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Short-term associations of fine particulate matter components and emergency hospital admissions among a privately insured population in Greater Houston

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HIGHLIGHTS

- Ambient $PM_{2.5}$ air pollution slightly affected the privately insured population.
- Arsenic and copper were associated with increased hospital admissions of stroke and pneumonia.
- Seasonal analysis showed weak variation among $PM_{2.5}$ mass and components.

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ABSTRACT

A number of time-series studies have associated $PM_{2.5}$ (particulate matter with aerodynamic diameter less than 2.5 μm) mass and components with various health outcomes. No studies have yet examined the associations between $PM_{2.5}$ components and hospital admissions among a privately insured population. We estimated the short-term associations between exposure to $PM_{2.5}$ mass and components and emergency hospital admissions for all-cause and cause-specific diseases in Greater Houston, Texas, during 2008–2013 using Blue Cross Blue Shield Texas claims data. A total of 90,085 emergency hospital admissions were included in this study, with an average of 34 ± 10 admissions 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 short-term effects of $PM_{2.5}$ mass and species on emergency hospital admissions. Effects were estimated without adjustment for other airborne pollutants. $PM_{2.5}$ mass was not statistically significantly associated with increased all-cause emergency hospital admissions and selected cause-specific admissions. For selected $PM_{2.5}$ species, we found interquartile range increases in arsenic (0.001 μg/m^3) and copper (0.017 μg/m^3) were significantly ($P < 0.05$) associated with increased admissions for stroke, (5.98% [95% confidence interval (CI): 0.73, 11.50%]) and pneumonia (4.07% [95% CI: 0.37, 7.90%]), respectively. Seasonal analysis showed weak variation among $PM_{2.5}$ mass and components, except that nickel significantly increased all-cause emergency hospital admissions (2.16% [95% CI: 0.21, 4.14%]) during the warm season. Our findings suggest that hospital admissions in the privately insured population are slightly affected by ambient fine particulate matter air pollution.

1. Introduction

While the accumulated epidemiologic evidence has associated exposure to outdoor $PM_{2.5}$ (particulate matter with an

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aerodynamic diameter of ≤2.5 μm) mass with a range of adverse health outcomes, uncertainty still exists as to which components of $PM_{2.5}$ are most dangerous to human health (Schlesinger, 2007). Several components (e.g., nickel, vanadium, elemental carbon, and organic carbon) have been suggested to be more closely associated with adverse health outcomes than other species (Chen and Lippmann, 2009; Rohr and Wyzga, 2012; Schlesinger, 2007). However, the roles of various components in $PM_{2.5}$-associated health effects are still not clear (Rohr and Wyzga, 2012).

Previous studies of $PM_{2.5}$ and hospital admissions (HA) in the United States (U.S.) commonly relied on HA data extracted from Medicare, a national social insurance program that provides health services for Americans age 65 years and older (Bell et al., 2009b, 2014; Lall et al., 2011; Levy et al., 2012; Peng et al., 2009; Zanobetti et al., 2009). For example, using Medicare data collected from 26 U.S. communities between 2000 and 2003, Zanobetti et al. (2009) found that bromine, chromium, nickel, and sodium significantly modified the associations between $PM_{2.5}$ mass and cardiovascular disease (CVD) admissions; arsenic, chromium, manganese, organic carbon, nickel, and sodium significantly modified myocardial infarction (MI) admissions; and arsenic, organic carbon, and sulfate significantly modified diabetes admissions. Peng et al. (2009) reported significant associations between elemental carbon and CVD admissions, and organic carbon and respiratory (RESP) admissions, in the Medicare population for the period 2000–2006 in 119 U.S. counties. In an effort to examine whether differences in chemical composition affect variation in effect estimates of hospitalization associated with $PM_{2.5}$ mass, Bell et al. (2009) conducted a multicity time-series study using Medicare data collected from 106 U.S. counties for the period 1999–2005. The authors found that $PM_{2.5}$ mass high in nickel, vanadium, and elemental carbon had higher risk of hospitalizations. In addition to multicity studies, a few single-city or regional studies also examined associations between $PM_{2.5}$ components and HA using health data extracted from local or regional hospitals (Ito et al., 2011; Kim et al., 2012; Ostro et al., 2009; Schreuder et al., 2006).

