APPENDIX AVAILABLE ON REQUEST

Special Report 17

Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects

Chapter 3. Assessment of Exposure to Traffic-Related Air Pollution

HEI Panel on the Health Effects of Traffic-Related Air Pollution

Appendix B. Table 3.B. Summary of Measures of Surrogates of Exposure to Traffic-Related Pollutants in Some Epidemiologic Studies

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APPENDIX B. Table 3.B. Summary of measures of surrogates of exposure to traffic-related pollutants in some epidemiologic studies

Citation Study Location	CO	NO_2	PM_{10}	$PM_{2.5}$	EC (BC)	Other	Pollutant measured & time period	Traffic measure	Health outcome and approach for estimating exposure to traffic pollution
Central and Other Fixed Monitoring Sites and Traffic Measures									
(Gehring et al 2006) North Rhine-Westphalia, Germany		X	X (from TSP)				Central sites' measurements. One year and 5 year averages.	Proximity of residence to major road (>10,000 cars/day).	Respiratory symptoms in children. Exposure to traffic estimated using the traffic proximity measure. In some models the proximity to road effects were adjusted for the NO_2 effects and vice versa.
(Gold et al 2005) Boston, Massachusetts	X	X		X	X	SO_2	Fixed site within 0.5 km of the subjects' residences for CO, $PM_{2.5}$, and BC; central state monitoring site for SO_2, O_3, and NO_2. Daily measurements.		ST-segment depression in elderly. Exposure estimated using 5-hr and 12-hr daily pollutant concentrations. BC used a surrogate for traffic pollution.
(Lipfert et al 2006) United States	X	X		X	X	SO_2 ozone sulfate $PM_{2.5-10}$	Annual summaries of EPA air quality and speciation data.	Population and housing density by zip-code; annual average vehicular traffic density (annual vehicle km traveled/unit of land) by county.	Mortality. Exposure estimated using each density measure alone or in joint regression models. Some analyses restricted to counties with NO_2 data.
(Schikowski et al 2005) North-Rhine Westphalia, Germany		X	X (from TSP)				Central monitoring stations from State Environment Agency (N=7) each located within a 8 km grid. Annual mean concentrations and 5 year average for long-term exposure were derived.	Proximity of residence to nearest major road (>10,000 cars/day) dichotomized as <100 m versus $\geq$ 100 m.	Lung function and chronic respiratory symptoms. Exposure estimated using traffic proximity measure.
(Schwartz et al 2005) Boston, Massachusetts	X	X		X	X	SO_2 ozone, secondary $PM_{2.5}$	Fixed sites within 1 km of residence for CO, $PM_{2.5}$, BC; central monitoring sites for NO_2, SO_2, and ozone. Daily measurements. Secondary $PM_{2.5}$ estimated by regressing BC against $PM_{2.5}$.		Heart rate variability in elderly. Exposure estimated using 1-hr and 24-hr average pollutant concentrations. BC used a surrogate for traffic pollution.

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(Roemer and van Wijnen, 2001) Amsterdam, the Netherlands	X	X	X (from TSP)		X	SO_2 NO, ozone	Central monitoring measurements at urban background and traffic-influenced sites. Daily averages.	Population stratified as living along roads with >10,000 vehicles (traffic population) or as living along roads with fewer vehicles.	Mortality. Exposure estimated as pollutant concentration at traffic sites or background sites for total population and population stratified by traffic density.
Mobile Monitoring									
(Adar et al 2007) St. Louis, Missouri				X	X	PM number	Measurements from continuous sampling by a mobile cart during trips in diesel bus, various activities, and in living facilities for 48 hours.		Heart rate variability in elderly. Exposure estimated as 5-, 30-, 60-minutes, and 4- or 24-hour moving averages of pollutant concentrations and by location (ie, on the bus and off the bus).
(Hirsch et al 1999) Dresden, Germany	X	X				SO_2 benzene ozone	Measurements at monitoring stations, within a 1x1 km grid, placed on caravans in each of the 182 grid points (29 in dense traffic); 0.5 hour samples were collected every two weeks for a year (total 26 values per site). For a subset of grids, samples were taken at each corner of the grid.		Respiratory and allergic symptoms in children. Exposure estimated at home address and school location based on the annual mean of the pollutant concentrations at the nearest monitoring station in each of the 4 geographical directions. The four values, weighted by the inverse of the square of their distance to the address, were averaged (for each pollutant). Benzene was used as the surrogate for exposure to traffic pollution.
(Sekine et al 2004) Tokyo, Japan		X	X				Measurements from monitoring stations at 0 m and 20 m from edge of trunk roads with varying amounts of traffic (8,000-32,000 vehicles/12 hr) sampling for 3 consecutive days every month from 1987-1994.	Traffic density on trunk roads (1990 data).	Pulmonary function in women. Subjects grouped into three exposure groups based on average pollutant concentrations and traffic density.

