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FEATURES

Potential Health Effects Associated with Residential Proximity to Freeways and Primary Roads: Review of Scientific Literature, 1999–2006

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Abstract This review presents epidemiologic evidence of adverse health effects associated with residential proximity to traffic. Of the 29 peer-reviewed studies that met the authors' defined criteria, 25 reported statistically significant associations with at least one adverse health effect across a broad range of exposure metrics and diverse geographical locations. Specific pollutants contributing to the associated health effects could not, however, be identified, and uncertainties existed because of the lack of individual exposure assessments that could rule out confounding by other factors. Improved exposure assessments and future studies should be considered for better identification of contributing pollutants and mechanisms of action. In the meantime, additional policies, additional regulations, and improved land use and urban planning can better protect the public and limit exposure, especially for vulnerable populations such as pregnant women, children, and the elderly.

Introduction

During the 1970s and 1980s, environmental regulations substantially reduced emissions from industry and stationary sources. Automobiles and other road traffic (mobile sources) became the most prominent contributors to urban air pollution in many areas of the United States (U.S. Environmental Protection Agency, 1994). Traffic emissions include nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs) including benzene and 1,3 butadiene, and particulate matter (PM). In addition, toxic air pollutants including aldehydes, polycyclic aromatic hydrocarbons (PAHs), and metals can adhere to traffic-generated particulate matter (Oberdörster, 2001).

Studies characterizing distributions of fresh vehicular exhaust documented that concentrations were higher near roadways but diminished to near background levels within 150–300 meters (m) (Gilbert, Goldberg, Beckerman, Brook & Jerrett 2005; Zhu, Hinds, Kim, & Sioutas, 2002; Zhu, Kuhn, Mayo, & Hinds, 2006). The steep declines in concentrations were attributed to evaporation of volatile constituents, atmospheric dispersion, and coagulation (Zhu, Hinds, Kim, Shen, & Sioutas, 2002).

Adverse health effects have been associated with residential proximity to traffic. Traffic constituents potentially affecting health include ultrafine ($PM_{0.1}$) and fine ($PM_{2.5}$) particles which can penetrate deep into the lungs (Oberdörster, 2001) and have been associated with respiratory, pulmonary, and cardiovascular morbidity and mortality (Brunekreef & Holgate, 2002; Dockery 2001; Pope, Burnett, Thun, Calle, & Kerwski, 2002). Exposures to traffic-related PM and CO have been associated with adverse birth outcomes (Ritz, Yu, Fruin, Chapa, Shaw, & Harris, 2002; Ritz & Yu, 1999; Ritz, Yu, & Fruin, 2000), which may lead to increased childhood morbidity and mortality and increased risk of hypertension and coronary heart disease in adulthood (Barker, 1995; Osmond & Baker, 2000). Diesel emissions have been associated with effects including lung cancer (Lloyd & Cackette, 2001; Mauderly, 1990; Sydbom, Blomberg, Parnia, Stenfors, Sandstrom, & Dahlen, 2001) and pulmonary/respiratory disorders (Nel, Diaz-Sanchez, & Li 2001). In addition, traffic emissions contain many known and suspected carcinogens. Because of their potency and high concentrations, most of the cancer risk has been attributed to benzene, 1,3 butadiene, and particle-bound PAHs (Rosenbaum, Axelrad, Woodruff, Wei, Ligocki, & Cohen 1999). Chronic benzene exposures have been linked to both structural and chromo-

TABLE 1a

Research on Traffic Proximity and Parent-Reported Adverse Respiratory Effects—Key Results

