Science of the Total Environment 566–567 (2016) 521–527

Contents lists available at ScienceDirect

Science of the Total Environment

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

Fine particulate matter components and emergency department visits among a privately insured population in Greater Houston

Suyang Liu [a], Cecilia M. Ganduglia [b], Xiao Li [c], George L. Delclos [a], Luisa Franzini [b,d], Kai Zhang [a,e,*]

[a] Department of Epidemiology, Human Genetics and Environmental Sciences, School of Public Health, University of Texas Health Science Center at Houston, TX 77030, USA
[b] Department of Management, Policy and Community, School of Public Health, University of Texas Health Science Center at Houston, TX 77030, USA
[c] Department of Biostatistics, School of Public Health, University of Texas Health Science Center at Houston, TX, USA 77030
[d] Department of Health Services Administration, School of Public Health, University of Maryland, College Park, MD 20742, USA
[e] Southwest Center for Occupational and Environmental Health, School of Public Health, University of Texas Health Science Center at Houston, TX 77030, USA

HIGHLIGHTS

- Br, K, Na^+, and SO_4^{2-} were significantly associated with total ED visits.
- Br and Ni were statistically associated with increased visits of stroke.
- Al, Cr, and K were associated with increased respiratory visits.
- $PM_{2.5}$ mass, As, Br, K, Na^+, NH_4^+, NO_3^-, and SO_4^{2-} were associated with increased SSID visits.
- Effect estimates for most $PM_{2.5}$ components were higher during the warm season.

ARTICLE INFO

Article history:
Received 23 February 2016
Received in revised form 15 April 2016
Accepted 5 May 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Fine particulate matter
Components
Emergency department visits
Poisson regression
Species
Time series

ABSTRACT

Although adverse health effects of $PM_{2.5}$ (particulate matter with aerodynamic diameter less than 2.5 μm) mass have been extensively studied, it remains unclear regarding which $PM_{2.5}$ components are most harmful. No studies have reported the associations between $PM_{2.5}$ components and adverse health effects among a privately insured population. In our study, we estimated the short-term associations between exposure to $PM_{2.5}$ components and emergency department (ED) visits for all-cause and cause-specific diseases in Greater Houston, Texas, during 2008–2013 using ED visit data extracted from a private insurance company (Blue Cross Blue Shield Texas [BCBSTX]). A total of 526,453 ED visits were included in our assessment, with an average of 236 (±63) visits per day. We selected 20 $PM_{2.5}$ components from the U.S. Environmental Protection Agency's Chemical Speciation Network site located in Houston, and then applied Poisson regression models to assess the previously mentioned associations. Interquartile range increases in bromine (0.003 μg/m^3), potassium (0.048 μg/m^3), sodium ion (0.306 μg/m^3), and sulfate (1.648 μg/m^3) were statistically significantly associated with the increased risks in total ED of 0.71% (95% confidence interval (CI): 0.06, 1.37%), 0.71% (95% CI: 0.21, 1.22%), 1.28% (95% CI: 0.34, 2.24%), and 1.22% (95% CI: 0.23, 2.23%), respectively. Seasonal analysis suggested strongest associations occurred during the warm season. Our findings suggest that a privately insured population, presumably healthier than the general population, may be still at risk of adverse health effects due to exposure to ambient $PM_{2.5}$ components.

1. Introduction

A recent assessment on health effects of particulate matter (PM) exposure conducted by the United States (U.S.) Environmental Protection Agency (EPA) has concluded that both short- and long-term exposure to ambient fine particulate matter ($PM_{2.5}$; PM with aerodynamic diameter less than 2.5 μm) cause mortality and cardiovascular effects (and likely cause respiratory effects) (EPA, 2012). However, simply relating $PM_{2.5}$ mass to health effects is not sufficient enough to explain the associations because $PM_{2.5}$ is a complex mixture of ions, trace metals, and carbonaceous species (Bell et al., 2007) and their proportions in $PM_{2.5}$ mass vary by source, season, and geographical location (Metzger et al., 2004). Many studies have found differential toxicity across $PM_{2.5}$ components, and these findings were summarized in several review articles (Chen and Lippmann, 2009; Kelly and Fussell, 2012; Rohr and Wyzga,

