Journal of Environmental Management 92 (2011) 1923–1930

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

# An inequality study of ambient nitrogen dioxide and traffic levels near elementary schools in the Tampa area

Amy L. Stuart*, Michelle Zeager[1]

*University of South Florida, 13201 Bruce B. Downs Blvd. MDC 56, Tampa, FL 33612-3805, USA*

ARTICLE INFO

*Article history:*
Received 16 November 2009
Received in revised form
18 January 2011
Accepted 6 March 2011
Available online 16 April 2011

*Keywords:*
Environmental equity
Intra-urban exposure disparities
Race/ethnicity
Traffic

ABSTRACT

Environmental equity has been identified as a challenge and goal of national to global air quality management. Here, relationships between traffic-related air pollution measures and the social demographics of elementary schools are investigated. Ogawa passive samplers were used to measure ambient nitrogen dioxide ($NO_2$) levels near 75 randomly selected elementary schools in the county containing Tampa, FL over one week in March 2008. Concentrations were determined using colorimetric reaction using Hach nitrite reagent and photometric detection at 545 nm. $NO_2$ levels, two metrics of traffic (highest annual average daily traffic count within 500 m and 1000 m), and school enrollment data by demographic subgroup (racial/ethnic and socioeconomic) were then compared. Data were analyzed for distribution statistics, linear correlations, and differences in subgroup category means. Weighted average values of $NO_2$ and traffic count were also calculated for each subgroup. All measured $NO_2$ levels were low, with a mean of 2.7 ppbv and range from 0.8 to 4.7 ppbv. Values were largest at sites near downtown. Results from all analyses show comparatively higher potential exposures to measured $NO_2$ and traffic count for black school children, and lower values for white and Asian or Pacific Islander school children. The economically disadvantaged and Hispanic subgroups were also associated with higher levels of $NO_2$ and traffic counts, but the relationship was not as strong or robust. Although measured $NO_2$ levels were low and the differences between groups are small, results suggest disparities by racial/ethnic and economic status in children's exposures to air pollution for the Tampa area.



## 1. Introduction

Social inequality in health status among population groups is a well-recognized phenomenon. Higher rates of morbidity and mortality for minority and low-income subpopulation groups have been documented since health statistics have been available (Kawachi and O'Neill, 2005). Recently there has been a resurgence of interest in understanding and ameliorating these disparities, with elimination listed as a Healthy People 2010 goal (U.S. Department of Health and Human Services, 2000).

Disparities associated with urban air quality are a significant concern. Air pollution contributes to respiratory conditions (bronchitis, asthma), cardiovascular diseases, adverse birth outcomes, premature death, and some cancers (American Lung Association, 2001). Children are known to be particularly susceptible (Gilliland et al., 1999). Prevalence of several health effects associated with air pollution is higher for some minority and low-income groups (Samet and White, 2004). For example, incidences of asthma-related outcomes have been found to be higher in blacks, some Hispanic subgroups, American Indians, and Alaskan Natives than in whites (Payne-Sturges and Gee, 2006).

Low socioeconomic level and racial/ethnic segregation play important roles in these disparities (Morello-Frosch and Lopez, 2006). This is likely due to many factors, including decreased access to health care and poorer overall health (O'Neill et al., 2003). However, segregation can also lead to disparities in exposure to ambient air pollutants. Minorities and poor people have been found to be more likely to live and attend school near sources of air pollution (Perlin et al., 1999). Large-scale studies also indicate that they are more likely to reside in areas with higher ambient concentrations of air pollutants (Woodruff et al., 2003; Grineski et al., 2007).

Comparative exposures and risks of traffic pollution have received particular attention. Overall, these studies indicate greater exposures for some minority and low-income groups (e.g. Green et al., 2004; Chaix et al., 2006). Additionally, measured concentrations of multiple criteria and toxic air pollutants have been found to be high in close proximity to roadways (e.g. Kaur et al., 2007). Indicators of nearby traffic pollution have also been associated with

* Corresponding author. Tel.: +1 (813) 974 6632; fax: +1 (813) 974 4986.
*E-mail addresses:* astuart@hsc.usf.edu (A.L. Stuart), Michelle.Zeager@childrens.harvard.edu (M. Zeager).
[1] Present address: Division of General Pediatrics, Children's Hospital Boston, USA.

0301-4797/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jenvman.2011.03.003

increased health impacts, particularly in children (e.g. McConnell et al., 2006). Nitrogen dioxide ($NO_2$), a criteria pollutant, is often used as a marker for traffic pollution, as levels of $NO_2$ in air vary substantially near roadways (Jerrett et al., 2005).

Interestingly, the strength and form of the relationship between social demographic metrics and air quality appear to depend on the spatial form and scale of the area studied (Buzzelli and Jerrett, 2007). The characteristics of the pollutant, which alter the spatial scale of pollution, are also likely important. Marshall et al. (2006) and Marshall (2008) found that exposures to several primary pollutants were higher for nonwhites and low-income households, while the reverse was true for ozone (a secondary pollutant). However, neither of these impacts on disparities in exposures or health effects is well understood.

In our work, we seek to understand how urban form and its design, at multiple spatial scales, impacts the relationships between pollution amounts, exposures, and health effects. The objectives of the study described here were to 1) measure ambient nitrogen dioxide levels near elementary schools in Hillsborough County, Florida, 2) investigate the impacts of nearby traffic counts on $NO_2$ levels near schools, and 3) investigate relationships between nitrogen dioxide, traffic levels, and the socio-demographic make-up of schools. The overarching question is whether there may be inequality in air pollution exposures of children associated with the current urban form of the Tampa area.