Reference	Location	Study Population *(N)*	Health Effects Assessed	Exposure Metric	Health Effects with Significant Associations	Distance to Traffic	Traffic Density	Adjusted Odds Ratio	95% CI
Venn et al., 2001	Nottingham, England	4–11 year olds (6,147)	Parent-reported wheeze prevalence	Postal code distance and daily traffic vehicles/day	Parent-reported wheeze prevalence	150 m	10,000–100,000 vehicles/day	1.08	1.00–1.16
		11–15 year olds (3,709)	Parent-reported wheeze prevalence	Postal code distance and vehicles/day	Parent-reported wheeze prevalence	150 m	10,000–100,000 vehicles/day	1.16	1.02–1.32
Janssen et al., 2003	20 city districts, Netherlands	7–12 year olds (2,083)	Parent-reported wheeze, nasal symptoms, lung function, conjunctivitis, itchy rash, bronchitis asthma, hay fever, eczema, allergy	Residential distance to truck traffic, trucks/day	Parent-reported conjunctivitis	500 m	5,190–22,326 trucks/day	2.57	1.00–6.58
					Parent-reported itchy rash	500 m	5,190–22,326 trucks/day	2.08	1.20–5.58
					Parent-reported current wheeze	50 m	>99,500 vehicles/day	1.67	1.07–2.58
					Parent-reported cough prevalence	50 m	>99,500 vehicles/day	1.62	1.62–2.27
Nicolai et al., 2003	Munich, Germany	4–6 year olds & 9–11 year olds (7,508)	Cough, current asthma wheeze, lung function, bronchial hyperreactivity	Average daily traffic count & distance to residence	Parent-reported asthma prevalence	50 m	>99,500 vehicles/day	1.79	1.05–3.05
					Parent-reported current wheeze	50 m	>99,500 vehicles/day	1.67	1.07–2.58
					Parent-reported cough prevalence				
Lewis et al., 2004	United Kingdom	4–6 yr olds (11,562)	Self-reported wheeze, asthma prevalence, medication use	Residential distance to main road	None	50 m	>99,500 vehicles/day	1.62	1.62–2.27
						150 m	N/A	No statistically significant results	
Gauderman et al., 2005	10 of 12 Southern California Communities in the Children's Health Study	4th graders (average age =10 years) (208)	Self-reported wheeze, asthma prevalence, asthma medication use	Residential distance to freeway	Parent-reported asthma prevalence	150 m	N/A	1.89	1.19–3.02
					Parent-reported wheeze	150 m	N/A	1.59	1.06–2.36
					Parent-reported wheeze with exercise	150 m			
Ryan et al., 2005	Cincinnati, Ohio	≤1 year old (622)	Parent-reported wheeze	Residential distance to freeway, state route with speed >50 mph; bus or state route with speed <50 mph	None	400 m	N/A	2.57	1.50–4.38
					None	100 m	Freeway	No statistically significant results	
					Parent-reported wheeze	100 m	State route, speed >50 mph	No statistically significant results	
							Bus/state route, speed <50 mph	2.50	1.15–5.42

Notes:
Relative risk (RR) by comparison with low- or no-exposure categories.
N/A = not available (i.e., not reported).

somal anomalies in humans and increased incidence of leukemia in individuals occupationally exposed (Finkelstein, 2000; Paxton, 1996; Rinsky, Smith, et al., 1987; Rinsky, Young, & Smith, 1981).

This paper summarizes available scientific findings published in peer-reviewed journals in English on health effects associated with defined residential proximity to traffic from January 1999 through June 2006.

Methods

An electronic search was performed on PubMed. Search terms included "traffic" and "traffic emissions" in combination with any of the following terms: "asthma," "adverse birth outcomes," "birth weight," "childhood cancer," "mortality," and "health effects." A total of 139 unique records were returned. Twenty-nine epidemiological studies defined residential proximity to traffic met specific inclusion criteria. Fifty-four records were excluded because they were exposure characterizations or assessments and did not address health effects; 26 were based on exposures in settings other than residences, such as workplaces or schools; 16 were based on air pollution monitoring or modeling; eight were risk assessments; three were animal studies; and three were not in English. It should be noted these criteria excluded some important studies conducted since 1999, such