* Corresponding author at: Department of Epidemiology, Human Genetics and Environmental Sciences, School of Public Health, University of Texas Health Science Center at Houston, TX 77030, USA.
E-mail address: kai.zhang@uth.tmc.edu (K. Zhang).

http://dx.doi.org/10.1016/j.scitotenv.2016.05.022
0048-9697/

2012; Schlesinger, 2007; Stanek et al., 2011). Although they suggest that certain $PM_{2.5}$ components (e.g., nickel, vanadium, elemental carbon, and organic carbon) were more closely associated with health impacts, no consensus has yet been reached regarding which $PM_{2.5}$ components are more harmful than others.

In the U.S., only a few studies have examined the associations between short-term exposure to $PM_{2.5}$ components and emergency department (ED) visits. Several studies were conducted in Atlanta, Georgia using ED data collected during 1993–2004. These studies examined the associations of short-term exposure to $PM_{2.5}$ mass and components with ED visits for cardiovascular diseases (CVD) and respiratory diseases (RESP) (Metzger et al., 2004; Peel et al., 2005; Sarnat et al., 2008; Sinclair et al., 2010; Strickland et al., 2010). Specifically, CVD visits were found to be associated with $PM_{2.5}$ mass, elemental carbon, and organic carbon (Metzger et al., 2004), whereas respiratory visits were associated with elemental carbon, water-soluble metals, and sulfate (Peel et al., 2005; Sarnat et al., 2008). In addition, asthma was also reported to have a significant association with elemental carbon, zinc, and air pollutants from traffic sources (Peel et al., 2005; Sinclair et al., 2010; Strickland et al., 2010). Despite the fact that most studies were conducted in the Atlanta metro area, a recent study examining the short-term associations between $PM_{2.5}$ components and ED visits was conducted in St. Louis, Missouri–Illinois from June 1, 2001 through May 30, 2003 (Sarnat et al., 2015). In this study, statistically significantly associations were found between CVD visits and zinc, as well as between respiratory visits and calcium.

Most previous time-series studies of $PM_{2.5}$ components and ED visits were based on ED visit data collected from hospitals that included patients without distinction. No studies have examined the health effects of $PM_{2.5}$ mass and components among a privately insured population. In our study, we retrieved ED visit data from a private insurance company (Blue Cross Blue Shield Texas [BCBSTX]), which is the state's largest health insurer, covering a relatively healthy, high-income population of more than 10 million persons. Taking advantage of this data set, we hypothesize that the insured population, presumably healthier than the general population due to healthy worker effect, would produce different results than previous studies. In this study, we performed a Poisson regression in generalized additive models (GAM) to estimate the association between all-cause and cause-specific ED visits and $PM_{2.5}$ components in Greater Houston during 2008–2013.

2. Methods

2.1. Study location

The study area is Houston-The Woodlands-Sugar Land Metropolitan Statistical Area (MSA), which is also commonly referred to as "Greater Houston" (U.S. Census Bureau, 2013) (see Supplemental Material Fig. S1). This area consists of nine counties, including Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties. As of 2013, Greater Houston had a population of 6.3 million (U.S. Census Bureau, 2014). As the fifth largest metropolitan area in the U.S. (U.S. Census Bureau, 2014) and a highly industrialized city, Greater Houston has many local sources of ambient $PM_{2.5}$. Examples include the petrochemical complex along the Houston Ship Channel, ports in Houston, Texas City, and Galveston, numerous industrial facilities scattered in the entire metropolitan area, and emissions from on-road motor vehicular traffic (Bahreini et al., 2009; Chiou et al., 2010; Nowak et al., 2010; Sexton et al., 2006). In addition to local sources, $PM_{2.5}$ in Greater Houston can be also transported from regional sources such as dust storms originating in areas of West Texas and the New Mexico area, agricultural burning in Mexico and Central America (TCEQ, 2013), and marine vessel emissions in the Gulf of Mexico and secondary particulate matter from upwind regions (Parrish et al., 2009).

