed using multipollutant Poisson generalized linear models controlling for time trends, meteorology, and daily nonasthma upper respiratory emergency department visit counts. Rate ratios (RRs) were calculated for the combined effect of an interquartile range increment in each pollutant's concentration.

RESULTS: Increases in all of the selected pollutant combinations were associated with increases in warm-season pediatric asthma emergency department visits (eg, joint-effect RR = 1.13 [95% confidence interval = 1.06-1.21] for criteria pollutants, including ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, and PM2.5). Cold-season joint effects from models without nonlinear effects were generally weaker than warm-season effects. Joint-effect estimates from multipollutant models were often smaller than estimates based on single-pollutant models, due to control for confounding. Compared with models without interactions, joint-effect estimates from models including first-order pollutant interactions were largely similar. There was evidence of nonlinear cold-season effects.

CONCLUSIONS: Our analyses illustrate how consideration of joint effects can add to our understanding of health effects of multipollutant exposures and also illustrate some of the complexities involved in calculating and interpreting joint effects of multiple pollutants.

# Woodruff, T. J., et al. (2008). "Air pollution and postneonatal infant mortality in the United States, 1999-2002." Environmental Health Perspectives 116(1): 110-115.

OBJECTIVE: Our goal was to evaluate the relationship between cause-specific postneonatal infant mortality and chronic early-life exposure to particulate matter and gaseous air pollutants across the United States. METHODS: We linked county-specific monitoring data for particles with aerodiameter of < or = 2.5 microm (PM2.5) and < or = 10 microm (PM10), ozone, sulfur dioxide, and carbon monoxide to birth and death records for infants born from 1999 to 2002 in U.S. counties with > 250,000 residents. For each infant, we calculated the average concentration of each pollutant over the first 2 months of life. We used logistic generalized estimating equations to estimate odds ratios of postneonatal mortality for all causes, respiratory causes, sudden infant death syndrome (SIDS), and all other causes for each pollutant, controlling for individual maternal factors (race, marital status, education, age, and primiparity), percentage of county population below poverty, region, birth month, birth year, and other pollutants. This analysis includes about 3.5 million births, with 6,639 postneonatal infant deaths. RESULTS: After adjustment for demographic and other factors and for other pollutants, we found adjusted odds ratios of 1.16 [95% confidence interval (CI), 1.06-1.27] for a 10-mug/m3 increase in PM10 for respiratory causes and 1.20 (95% CI, 1.09-1.32) for a 10-ppb increase in ozone and deaths from SIDS. We did not find relationships with other pollutants and for other causes of death (control category). CONCLUSIONS: This study supports particulate matter air pollution being a risk factor for respiratory-related postneonatal mortality and suggests that ozone may be associated with SIDS in the United States.

# Wu, J., et al. (2011). "Comparing exposure assessment methods for traffic-related air pollution in an adverse pregnancy outcome study." Environmental Research 111(5): 685-692.

Previous studies reported adverse impacts of traffic-related air pollution exposure on pregnancy outcomes. Yet, little information exists on how effect estimates are impacted by the different exposure assessment methods employed in these studies.

To compare effect estimates for traffic-related air pollution exposure and preeclampsia, preterm birth (gestational age less than 37 weeks), and very preterm birth (gestational age less than 30 weeks) based on four commonly used exposure assessment methods.

We identified 81,186 singleton births during 1997-2006 at four hospitals in Los Angeles and Orange Counties, California. Exposures were assigned to individual subjects based on residential address at delivery using the nearest ambient monitoring station data [carbon monoxide (CO), nitrogen dioxide (NO(2)), nitric oxide (NO), nitrogen oxides (NO(x)), ozone (O(3)), and particulate matter less than 2.5 (PM(2.5)) or less than 10 (PM(10)) μm in aerodynamic diameter], both unadjusted and temporally adjusted land-use regression (LUR) model estimates (NO, NO(2), and NO(x)), CALINE4 line-source air dispersion model estimates (NO(x) and PM(2.5)), and a simple traffic-density measure. We employed unconditional logistic regression to analyze preeclampsia in our birth cohort, while for gestational age-matched risk sets with preterm and very preterm birth we employed conditional logistic regression.