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Modeled Exposures									
(Beelen et al 2008 and 2007; Brauer et al 2003) The Netherlands		X			X	SO_2 NO	Central monitoring measurements at regional background sites used to estimate regional background concentrations (by distance weighting); measurements at urban monitoring sites used to estimate urban background by regression with estimated regional background (and predictors variables such as locations of the monitors, address density); sum of the measurements = background. Local traffic contribution estimated from 40 monitoring sites' measurements of NO_2, $PM_{2.5}$, and BC, after subtracting the background component, in regression models with the sum of traffic intensity a buffer of 100m as predictor (as in Brauer 2002 and 2003). Data averaged over 5-year periods.	Traffic density on nearest road; sum of traffic density in a 100 m radius; proximity of residence to a motorway (<100 m) or to a local road with >10,000 vehicles/day (<50 m).	All-cause, cardiopulmonary, and cancer mortality. Exposure to traffic-pollution was assessed primarily using the traffic measures at the home address.
(Brauer et al 2002) The Netherlands		X		X	X		Measurements at 40 individual sites chosen to capture variability in pollution from traffic modeled at the residence using GIS traffic variables (# of high traffic roads within 250 m of home and medium traffic roads within 1000 m radius) at the subjects' residences. Measurements taken for four 2-week periods for one year.		Asthma, respiratory symptoms, and allergies in children. Exposure to traffic estimated as the modeled concentrations NO_2, $PM_{2.5}$, and EC at the residence.

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(Brauer et al 2006) The Netherlands & Munich, Germany		X		X	X		Measurements at 40 sites (as in Gehring et al 2002) modeled at the residence using GIS traffic variables for each home (traffic, population, and building densities within a buffer around the residence, distance of residence to major roads).		Otitis media in children. Exposure to traffic estimated as the modeled concentrations NO_2, $PM_{2.5}$, and EC at the residence.
(Hoek et al 2002 and 2001) The Netherlands		X			X		Same as Beelen et al 2008 for regional and urban background concentrations estimates. Local traffic contribution to pollutants estimated using spatial measurements of NO_2 and BC (Roorda-Knape et1998) weighted based on distance of the residence to a major road and time downwind.	Proximity of residence to freeway (<100 m) and to major road (< 50 m).	All-cause mortality. Long-term cumulative exposure estimated at the residence based urban background + local concentrations of traffic-related NO_2 or EC or the proximity to road measure.
(Gehring et al 2002) Munich, Germany		X		X	X		Measurements at 40 individual sites chosen to capture variability in pollution from traffic modeled at the residence using GIS traffic variables (traffic, heavy vehicle, household, and population densities) at the subjects' residences. Measurements taken for four 2-week periods for one year.		Respiratory symptoms. Exposure to traffic estimated as the modeled concentrations NO_2, $PM_{2.5}$, and EC at the residence .

