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Short Communication

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Comparison of modeled traffic exposure zones using on–road air pollution measurements

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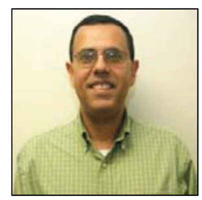
ABSTRACT

Modeled traffic data were used to develop traffic exposure zones (TEZs) such as traffic delay, high volume, and transit routes in the Research Triangle area of North Carolina (USA). On–road air pollution measurements of nitrogen dioxide (NO_2), carbon monoxide (CO), carbon dioxide (CO_2), black carbon (BC), coarse ($PM_{2.5–10}$), fine ($PM_{2.5}$) particulate matter and ultrafine particles (UFPs) were made on routes that encountered these TEZs. Results indicated overall greater traffic pollutant levels in high volume and delay road sections than bus routes or areas of higher signal light density. The combination of delineating roadways into TEZs with highly time resolved on–road measurements demonstrated how pollutant levels can vary within roadways.



Keywords: *Air pollution, geographic information system (GIS), mobile monitor, traffic*

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1. Introduction

Traffic emissions are a major contributor to urban air pollution, especially near busy highways. Traffic pollutants from gasoline and diesel vehicles include nitrogen dioxide (NO_2), carbon monoxide (CO), carbon dioxide (CO_2), black carbon (BC), coarse ($PM_{2.5–10}$), fine ($PM_{2.5}$) particulate matter and ultrafine particles (UFPs), and air toxics. These pollutants come from traffic and other combustion sources (HEI, 2010).

Epidemiologic studies have shown association of specific adverse respiratory, cardiovascular, and birth outcomes with traffic pollution (Wilhelm and Ritz, 2003; McConnell et al., 2006; McCreanor et al., 2007; Chang et al., 2009; van den Hooven et al., 2009). In addition to limited air monitoring, many of these health studies have used exposure metrics from geographic information system (GIS)–based proximity and related spatial models or dispersion models to assess inter–urban as well as roadway gradients of traffic pollution (Jerrett et al., 2005). Limited studies have also used direct exposure measures of PM and UFPs while walking or bicycling in traffic areas to assess health effects (Vinzents et al., 2005; McCreanor et al., 2007).

Spatial gradients of traffic pollutant levels vary inversely with roadway distance and traffic volume. Depending on the pollutant measured, downwind concentrations of roadways generally drop to background levels within 100 to 500 m (Zhou and Levy, 2007; Karner et al., 2010; HEI, 2010). Measurements of traffic pollutant spatial gradients have typically involved stationary air samplers at varying distances from selected roadways with meteorology, traffic count and roadway classification (Zhu et al., 2002; Baldauf et al., 2008; Vette et al., 2013). Traffic pollutants downwind of roads are generally used to assess near road gradients, although trajectory models have shown that other urban and background sources near monitored roads can contribute to measured roadside concentrations (Henry et al., 2011). As a result of the variability of spatial gradients for different traffic pollutants, it has been recommended that high–resolution monitoring near traffic sources be conducted to adequately assess impacts from traffic exposure zones (Zhou and Levy, 2007).

An increasing number of studies have used mobile air monitoring near and on roadways to assess traffic pollution from different roadway classifications. Real–time mobile air monitoring has been demonstrated to have an advantage of identifying spatial and temporal differences of on–road traffic pollutants from different road types, traffic intensities, and road features, such as roadway barriers, that can affect pollutant dispersion. These studies have also revealed that differing background levels should be considered when assessing on–road traffic pollutants (Hagler et al., 2010; Van Poppel et al., 2013). However, access to real–time mobile air monitoring technology is limited because of the requirement for fine time–scale, advanced air monitoring instruments. Therefore, it is of interest to understand whether existing available data such as traffic volume and signal light density, combined with traffic demand models could discriminate between areas differentially influenced by traffic conditions.

This study seeks to address this knowledge gap by delineating and comparing traffic exposure zones (TEZs) using very fine scale on–road ambient air monitoring. Using detailed information on traffic conditions combined with GIS capabilities, roadways were partitioned into TEZs. The TEZs were: traffic delay, high traffic volume, transit routes, signal light density, urban areas, and remainder of the study area. On–road measurements of NO_2, CO, CO_2, BC, $PM_{2.5-10}$, $PM_{2.5}$, PM_{10}, and UFPs were made on the 12 selected routes using a real–time mobile air monitoring vehicle. Traffic–dominated TEZs were compared to assess spatial variability of these traffic pollutants across and within TEZs. Evaluation of these TEZs is being used to assess cardiopulmonary association with traffic pollution for the study area (Ward–Caviness et al., 2014a; Ward–Caviness et al., 2014b).