We observed elevated risks for preeclampsia, preterm birth, and very preterm birth from maternal exposures to traffic air pollutants measured at ambient stations (CO, NO, NO(2), and NO(x)) and modeled through CALINE4 (NO(x) and PM(2.5)) and LUR (NO(2) and NO(x)). Increased risk of preterm birth and very preterm birth were also positively associated with PM(10) and PM(2.5) air pollution measured at ambient stations. For LUR-modeled NO(2) and NO(x) exposures, elevated risks for all the outcomes were observed in Los Angeles only-the region for which the LUR models were initially developed. Unadjusted LUR models often produced odds ratios somewhat larger in size than temporally adjusted models. The size of effect estimates was smaller for exposures based on simpler traffic density measures than the other exposure assessment methods.

We generally confirmed that traffic-related air pollution was associated with adverse reproductive outcomes regardless of the exposure assessment method employed, yet the size of the estimated effect depended on how both temporal and spatial variations were incorporated into exposure assessment. The LUR model was not transferable even between two contiguous areas within the same large metropolitan area in Southern California.

# Xu, X., et al. (2014). "Ambient air pollution and hypertensive disorder of pregnancy." Journal of Epidemiology and Community Health 68(1): 13-20.

BACKGROUND: Ambient air pollution has been implicated in the development of hypertensive disorders of pregnancy (HDP). However, evidence of the association between air pollution and HDP is still limited, and the effects of gaseous air pollutants on HDP and their time windows of exposure have not been well studied.

METHODS: We used the Florida birth registry data to investigate the associations between air pollutants (NO2, SO2, PM(2.5), O3 and CO) and the risks of HDP in 22,041 pregnant women in Jacksonville, Florida, USA from 2004 to 2005. Further, we examined whether air pollution exposure during different time windows defined by trimesters and the entire pregnancy had different effects on HDP.

RESULTS: The single-pollutant logistic regression model showed that exposure to four pollutants during the full pregnancy period was significantly associated with prevalence of HDP after adjusting for covariates: NO2 (OR=1.21, 95% CI 1.09 to 1.35), PM2.5 (OR=1.24, 95% CI 1.08 to 1.43), SO2 (OR=1.13, 95% CI 1.01 to 1.25) and CO (OR=1.12, 95% CI 1.03 to 1.22) per IQR increase. Similar effects were observed when first trimester exposure to NO2, SO2 and CO, and second trimester exposures to PM2.5 were examined. Consistent results were confirmed in multiple-pollutant models.

CONCLUSIONS: This study suggests that exposure to high levels of air pollution during early pregnancy and the full gestational period was associated with increased prevalence of HDP in Florida, USA.

# Xue, J., et al. (2005). "Parameter evaluation and model validation of ozone exposure assessment using Harvard Southern California Chronic Ozone Exposure Study data." Journal of the Air and Waste Management Association 55(10): 1508-1515.

To examine factors influencing long-term ozone (O3) exposures by children living in urban communities, the authors analyzed longitudinal data on personal, indoor, and outdoor O3 concentrations, as well as related housing and other questionnaire information collected in the one-year-long Harvard Southern California Chronic Ozone Exposure Study. Of 224 children contained in the original data set, 160 children were found to have longitudinal measurements of O3 concentrations in at least six months of 12 months of the study period. Data for these children were randomly split into two equal sets: one for model development and the other for model validation. Mixed models with various variance-covariance structures were developed to evaluate statistically important predictors for chronic personal ozone exposures. Model predictions were then validated against the field measurements using an empirical best-linear unbiased prediction technique. The results of model fitting showed that the most important predictors for personal ozone exposure include indoor O3 concentration, central ambient O3 concentration, outdoor O3 concentration, season, gender, outdoor time, house fan usage, and the presence of a gas range in the house. Hierarchical models of personal O3 concentrations indicate the following levels of explanatory power for each of the predictive models: indoor and outdoor O3 concentrations plus questionnaire variables, central and indoor O3 concentrations plus questionnaire variables, indoor O3 concentrations plus questionnaire variables, central O3 concentrations plus questionnaire variables, and questionnaire data alone on time activity and housing characteristics. These results provide important information on key predictors of chronic human exposures to ambient O3 for children and offer insights into how to reliably and cost-effectively predict personal O3 exposures in the future. Furthermore, the techniques and findings derived from this study also have strong implications for selecting the most reliable and cost-effective exposure study design and modeling approaches for other ambient pollutants, such as fine particulate matter and selected urban air toxics.