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Citation Study Location	CO	NO_2	PM_{10}	$PM_{2.5}$	EC (BC)	Other	Pollutant measured & time period	Traffic measure	Health outcome and approach for estimating exposure to traffic pollution
(Morgenstern et al 2006) Munich, Germany		X		X	X		Same as Gehring et al 2002 for measurements. Estimates of pollution from traffic at the residence made using GIS traffic variables (distance of residence to nearest motorway, land use coverage, population density, and length of rural roads within buffer).	Distance of residence to nearest main road (<50 m versus >50 m).	Development of asthma and allergy. Exposure to traffic estimated as the modeled concentrations NO_2, $PM_{2.5}$, and EC at the residence or the traffic measure.
(Nicolai et al 2003) Munich, Germany		X			X	benzene	Measurements at 18 heavy traffic site and 16 low-to-medium traffic sites modeled using car-traffic counts and a weighting function, to account for the distance between measurement point and street, together with street characteristics (% of time with stop-and-go conditions in the segment).	GIS traffic variables: average daily traffic counts for all roads within 50 m, >50 m to 300 m, and >300 m to the subjects' residences.	Lung function and airway responsiveness in children. Exposure estimated based on modeled pollutant concentrations at the home (as low, medium and high) or volume of vehicles (low, medium, high) ≤ 50 m from the home versus rest of population to those with no traffic counts within 300 m of the residence.
(Rosenlund et al 2006) Stockholm, Sweden	X	X	X	X		SO_2 NO_x	Source-specific concentrations at the homes (specifically traffic and heating) estimated from a dispersion model using emissions databases for different sources and geographic coordinates.		Acute myocardial infarction Exposure estimated as mean exposure over 30 years at the home addresses. NO_2, CO, and PM_{10} were used as surrogates of exposure to traffic pollution, SO_2 as a surrogate for heating sources.
Integrated Measure (Passive Monitoring)									
(Sunyer et al 2006) 21 European cities (10 countries)		X		X			Central site measurements every second day for 2 weeks each month for 18 months in each city (annual mean). Measurement of NO_2 outside and inside each home for 2 weeks (annual mean).	Self-reported traffic intensity (cars, buses, or trucks). Categories: never, seldom, frequent, constant.	Prevalence and incidence of bronchitis in adults. Exposure estimated based on NO_2 measurements outside the residences or self-reported traffic intensity.

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Citation Study Location	CO	NO_2	PM_{10}	$PM_{2.5}$	EC (BC)	Other	Pollutant measured & time period	Traffic measure	Health outcome and approach for estimating exposure to traffic pollution
(Gauderman et al 2005) 10 Southern California communities		X					Measurements outside the homes for two 2-week periods (summer & fall). Modeled concentrations at the homes using a dispersion model (CALINE) that incorporated distance to roadways, vehicle counts, vehicle emission rates, and meteorologic conditions.	Distance of residence to nearest freeway; annual average vehicle number on roads <150m from the residence.	Asthma and wheeze in children. Exposure estimated using each of the four approaches, that is measured or modeled NO_2 concentration, distance to freeway, or traffic density.
Combination of Passive (Integrated) Monitoring + Modeling									
(Kramer et al 2000) West Germany		X					1) Personal monitoring. 2) Stationary monitoring at 158 sampling points with 150-200m spatial resolution interpolated to derive concentrations at each home; 3) Stationary monitor measurements in four microenvironments (in homes and schools, outside homes, and near main roads) combined with time-activity diaries to obtain an indirect measure of personal exposure. All samples were collected during a 1-week period in different seasons.	Traffic counts on main roads to create a traffic index (0=suburban, 1=urban; + 1 to index if 2000-25000 vehicles or +2 if >25000 vehicles).	Atopic sensitization and allergy symptoms in children. Exposure estimated as the time weighted average of the NO_2 concentration outside the residence as in (2), as the personal exposure calculated as in (3) or as traffic counts for the urban and the total (urban plus suburban) populations. Correlations between these concentrations and the traffic index were estimated.
(Zmirou et al 2004) Five cities in France		X		X		NO	Fixed site monitoring measurement used to derive annual outdoor background concentrations.	Traffic exposure estimated as the ratio of the yearly average traffic density with the distance of the road to the home and school (for the nearest major road within 300 m of each address).	Incidence of asthma in children. Lifetime exposure estimated using the traffic metric [(vehicle/day)/m] by tertile.