TABLE 1b

Research on Traffic Proximity and Self-Reported Adverse Respiratory Effects—Key Results

Reference	Location	Study Population *(N)*	Health Effects Assessed	Exposure Metric	Health Effects with Significant Associations	Distance to Traffic	Traffic Density	Adjusted Odds Ratio	95% CI
Garshick et al., 2003	Southeastern Massachusetts	U.S. veterans 60.6 ± 12.8 years old 2,628	Self-reported persistent wheeze, chronic cough, chronic phlegm	Average daily traffic count & distance to residence	Self-reported persistent wheeze	50m	9,351 vehicles/day median	1.31	1.00–1.71
							>10,000 vehicles/day	1.71	1.22–2.40
Heinrich et al., 2005	East Germany	18–79 year olds (6,896)	Self-reported wheeze, nocturnal coughing, current asthma, hay fever, chronic, bronchitis, allergic sensation	Self-reported residential proximity to traffic intensity	Self-reported chronic bronchitis	Street of residence	Self-reported extremely or considerably busy roads	1.36	1.01–1.83
Schikowski et al., 2005	Dortmund, Duisburg, Essen, Gelsenkirchen, & Herne, Germany	Women 54–55 years old (4,757)	Frequent cough, chronic bronchitis, COPD, forced expiratory volume, forced vital capacity	Average daily traffic count & distance to residence	Self-reported COPD	100 m	>10,000 vehicles/day	1.79	1.06–3.02
					Self-reported frequent cough	100 m	>10,000 vehicles/day	1.24	1.03–1.49
Venn et al., 2005	21 districts of Jimma, Ethiopia	Children and adults	Self-reported wheeze, rhinitis, eczema, dust mite sensitivity	Residential distance to road and density of vehicles/12 hours	Self-reported wheeze	150 m	653 vehicles per 12 hours median	1.17 per 30 m	1.01–1.36
McConnell et al., 2006	13 California communities	5–7 year olds (4,762)	Self-reported asthma prevalence, asthma medication use, wheeze	Residential distance to freeways, highways, & arterial roads	Lifetime asthma	75 m	N/A	1.29	1.01–1.86
					Asthma prevalence	75 m	N/A	1.50	1.16–1.95
						75–150 m	N/A	1.33	1.02–1.72
					Asthma prevalence with no family asthma history	75 m	N/A	2.46	1.48–4.09
					Current wheeze with no family asthma history	75 m	N/A	2.74	1.71–4.39

Notes:
Relative risk (RR) by comparison with low- or no-exposure categories.
N/A = not available (i.e., not reported).

as that by Wilhelm and Ritz (2005), which used residential proximity to central-site ambient-air-monitoring stations to evaluate potential associations between adverse birth outcomes and traffic-related pollutants.

Literature Review Results

Respiratory Effects

Nineteen studies evaluated residential proximity to traffic and respiratory effects. The results for studies of parent-reported respiratory effects are summarized in Table 1a, those for self-reported respiratory effects are summarized in Table 1b, and those for physician-diagnosed respiratory effects are summarized in Table 1c. Of the 19 studies, 10 examined respiratory symptoms such as wheeze, frequent coughs, and chronic phlegm; four examined indicators of asthma severity including hospitalizations and doctor visits; and six investigated the relationship between residential proximity to traffic and prevalence of asthma.