# Yang, C. Y., et al. (2003). "Effects of air pollution on birthweight among children born between 1995 and 1997 in Kaohsiung, Taiwan." Journal of Toxicology and Environmental Health, Part A: Current Issues 66(9): 807-816.

Recent studies have suggested that exposure to air pollution might be associated with low birth weight. The effects of sulfur dioxide (SO(2)) and particulate matter less than 10 microm (PM(10)) were examined on birth weight in each trimester of pregnancy. The study group included all full-term singleton live births during 1995-1997 to women living within about 2 km of an air pollution monitoring site in Kaohsiung. Measurements of SO(2) and PM(10) collected at six air quality monitoring stations were used to estimate the influence of exposures on different pregnancy trimesters. This was done by averaging daily ambient air pollution concentrations during the corresponding days based on the birth date and gestational age of each child. Multiple linear regression analysis was used to estimate the effects of air pollution on birth weight adjusting for possible confounders including maternal age, season, marital status, maternal education, and infant gender. The estimated reduction in birth weight was 0.52 g for 1 microg/m (3) increase in either SO(2) or PM(10) in the first trimester of pregnancy. Data provide further support for the hypothesis that air pollution can affect the outcome of pregnancy.

# Yang, Q., et al. (2003). "Association between ozone and respiratory admissions among children and the elderly in Vancouver, Canada." Inhalation Toxicology 15(13): 1297-1308.

In this study, we examine the impact of ozone on daily respiratory admissions in both young children and the elderly in greater Vancouver, British Columbia. Study subjects included children less than 3 yr of age and adults 65 yr of age or over living in greater Vancouver who had acute hospital admissions for any respiratory diseases (ICD-9 codes 460-519) during the 13-yr period 1986-1998. Bidirectional case-crossover analysis was used to investigate associations between ambient ozone and respiratory hospitalizations after adjustment for other pollutants, including carbon monoxide, nitrogen dioxide, sulfur dioxide, and coefficient of haze. Potential effect modification by socioeconomic status as measured by household income was also examined. Respiratory admissions were associated with ozone levels 2, 3, 4, and 5 days prior to admission in both children and the elderly, with the strongest association observed at a lag of 4 days. Odds ratios for hospital admission of 1.22 (95% CI: 1.15-1.30) for children and 1.13 (1.09-1.18) for the elderly, respectively, were found, based on an increment in exposure corresponding to the interquartile range for ozone. Adjusting for other pollutants did not attenuate the ozone effect on respiratory admissions. Nor did socioeconomic status appear to modify the association between ozone and respiratory admissions in either children or the elderly. We concluded that ambient ozone is positively associated with respiratory hospital admission among young children and the elderly in Vancouver, British Columbia. These associations persisted after adjustment for both copollutant exposures and socioeconomic status.

# Zeger, S. L., et al. (2000). "Exposure measurement error in time-series studies of air pollution: Concepts and consequences." Environmental Health Perspectives 108(5): 419-426.

Misclassification of exposure is a well-recognized inherent limitation of epidemiologic studies of disease and the environment. For many agents of interest, exposures take place over time and in multiple locations; accurately estimating the relevant exposures for an individual participant in epidemiologic studies is often daunting, particularly within the limits set by feasibility, participant burden, and cost. Researchers have taken steps to deal with the consequences of measurement error by limiting the degree of error through a study's design, estimating the degree of error using a nested validation study, and by adjusting for measurement error in statistical analyses. In this paper, we address measurement error in observational studies of air pollution and health. Because measurement error may have substantial implications for interpreting epidemiologic studies on air pollution, particularly the time-series analyses, we developed a systematic conceptual formulation of the problem of measurement error in epidemiologic studies of air pollution and then considered the consequences within this formulation. When possible, we used available relevant data to make simple estimates of measurement error effects. This paper provides an overview of measurement errors in linear regression, distinguishing two extremes of a continuum-Berkson from classical type errors, and the univariate from the multivariate predictor case. We then propose one conceptual framework for the evaluation of measurement errors in the log-linear regression used for time-series studies of particulate air pollution and mortality and identify three main components of error. We present new simple analyses of data on exposures of particulate matter < 10 "mu"m in aerodynamic diameter from the Particle Total Exposure Assessment Methodology Study. Finally, we summarize open questions regarding measurement error and suggest the kind of additional data necessary to address them.