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Surrogate Measure for Traffic									
(Bayer-Oglesby et al 2006) Switzerland								Distance (by GIS) of each home to the nearest major road or highway within a 200 m buffer and road length within the buffer.	Reported respiratory symptoms in adults. Exposure estimated based on either distance or road length.
(Yang et al 2002) Taiwan		X					Monitors placed in school.	Children attending a school located within 150 m from a highway and living within 500 m of the same highway (compared to children attending a school within 1500 m from the highway and living at 1000 to 2000 m from the highway).	Reported respiratory symptoms in children. Exposure estimated based on location of school relative to highway.

REFERENCES

Adar SD, Gold DR, Coull BA, Schwartz J, Stone PH and Suh H. 2007. Focused exposures to airborne traffic particles and heart rate variability in the elderly. Epidemiology 18:95-103.

Bayer-Oglesby L, Schindler C, Hazenkamp-von Arx ME, Braun-Fahrländer C, Keidel D, Rapp R, Künzli N, Braendli O, Burdet L, Liu SL-J, Leuenberger P and Ackermann-Liebrich U. 2006. Living near main streets and respiratory symptoms in adults: The swiss cohort study on air pollution and lung diseases in adults. Am J Epidemiol 164:1190-1198.

Beelen R, Hoek G, Fischer P, van den Brandt PA and Brunekreef B. 2007. Estimated long-term outdoor air pollution concentrations in a cohort study. Atmos Environ 41:1343-1358.

Beelen R, Hoek G, van den Brandt PA, Goldbohm RA, Fischer P, Schouten LJ, Jerrett M, Hughes E, Armstrong B and Brunekreef B. 2008. Long-term effects of traffic-related air pollution on mortality in a Dutch cohort (NLCS-AIR study). Environ Health Perspect 116:196-202.

Brauer M, Gehring U, Brunekreef B, de Jongste JC, Gerritsen J, Rovers M, Wichmann HE, Wijga A and Heinrich J. 2006. Traffic-related air pollution and otitis media. Environ Health Perspect 114:1414-1418.

Brauer M, Hoek G, van Vliet P, Meliefste K, Fischer P, Gehring U, Heinrich J, Cyrys J, Bellander T, Lewné M and Brunekreef B. 2003. Estimating long-term average particulate air pollution concentrations: Application of traffic indicators and geographic information systems. Epidemiology 14:228-239.

Brauer M, Hoek G, van Vliet P, Meliefste K, Fischer PH, Wijga A, Koopman LP, Neijens HJ, Gerritsen J, Kerkhof M, Heinrich J, Bellander T and Brunekreef B. 2002. Air pollution from traffic and the development of respiratory infections and asthmatic and allergic symptoms in children. Am J Respir Crit Care Med 166:1092-1098.

Gauderman WJ, Avol E, Lurmann F, Künzli N, Gilliland F, Peters J and McConnell R. 2005. Childhood asthma and exposure to traffic and nitrogen dioxide. Epidemiology 16:737-743.

Gehring U, Cyrys J, Sedlmeir G, Brunekreef B, Bellander T, Fischer P, Bauer CP, Reinhardt D, Wichmann HE and Heinrich J. 2002. Traffic-related air pollution and respiratory health during the first 2 yrs of life. Eur Respir J 19:690-698.

Gehring U, Heinrich J, Krämer U, Grote V, Hochadel M, Sugiri D, Kraft M, Rauchfuss K, Eberwein HG and Weichmann HE. 2006. Long-term exposure to ambient air pollution and cardiopulmonary mortality in women. Epidemiology 17:545-551.

Gold DR, Litonjua AA, Zanobetti A, Coull BA, Schwartz J, MacCallum G, Verrier RL, Nearing BD, Canner MJ, Suh H and Stone PH. 2005. Air pollution and ST-segment depression in elderly subjects. Environ Health Perspect 113:883-887.