Seven of the 10 studies examining self- or parent-reported respiratory symptoms reported statistically significant associations between proximity to traffic and wheeze (McConnell et al., 2006; Garschick, Laden, Hart, & Caron, 2003; Gauderman et al., 2005; Nicolai et al., 2003; Ryan et al., 2005; Venn, Lewis, Cooper, Hubbard, & Britton, 2001; Venn, Yemaneberhan, Lewis, Parry, & Britton, 2005). Persistent or current wheeze was found to be associated with residential proximity within 50, 75, and 150 m of busy roads (McConnell et al., 2006; Gauderman et al., 2005; Venn et al., 2005; Garschick et al. 2003; Janssen et al. 2003; Venn et al. 2001). McConnell and co-authors (2006) reported statistically significant associations for residential proximity within 75 m and between 75 and 150 m but not for residences at distances of 150–300 m or greater. Heinrich and co-authors (2005) reported only marginal increases in wheeze, nocturnal coughing attacks, and hay fever in a group of East German adults with self-reported residential proximity to traffic. Lewis and co-authors (2004) reported no statistically significant associations between residential proximity to traffic within 150 m and self-reported asthma prevalence, medication usage, or wheeze in children in the United Kingdom.

Results were mixed for five studies examining associations between proximity to traffic and respiratory-related doctor visits and hospitalizations. In a study of San Diego children, English and co-authors (1999) reported that doctor visits for asthma were associated with traffic density at the second quintile (5,500–9,000 cars/day) and 95th percentile (>41,000 cars/day) within

TABLE 1c

Research on Traffic Proximity and Physician-Diagnosed Respiratory Effects—Key Results

Reference	Location	Study Population *(N)*	Health Effects Assessed	Exposure Metric	Health Effects with Significant Associations	Distance to Traffic	Traffic Density	Adjusted Odds Ratio	95% CI
English et. al., 1999	San Diego, California	≤14 year olds w/ asthma (5,996)	Asthma prevalence and asthma doctor visits	Average daily traffic vehicles/day & distance to residence	Asthma doctor visits	550 ft	5,500–9,000 vehicles/day	2.14	1.10–4.16
							>41,000 vehicles/day	2.91	1.28–6.91
Wilkinson et al., 1999	North Thames London, England	5–14 year olds w/asthma & respiratory illnesses (9,214)	Asthma and respiratory illness hospitalizations 1992–1994	Postal code centroid distance to road and peak hourly traffic vehicles/hour	None	150 m	>1,000 vehicles/hour	No statistically significant results	
Lin et al., 2002	Erie County, New York	≤14 year olds w/ asthma (417)	Asthma hospital. admissions	Average vehicle miles traveled & distance to residence	Asthma hospital. admissions	200 m	>4,043 vehicle miles traveled	1.93	1.13–3.29
				Residential distance to heavy truck traffic	Asthma hospital admissions	200 m	≥1% heavy trucks	1.43	1.03–1.99
Lwebuga-Mukasa et al., 2004	16 ZIP codes near Peace Bridge on U.S./Canada Border	≥18 yr olds (13,910)	Asthma hospitalizations and outpatient visits 1991–1996	Pre- and post-NAFTA traffic volumes	None	N/A	N/A	No statistically significant results	
Zmirou et al., 2004	France	0–3 year olds (434)	Diagnosed asthma incidence, asthma prevalence	Lifetime average time weighted traffic density (vehicles/meter)	Diagnosed asthma incidence	300 m	>30 vehicles per day per meter	2.28	1.14–4.56
Gordian et al., 2006	Anchorage, Alaska	5–7 year olds (756)	Asthma prevalence	Average daily traffic per meter vehicle within buffer around residence	Asthma prevalence in children with no family asthma history	100 m	40,000–80,000 vehicle meters	2.43	1.23–5.28
							>80,000 vehicle meters	5.43	2.08–13.74
Smargiassi et al., 2006	Montreal, Canada	≥60 year olds (35,309)	Respiratory hospitalizations	Residences along roads and density of vehicles during 3-hour daily peak	Respiratory hospitalizations compared to other diagnostic groups	N/A	>3,160 vehicles/3- hour peak	1.18*	1.06–1.31
Sugiri et al., 2006	East & West Germany	5–7 yr olds (2,574)	Total lung capacity, airway resistance	Average daily traffic density kilometers/day & distance to highway	Total lung capacity	50 m	216–214 km/day mean	1.07	1.06–1.09
					Airway resistance	50 m	216–214 km/day mean	1.02	1.00–1.03

Notes:
Relative risk (RR) by comparison with low- or no-exposure categories.
N/A = not available (i.e., not reported).