# Zhao, Q. G., et al. (2011). "Effects of air pollution on neonatal prematurity in Guangzhou of China: A time-series study." Environmental Health: A Global Access Science Source 10(2).

Background: Over the last decade, a few studies have investigated the possible adverse effects of ambient air pollution on preterm birth. However, the correlation between them still remains unclear, due to insufficient evidences. Methods: The correlation between air pollution and preterm birth in Guangzhou city was examined by using the Generalized Additive Model (GAM) extended Poisson regression model in which we controlled the confounding factors such as meteorological factors, time trends, weather and day of the week (DOW). We also adjusted the co linearity of air pollutants by using Principal Component Analysis. The meteorological data and air pollution data were obtained from the Meteorological Bureau and the Environmental Monitoring Centre, while the medical records of newborns were collected from the perinatal health database of all obstetric institutions in Guangzhou, China in 2007. Results: In 2007, the average daily concentrations of NO(2), PM(10) and SO(2) in Guangzhou, were 61.04, 82.51 and 51.67 mu g/m(3) respectively, where each day an average of 21.47 preterm babies were delivered. Pearson correlation analysis suggested a negative correlation between the concentrations of NO(2), PM(10), SO(2), and temperature as well as relative humidity. As for the time-series GAM analysis, the results of single air pollutant model suggested that the cumulative effects of NO(2), PM(10) and SO(2) reached its peak on day 3, day 4 and day 3 respectively. An increase of 100 mu g/m(3) of air pollutants corresponded to relative risks (RRs) of 1.0542 (95%CI: 1.0080 similar to 1.1003), 1.0688 (95%CI: 1.0074 similar to 1.1301) and 1.1298 (95%CI: 1.0480 similar to 1.2116) respectively. After adjusting co linearity by using the Principal Component Analysis, the GAM model of the three air pollutants suggested that an increase of 100 mu g/m(3) of air pollutants corresponded to RRs of 1.0185 (95%CI: 1.0056 similar to 1.0313), 1.0215 (95%CI: 1.0066 similar to 1.0365) and 1.0326 (95%CI: 1.0101 similar to 1.0552) on day 0; and RRs of the three air pollutants, at their strongest cumulative effects, were 1.0219 (95%CI: 1.0053 similar to 1.0386), 1.0274 (95%CI: 1.0066 similar to 1.0482) and 1.0388 (95%CI: 1.0096 similar to 1.0681) respectively. Conclusions: This study indicates that the daily concentrations of air pollutants such as NO(2), PM(10) and SO(2) have a positive correlation with the preterm births in Guangzhou, China.

# Zheng, S., et al. (2013). "Short-term effects of gaseous pollutants and particulate matter on daily hospital admissions for cardio-cerebrovascular disease in Lanzhou: Evidence from a heavily polluted city in China." International Journal of Environmental Research and Public Health 10(2): 462-477.

Panel studies show a consistent association between increase in the cardiovascular hospitalizations with air pollutants in economically developed regions, but little evidence in less developed inland areas. In this study, a time-series analysis was used to examine the specific effects of major air pollutants [particulate matter less than 10 microns in diameter (PM(10)), sulfur dioxide (SO(2)), and nitrogen dioxides (NO(2))] on daily hospital admissions for cardio-cerebrovascular diseases in Lanzhou, a heavily polluted city in China. We examined the effects of air pollutants for stratified groups by age and gender, and conducted the modifying effect of seasons on air pollutants to test the possible interaction. The significant associations were found between PM(10), SO(2) and NO(2) and cardiac disease admissions, SO(2) and NO(2) were found to be associated with the cerebrovascular disease admissions. The elderly was associated more strongly with gaseous pollutants than younger. The modifying effect of seasons on air pollutants also existed. The significant effect of gaseous pollutants (SO(2) and NO(2)) was found on daily hospital admissions even after adjustment for other pollutants except for SO(2) on cardiac diseases. In a word, this study provides the evidence for the detrimental short-term health effects of urban gaseous pollutants on cardio-cerebrovascular diseases in Lanzhou.