2.2. Emergency department visit data

We retrieved daily counts of ED visits for Greater Houston from claims data insured by BCBSTX from January 1, 2008 through December 31, 2013. BCBSTX covers approximately one-third of the privately insured population in the Texas. It includes mostly people under 65 who are receiving insurance through employment (their dependents were also covered). There is a small portion of individuals over 65 years of age, though they were still fully employed and included in the study. We restricted our analysis to BCBSTX enrolled members living in Greater Houston and visiting a hospital or clinic located in Greater Houston. In addition, observations with ICD-9 codes greater than 799 (injury, poisoning, external causes of injury, and supplemental classification) and those with ICD-9 codes missing (2% of total visits) were excluded from the main analysis.

International Classification of Diseases 9th Revision (ICD-9) diagnosis codes were used to classify outcome groups, which include: total ED visits [001–799], CVD visits [390–429], stroke visits [430–438], RESP visits [460–519], chronic obstructive pulmonary disease (COPD) visits [490–492, 494, and 496], pneumonia (PNA) visits [480–486], asthma visits [493], and symptoms, signs, and ill-defined conditions (SSID) visits [780–799]. Three SSID subgroups were further analyzed, including general symptoms [780], symptoms involving cardiovascular system [785], and symptoms involving respiratory system and other chest symptoms [786]. Additionally, because injuries were positively associated with air pollution (Ha et al., 2015), we performed analyses on the outcome group injury and poisoning [800–999] and its subgroups, including effects of foreign body entering through body orifice [930–939], burns [940–949], and other and unspecified effects of external causes (e.g., overexertion, drowning, exposure to electric current, and submersion) [990–995]. This study was approved by the Committee for the Protection of Human Subjects at The University of Texas Health Science Center at Houston.

2.3. Air quality and weather data

We obtained $PM_{2.5}$ mass and speciation data from U.S. EPA Air Quality System (AQS) (https://aqs.epa.gov/api) for 2008–2013. $PM_{2.5}$ mass data were extracted from four $PM_{2.5}$ monitoring sites in Greater Houston using federal reference methods (FRM) (see Supplemental Material Fig. S1). Three of the four monitoring sites continuously monitored $PM_{2.5}$ mass in the study period while the fourth operated during 2013. Daily average concentrations for $PM_{2.5}$ mass across multiple monitors in Greater Houston were calculated for each day in the study period. Speciation data were extracted from the monitor located in "Houston Deer Park", the only chemical speciation network (CSN) site in Greater Houston (see Supplemental Material Fig. S1). CSN typically collects $PM_{2.5}$ samples on a one-in-three or one-in-six day schedule. This schedule restricted our analysis to include only days when data on both hospital admissions and $PM_{2.5}$ component concentrations were available for our primary analyses. We included 20 species in our analysis: aluminum (Al), ammonium (NH_4^+), arsenic (As), bromine (Br), calcium (Ca), chromium(Cr), copper (Cu), elemental carbon (EC), iron (Fe), manganese (Mn), nickel (Ni), nitrate (NO_3^-), organic carbon (OC), potassium (K), silicon (Si), sodium ion (Na^+), sulfate (SO_4^{2-}), titanium (Ti), vanadium (V), and zinc (Zn). These species were chosen because they represented major local sources (Sullivan et al., 2013) and had been studied previously in other epidemiologic studies (Dai et al., 2014; Krall et al., 2013; Ostro et al., 2007; Zanobetti et al., 2009). EPA implemented a new method to analyze EC and OC at Houston Deer Park in 2009 and a validated correction method is not yet available; therefore, we included only EC and OC data that were collected between 2009 and 2013 in our assessment.

We retrieved hourly weather observations measured at George Bush Intercontinental Houston Airport (IAH) from the National Climate Data