550 feet (ft) of residences; this association was strongest for girls. Lin and co-authors (2002) reported increased risk of asthma hospitalization for children living in New York neighborhoods with heavy truck traffic and increased traffic density within 200 m of their homes. Smargiassi and co-authors (2006) reported increased risks of respiratory-related hospitalizations for older adults living in areas of Montreal with high traffic volumes. Wilkinson and co-authors (1999), however, using a postal-code centroid within 150 m of a busy road, reported no association between respiratory-related hospital visits and residential proximity for school children in London. Lwebuga-Mukasa and co-authors (2004) also did not find a statistically significant association for respiratory-related children's hospital visits when they examined the change in traffic patterns before and after implementation of the North American Free Trade Agreement (NAFTA) near the Peace Bridge on the U.S./Canada Border.

Four of six studies examining asthma prevalence reported statistically significant findings with residential proximity within 75, 100, 150, and 300 m of dense traffic across geographically diverse locations including Alaska, California, and France (Gordian, Haneuse, & Wakefield, 2006; McConnell et al., 2006; Gauderman et al., 2005; Zmirou et al., 2004).

Additional respiratory effects were reported to be associated with residential proximity to traffic. Schikowski and co-authors (2005) reported elevated risks of diagnosed chronic obstructive pulmonary disease, frequent cough, and reduced lung function associated

TABLE 2

Traffic Proximity and Childhood Cancer Research—Key Results

Reference	Location	Study Population (*N*)	Health Effects Assessed	Exposure Metric	Health Effects with Significant Associations	Distance to Traffic	Traffic Density	Adjusted Odds Ratio	95% CI
Pearson et al., 2000	Denver, CO	≤14-yr-olds with cancer (579)	All cancers, leukemia	Daily distance-weighted traffic density—vehicles/day and distance to residence	All cancers	750 ft	5000–9999 vehicles/day	1.68	1.02–2.80
						750 ft	≥20,000 vehicles/day	5.90	1.69–20.56
					Leukemia	750 ft	5000–9999 vehicles/day	2.04	1.05–3.95
						750 ft	≥20,000 vehicles/day	8.28	2.09–32.80
Reynolds et al., 2002	California	≤15-yr-olds with cancer (6,988)	All cancers, leukemia, gliomas	Vehicles per square mile and miles of road per square mile within block group of residence	All cancers	N/A	6081–8530 vehicles/square mile	1.10*	1.01–1.19
							21.7–24.8 miles/square mile	1.11*	1.02–1.20
					Leukemia	N/A	6081–8530 v/m2	1.18*	1.03–1.35
Crosignani et al., 2003	Varese Province, Italy	≤14-yr-olds with childhood leukemia (120)	Childhood leukemia	Distance to residence plus Caline model to estimate benzene concentration	Childhood leukemia	300 m	Benzene over 10 µg/m3 estimated annual average.	3.91*	1.36–11.27
Steffen et al., 2004	Nancy, Lille, Lyon, & Paris, France	≤14-yr-olds with childhood leukemia (567)	Acute leukemia, acute non-lymphocytic leukemia, acute lymphocytic leukemia	Self-reported exposure to heavy-traffic roads & neighboring business	Acute leukemia	N/A	N/A	No statistically significant results	

Notes:
Relative risk (RR) by comparison with low- or no-exposure categories.
N/A = not available (i.e., not reported).

with residential exposure to traffic within 100 m for women 54–55 years of age in Germany. Sugiri and co-authors (2006) reported that residential proximity to a busy road of within 50 m was associated with reduced lung function in a group of German children.