2. Methods

2.1. Establishment of TEZs

Traffic and census data were acquired for the North Carolina counties of Wake, Durham, and Orange which encompass the Raleigh–Durham–Chapel Hill metro area (Figure 1). The Institute for Transportation Research and Education at North Carolina State University supplied estimates from a 2005 traffic demand model which incorporated traffic volume, signal light, and transit route information (TRMSB, 2009). The supplied data represent a typical workday (Monday through Thursday) in the spring and fall. Urbanized areas were based on U.S. Census 2000 urbanized areas (U.S. Census, 2002). Spatial processing primarily used ArcGIS Desktop 10 (ESRI, 2011).

Six, mutually–exclusive TEZs were formed based on traffic variables, transit routes, county, and urbanization data. Figure 1 shows their locations in the study area. TEZs were categorized from lowest to highest expected traffic exposure. The first three TEZs were based on areas: the three county study area (TEZ 1), Census urbanized area (TEZ 2), and areas with high signal light density (TEZ 3). An additional three TEZs with higher expected traffic exposure were based on road segments defining areas near roadways with transit authority bus routes (TEZ 4), roadways with high traffic volume (TEZ 5), and roadways with large traffic delays (TEZ 6). The supporting material (SM) provides further detail on TEZ definitions.

For the analysis conducted here, a hierarchical approach was used to overlay TEZs with higher numbered, traffic dominated TEZs taking priority in the overlay. For example, if TEZ 6 overlapped TEZ 5, the higher priority TEZ 6 remained intact and overlapping portions of TEZ 5 were clipped. This was true for all layers, so TEZ 6 took precedence, followed by TEZ 5, and so on. An exclusion zone was created by applying a 1 km buffer to the Raleigh–Durham International Airport (RDU) boundaries (Figure 1). An examination of EPA's National Emissions Inventory and Toxics Release Inventory for the study area showed that RDU was the only major point source for these pollutants, especially fine particulate matter. TEZs falling in the RDU zone were not considered in the study to avoid air traffic and related influences as a potential interference.

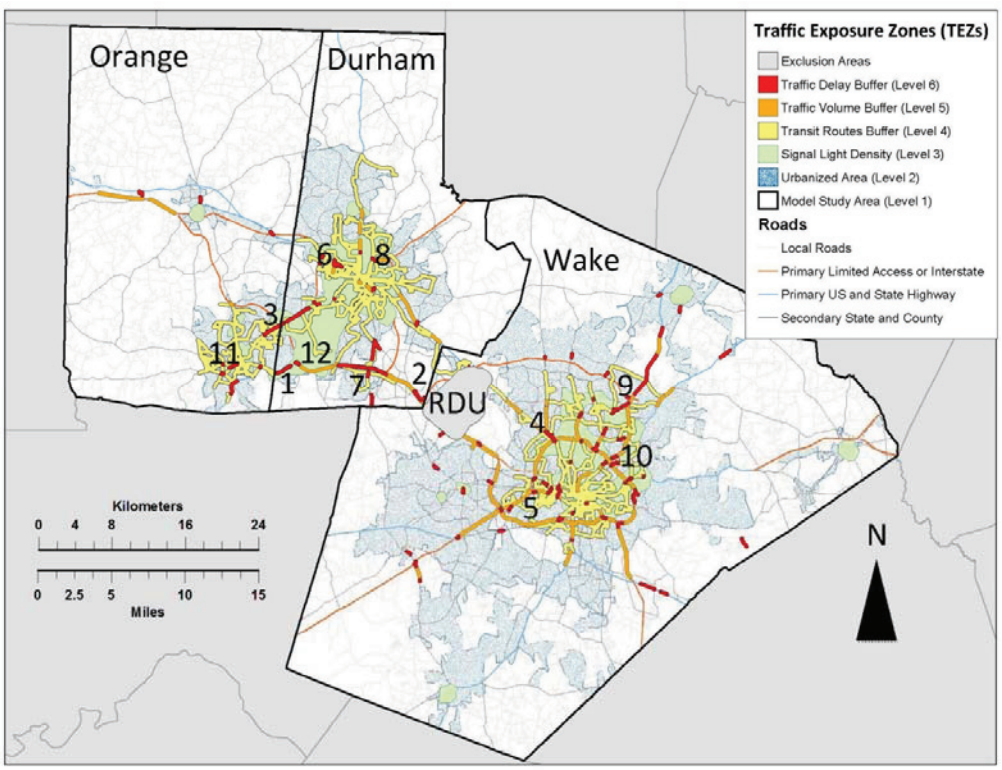

Figure 1. *Three–county study area in North Carolina with TEZs [a]; approximate location of mobile monitoring routes as numbers, and RDU exclusion area labeled ([a]A 200 m buffer around road segments is used to display TEZs 4 to 6).*