Hirsch T, Weiland SK, von Mutius E, Safeca AF, Gräfe H, Csaplovics E, Duhme H, Keil U and Leupold W. 1999. Inner city air pollution and respiratory health and atopy in children. Eur Respir J 14:669-677.

Hoek G, Brunekreef B, Goldbohm S, Fischer P and van den Brandt PA. 2002. Association between mortality and indicators of traffic-related air pollution in the Netherlands: A cohort study. Lancet 360:1203-1209.

Hoek G, Fischer P, nan den Brandt P, Goldbohm S and Brunekreef B. 2001. Estimation of long-term average exposure to outdoor air pollution for a cohort study on mortality. J Expo Anal Environ Epidemiol 11:459-469.

Krämer U, Koch T, Ranft U, Ring J and Behrendt H. 2000. Traffic-related air pollution is associated with atopy in children living in urban areas. Epidemiology 11:64-70.

Lipfert FW, Baty JD, Miller JP and Wyzga RE. 2006. PM2.5 constitutents and related air quality variables as predictors of survival in a cohort of U.S.military veterans. Inhal Toxicol 18:646-657.

Morgenstern V, Cyrys J, Zutavern A, Wichmann HE and Heinrich J. 2006. Traffic-related air pollution and respiratory health during the first 2 years using an extended GIS-based exposure model. Epidemiology 17:S285.

Nicolai T, Carr D, Weiland SK, Duhme H, von Ehrenstein O, Wagner C and von Mutius E. 2003. Urban traffic and pollutant exposure related to respiratory outcomes and atopy in a large sample of children. Eur Respir J 21:956-963.

Roemer WH and van Wijnen JH. 2001. Daily mortality and air pollution along busy streets in Amsterdam, 1987-1998. Epidemiology 12:649-653.

Roorda-Knape MC, Janssen NAH, de Hartog JJ, van Vliet PHN, Harssema H and Brunekreef B. 1998. Air pollution from traffic in city districts near major motorways. Atmos Environ 32:1921-1930.

Rosenlund M, Berglind N, Pershagen G, Hallqvist J, Jonson T and Bellander T. 2006. Long-term exposure to urban air pollution and myocardial infarction. Epidemiology 17:383-390.

Schikowski T, Sugiri D, Ranft U, Gehring U, Heinrich J, Wichmann HE and Krämer U. 2005. Long-term air pollution exposure and living close to busy roads are associated with COPD in women. Respir Res 6:152.

Schwartz J, Litonjua A, Suh H, Verrier M, Zanobetti A, Syring M, Nearing B, Verrier R, Stone P, MacCallum G, Speizer FE and Gold DR. 2005. Traffic related pollution and heart rate variability in a panel of elderly subjects. Thorax 60:455-461.

Sekine K, Shima M, Nitta Y and Adachi M. 2004. Long term effects of exposure to automobile exhaust on the pulmonary function of female adults in Tokyo, Japan. Occup Environ Med 61:350-357.

Sunyer J, Jarvis D, Götschi T, García-Esteban R, Jacquemin B, Aguilera I, Ackerman U, de Marco R, Forsberg B, Gislason T, Heinrich J, Nörback D, Villani S and Künzli N. 2006. Chronic bronchitis and urban air pollution in an international study. Occup Environ Med 63:836-843.

Yang CY, Yu ST and Chang CC. 2002. Respiratory symptoms in primary schoolchildren living near a freeway in Taiwan. J Toxicol Environ Health A 65:747-755.

Zmirou D, Gauvin S, Pin I, Momas I, Sahraoui F, Just J, Le Moullec Y, Brémont F, Cassadou S, Reungoat P, Albertini M, Lauvergne N, Chiron M and Labbé A. 2004. Traffic related air pollution and incidence of childhood asthma: Results of the Vesta case-control study. J Epidemiol Community Health 58:18-23.