Childhood Cancers

The studies that we examined augmented scientific evidence on potential associations between residential proximity to traffic and childhood cancers including acute non-lymphocytic leukemia and acute lymphocytic leukemia. Three of four studies (Table 2) reported a statistically significant association between childhood cancer and traffic exposure metrics and residential proximity within 750 ft (229 m), 200 m, and 300 m in Denver, Colorado; California; and Varese Province, Italy (Crosignani et al., 2003; Pearson, Wachtel, & Ebi, 2000; Reynolds et al., 2002). Steffen and co-authors (2004) reported an association for self-reported residential proximity to automobile repair stations and petrol stations but not for exposure to heavy traffic. That study, however, was one of the few relying on the participant's perception of living near heavy traffic rather than more objective traffic and exposure metrics.

Adverse Birth Outcomes

Three studies examined the relationship between adverse birth outcomes and traffic exposure and reported statistically significant associations (Table 3). Maternal residence within 500 m of a major freeway in Taiwan was reported to be a significant risk factor for preterm birth (Yang et al., 2003). Wilhelm and Ritz (2003) reported that California mothers who lived within 750 ft (229 m) of the highest quintile of heavy-traffic roadways during pregnancy were more likely to have a preterm baby. These researchers reported higher risks of preterm and low-birth-weight babies being born in the fall and winter to mothers living nearer the highest-quintile traffic density. An extended analysis of these California births by Ponce and co-authors (2005) further confirmed the association between proximity to dense traffic and low birth weight for births occurring in the winter.

Mortality Risks

Three studies examined the relationship between residential proximity to traffic and mortality. Associations were reported for cardiopulmonary, stroke, and cardiovascular mortality in the Netherlands, the United Kingdom, and Canada (Finkelstein, 2000; Maheswaran & Elliot, 2003; Hoek, Brunekreef, Goldbohm, Fischer, & van den Brandt, 2002). Both Finkelstein (2000) and Hoek and co-authors (2002) reported statistically significant mortality risks for residences within 100 m of a highway (freeway) and 50 m of an urban road. Maheswaran and Elliot (2003) reported elevated mortality risks at a distance of up to 1000 m from the centroid of the residential enumeration district. These findings were consistent with those of previous studies establishing PM as a well-defined risk factor for premature mortality; more than 50 percent of total PM emissions in urban

TABLE 3

Traffic Proximity and Adverse Birth Outcomes Research—Key Results

Reference	Location	Study Population (*N*)	Health Effects Assessed	Exposure Metric	Health Effects with Significant Associations	Distance to Traffic	Traffic Density	Adjusted Odds Ratio	95% CI
Wilhelm & Ritz, 2003	Los Angeles County, CA	1994–1996 live births (50,933)	Low birth weight, preterm births, low birth weight and preterm births	Distance-weighted traffic density (DWTD), and one or more freeways and distance to residence	Preterm births	750 ft	Highest-quintile DWTD	1.08*	1.01–1.15
					Preterm births during fall/winter	750 ft	Highest-quintile DWTD	1.15*	1.05–1.26
					Low birth weight and preterm during fall/winter	750 ft	Highest-quintile DWTD	1.24*	1.03–1.48
					Low birth weight	750 ft	40th to 59th percentile DWTD	1.16*	1.03–1.30
							60th to 79th percentile DWTD	1.15*	1.02–1.29
					Low birth weight during fall/winter	750 ft	Highest-quintile DWTD	1.33*	1.11–1.58
Yang et al., 2003	East Kaohsiung, Taiwan	1992–1997 live births (6,251)	Preterm delivery	Residential distance to a major freeway with average daily traffic count—vehicles/day	Preterm delivery	500 m	93,000 vehicles/day	1.30	1.03–1.65
Ponce et al., 2005	112 ZIP codes in Los Angeles County	1994-1996 live births (37,347)	Low birth Weight	Residential ZIP codes distance intersected by freeways and major arterials, and DWTD	Low birth weight during winter	3.2-km buffer	DWTD 80th percentile	1.30	1.07–1.58

Notes:
Relative risk (RR) by comparison with low- or no-exposure categories.
N/A = not available (i.e., not reported).

areas of industrialized countries have been estimated to come from traffic (Wróbel, Rokita, & Maenhaut, 2000; Briggs et al., 1997).