It is noteworthy that the majority of previously mentioned studies were limited to examination of susceptible populations, such as youth and elderly. To date, no studies of $PM_{2.5}$ and HA have focused on a privately insured population. We examined a privately insured population (Blue Cross Blue Shield Texas [BCBSTX]) who are younger and presumably healthier than the aged or disabled Medicare population. They also have a higher socioeconomic status than those enrolled in Medicaid. Our aim was to assess whether such a population would produce a "weaker-than-usual" association between $PM_{2.5}$ components and emergency HA due to the healthy worker effect: workers are healthier than the general population because unhealthier individuals are ordinarily excluded from employment (Last, 2001). In this study, we performed a Poisson regression in generalized additive models (GAM) to estimate the association between all-cause and cause-specific HA and $PM_{2.5}$ components in Greater Houston during the period 2008–2013.

2. Methods

2.1. Study area

Greater Houston, with an area of 10,062 mi^2 and a population of 6.3 million in 2013, is the fifth largest metropolitan area in the U.S. (U.S. Census Bureau, 2014). Greater Houston encompasses nine counties in Texas, including Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery and Waller counties (U.S. Census Bureau, 2013) (see Supplemental Material Fig. S1). As a highly industrialized metropolitan area, Greater Houston has many local sources of ambient $PM_{2.5}$, such as petrochemical complex, ports, and on-road motor vehicular traffic (Bahreini et al., 2009; Chiou et al., 2010; Nowak et al., 2010; Sexton et al., 2006). In addition, regional transport of $PM_{2.5}$ is also an issue in Greater Houston. Examples include dust storms from West Texas and New Mexico, agricultural burning in Mexico and Central America (TCEQ, 2013), and marine vessel emissions in the Gulf of Mexico (Parrish et al., 2009).

2.2. Emergency hospital admissions

Data on daily HA were obtained from billing claims of BCBSTX enrollees for Greater Houston from January 1, 2008 to December 31, 2013. BCBSTX provides hospital coverage for approximately one-third of the privately insured population in Texas. The analysis was limited to those who were enrolled in preferred provider organization (PPO) or PPO + plans, which accounted for over 95% of BCBSTX enrollees. Additionally, our analysis was restricted to BCBSTX enrollees who were living and visiting hospitals or clinics in Greater Houston. Because the inclusion of scheduled admissions could attenuate observed associations with air pollution (Winquist et al., 2012), we included only a subset of admissions that were categorized as "emergency" or "urgent" (emergency HA). Observations with International Classification of Diseases 9th Revision (ICD-9) codes greater than 799 (injury, poisoning, external causes of injury, and supplemental classification) and those without ICD-9 codes (2% of all-cause hospital admissions) were excluded. ICD-9 diagnosis codes were further used to classify outcome groups, including all-cause HA 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]. 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

$PM_{2.5}$ mass and speciation data were obtained online from the U.S. Environmental Protection Agency (EPA) Air Quality System (AQS) (https://aqs.epa.gov/api). $PM_{2.5}$ mass data were extracted from four $PM_{2.5}$ monitoring sites in Greater Houston collected by 24-h integrated-filter (see Supplemental Material Fig. S1). Except for one site that operated only during 2013, all three remaining monitoring sites continuously monitored $PM_{2.5}$ mass throughout the study period. Prior to the analysis, concentrations of $PM_{2.5}$ mass across all monitors in Greater Houston were averaged for each day. 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). Speciation samples were collected on a one-in-three or one-in-six day schedule. We selected 20 species for 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). The choices were made because they were representatives of major local sources (Sullivan et al., 2013) and had been examined in previous epidemiologic studies (Dai et al., 2014; Franklin et al., 2008; Krall et al., 2013; Ostro et al., 2007; Zanobetti et al., 2009). Because EPA applied the new instrument (URG 3000N) to collect EC and OC at Houston Deer Park in 2009, and because no validated correction method is currently