## 2. Materials and methods

### 2.1. Field study area

Hillsborough county Florida, the field study area, has a population of approximately one million (U.S. Census Bureau, 2000). 12% of the population live below poverty, 75% are white, 18% are Hispanic, and 15% are black or African American (with overlap). The residential locations of these subgroups are somewhat segregated, allowing for potential disparities in exposures at residences and neighborhood elementary schools (Stuart et al., 2009). The county contains both rural areas and a few urban centers, including Tampa. Air pollution sources include motor vehicles, power plants, waste facilities, major international air and water ports, a military base, and a diverse mix of industrial sources (Stuart et al., 2009). Regarding meteorology, the area is a coastal environment, with mild temperatures year round and high rainfall during the summer. The land-sea breeze is an important weather pattern, with multidirectional complexities in winds due to interaction between the Gulf and Atlantic coasts (Dasgupta et al., 2005; Gunter, 2007).

### 2.2. Passive sampling of $NO_2$ near elementary schools

For measurement site selection, a simple random sample of 75 schools was drawn from a total of 143 public elementary schools in the county (Hillsborough County Public Schools, 2007). Location selection near each school was based on ease of access and lack of nearby obstructions or direct emissions sources, with locations near playgrounds preferred. Utility poles (or trees) adjacent to each school were used as measurement infrastructure. Ogawa $NO_2$ passive samplers (Ogawa, 2006) were placed under shelters mounted 3 m above the ground surface. 75 samplers and 10 duplicates were exposed for one week (March 23 to 30, 2008). All samplers were deployed, and later retrieved, within 6-h windows. The times of deployment and retrieval and notes about the site (e.g. nearby activities, types of nearby roadways) were recorded in a log. Each sampler was transported to and from the site in a sealed plastic bag in an airtight container. Four field blanks traveled with the samplers. A map of the sampling locations is provided in Fig. 1. An example sampling assembly is provided in Fig. 2.

### 2.3. Laboratory analyses for ambient $NO_2$ concentrations

Collected samples were analyzed for $NO_2$ using the Ogawa $NO_2$ sampling protocol (Ogawa, 2006), with modification to use color-producing reagent powder pillows (HACH Co.). Specifically, after extraction and cooling, a NitriVer 3 packet was added to each sample. After sealing, shaking, cooling, and equilibration to room temperature, the absorbance was measured at 545 nm using a Varian CARY 50 Probe UV–Visible Spectrophotometer. Absorbances were measured after 40 min of reaction time (the observed time to reach steady values for a 1.0 μg/ml test solution). Absorbances were converted to mass using a daily standard curve (0–1.0 μg/ml working standards) from nitrite stock (Fisher Scientific – SPEX CentriPrep). 4 field blanks and 5 laboratory blanks were analyzed following the same protocols as the field samples. The mean blank mass was subtracted from each field sample mass. The sample mass was then converted to $NO_2$ ambient mixing ratio using a conversion factor that accounts for the sampling rate (Ogawa, 2006). The factor used here (57) was calculated using the average temperature (19 °C) and relative humidity (68%) values for the sampling period from local meteorological data at the Tampa International Airport.

### 2.4. Data analyses of comparative $NO_2$ and traffic exposures

To study school exposures to ambient levels of $NO_2$, measured concentrations of $NO_2$ were compared with school enrollments of a few population subgroups of interest. Annual average daily traffic counts on nearby roads were also used as pollution surrogates and to evaluate their explanatory value to $NO_2$ levels.

Demographic data for each school were obtained for the 2007–2008 school year (Hillsborough County Public Schools, 2007). Available data include enrollment percentages for a few racial/ethnic groups, specifically American Indian or Alaska Native (AI/AN), Asian or Pacific Islander (API), black (non-Hispanic), Hispanic, multi-racial, white (non-Hispanic). Data were also available for a low socio-economical level group (based on percentage of enrollment in the free/reduced lunch program), called the economically disadvantaged. (All group names are those used by the school district.) For this last group, two schools reported values greater than 100%, which were set to 100% for further analyses.

Roadway traffic count data were obtained from the 2006 Florida Traffic Information dataset (Florida Department of Transportation, 2006). Traffic counts for most major roadways in the county are available, based on measurements at thousands of count sites. The highest annual average daily traffic (AADT) on any roadway within two influence radii (500 m and 1000 m) of each school were used for further analyses. Distances were determined using mapping software (Garmin Map Source, version 6.5). Since traffic is not regularly counted on most small roadways, the lowest recorded AADT for the dataset (1500) was assumed for locations with no recorded data within the chosen radius (40 and 24 sites, respectively by radius).

Using this data, several analyses were performed. First, distribution statistics and plots for each variable, correlations, and scatter diagrams were used to explore relationships. Second, sampled schools were categorized by predominant race/ethnic group (white, Hispanic, black) and the distributions of measured $NO_2$ and highest AADT were compared. Categorization was set as the subgroup with the highest student enrollment percentage. Distribution statistics, histograms, and side-by-side box plots were used to explore differences. Finally, a weighted average value of each pollution measure ($NO_2$ level, highest AADT within 500 m, and