Discussion and Policy Implications

Of the 29 studies reviewed, 25 reported statistically significant associations between residential proximity to traffic and at least one of the following adverse health effects: increased prevalence and severity of symptoms of asthma and other respiratory diseases; diminished lung function; adverse birth outcomes; childhood cancer; and increased mortality risks. These associations were reported across a broad range of exposure metrics ranging from self-report to sophisticated mobile-source models, a wide variety of analytical designs controlling for diverse confounders, and diverse geographical locations. The results were particularly consistent for 9 of 10 non-respiratory studies reporting statistically significant associations between residential proximity to traffic and childhood cancer; adverse birth outcomes; and cardiopulmonary, cardiovascular, cerebrovascular, and stroke mortality.

Mixed findings from studies of respiratory outcomes and residential proximity to traffic may be partly explained by issues related to case identification and definitions used for asthma diagnosis. First, asthma prevalence and respiratory symptoms in many of the studies were self-reported through surveys and were subject to recall bias (Garshick et al., 2003; Gauderman et al., 2005; Heinrich et al., 2005; Janssen et al., 2003; Lewis et al., 2004; McConnell et al., 2006; Schikowski et al., 2005;Venn et al., 2001; Venn et al., 2005). Obtaining accurate reporting of symptoms by young children is especially challenging because they may not be aware of or capable of verbalizing symptoms, or may not be able to recall symptoms as well as older children or adults (Kuehni & Frey, 2002). Second, studies have demonstrated that parental conceptual understanding of wheeze varies across ethnic groups (Cane, Pao, & McKenzie, 2001) and differs from definitions used by epidemiologists (Cane, Ranganathan, & McKenzie, 2000). Third, even a physician's diagnosis of asthma can be unreliable because of changes in diagnostic practices and definitions over time (Hill, Williams, Tattersfield, & Britton 1989).

Residential distance to and density of traffic were reported to be important factors in the assessment of the relationship between traffic exposure and adverse health outcomes. The majority of studies using varying distances to residences as exposure metrics reported associations with adverse health effects for distances up to 200 m but not for greater distances (Garshick et al., 2003; Gordian et al., 2006; Lin et al., 2002; McConnell et al., 2006; Nicolai et al., 2003; Schikowski et al., 2005; Sugiri et al., 2006; Venn et al., 2001; Wilkinson et al., 1999). Only three studies reported health effects associated with residential proximity greater than 300 m (Ponce et al., 2005; Yang et al., 2003; Maheswaran & Elliot, 2003).

Four of five studies evaluating residential proximity to major highways (freeways) reported statistically significant associations with adverse health effects (Finkelstein et al., 2004; Ponce et al., 2005; Hoek et al., 2002; Yang et al., 2003). Adverse effects were reported for traffic counts as low as 5,500–9,000 vehicles/day (English et al., 1999), 10,000 vehicles/day (Garshick et al., 2003; Schikowski et al., 2005), and approximately 24,000 vehicles/day (Smargiassi, Berrada, Fortier, & Kosatsky 2006; Wilkinson et al., 1999), as well as for busy-highway (freeway) averages of up to 93,000 vehicles/day (Yang et al., 2003).

Vehicle mix was also suggested as an important factor. Lin and co-authors (2002) reported an association between asthma hospitalizations and residential proximity within 200 m of heavy truck traffic. Ryan and co-authors (2005) reported a statistically significant association between residential proximity within 100 m of stop-and-go bus and truck traffic and parent-reported wheeze in infants less than 12 months old. Janssen and co-authors (2003) assessed health impacts of residential proximity to car and truck traffic and reported elevated risks of conjunctivitis and an itchy rash only for truck traffic.

Several challenges existed to the assessment of relationships between exposure to traffic and health effects. First, personal monitoring that documents duration of exposure and air concentrations of traffic emissions that people actually breathe is typically cost-prohibitive and not practical for most epidemiological studies to date. Therefore, researchers used surrogate exposure metrics to estimate exposure. The precision of exposure metrics used by studies covered in this review ranged from self-report (Heinrich et al., 2005; Steffan et al., 2004; Sugiri et al., 2006) to outputs of sophisticated mobile-source models and geographic information system mapping of residential addresses (Gauderman et al., 2005; Smargiassi et al., 2006). Second, most studies did not account for the relative amount of time people spend in microenvironments other than residences such as work, school, or commuting, where levels of exposure to traffic emissions can vary. Third, estimates of exposure typically do not take into account indoor sources of air pollutants or the variability in residential penetration of pollutants such as benzene and PM (Sioutas, Delfino, & Singh, 2005). Fourth, physical and chemical properties, composition, and toxicity of fuel mixtures for natural gas, gasoline, and diesel vary in different parts of the world and even within countries (Verma & Tombe, 2002). Finally, constituents, concentrations, and duration of traffic-related residential exposures are affected by many factors, including varied fleet characteristics such as average ages and types of vehicles; designs, grades, and distributions of roads; traffic congestion and driving habits; and different inspection and maintenance programs, as well as variations in national and local regulations (Gwilliam, 2003).

The consistency of reported results across the studies we reviewed provided a "weight-of-evidence" finding suggesting that residential proximity to traffic can be associated with adverse health effects and poses a public health threat. A number of steps can be taken to decrease exposure to traffic-related pollutants and to protect the public. Exposures, especially diesel, can be minimized for children, the elderly, and other vulnerable populations by improved land use and community planning that ensures that schools, daycare centers, and nursing homes are not located within 300 m of a busy road. Also, prohibiting prolonged idling of school buses outside schools and widespread conversion of diesel buses to cleaner alternatives, including buses that use low-sulfur fuels and particulate traps, can reduce exposures of school-aged children (Behrentz et al., 2005; Sabin et al., 2005). Furthermore, federal, state, and local governments can reduce emissions by adopting and enforcing regulations on tailpipe emissions and higher fuel economy standards; promoting use of alternative fuels and low-sulfur diesel; promoting carpooling through use of subsidies and high-occupancy vehicle lanes; implementing smart-growth strategies to reduce urban sprawl; and providing convenient, affordable mass transit options. Employers can reduce traffic-related emissions by providing car- and van-pooling incentives and allowing employees to telecommute. Individuals can purchase low-polluting vehicles, combine trips, and use alternative means of transportation such as bicycling or walking.

Conclusions

Studies we reviewed consistently reported statistically significant associations between residential proximity to traffic and at least one of the following adverse health effects: increased prevalence and severity of symptoms of asthma and other respiratory diseases; diminished lung function; adverse birth outcomes; childhood cancer; and increased mortality risks. At present, however, epidemiological studies cannot determine causality, and uncertainties exist because of a lack of individual exposure assessments that could rule out confounding by other, unmeasured factors. Also, the studies reviewed did not elucidate which traffic-related pollutant or mixtures of pollutants may have contributed most to the observed adverse health effects. Improved exposure assessments and mechanistic or toxicological studies are needed to identify contributing pollutants and mechanisms of action. Meanwhile, public health can be better protected through enhanced, precautionary land use; smart growth; and transportation policies, as well as through government and private-sector incentive programs and individual actions.

Disclaimer: This report does not constitute an endorsement by CDC of authors or organizations whose work is reviewed here. The views and opinions of these authors and organizations are not necessarily those of CDC or the U.S. Department of Health and Human Services (HHS).

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continued on page 40

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