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Abbreviations

Al	aluminum
Ca	calcium
Cl	chlorine
EC	elemental carbon
Na ⁺	sodium ion
NH ₄ ⁺	ammonium
Ni	nickel
NO ₃ ⁻	nitrate
NO ₂	nitrogen dioxide
OCM	organic carbon matter
PM _{2.5}	particulate matter with aerodynamic diameter $\leq 2.5 \mu\text{m}$
PM ₁₀	particulate matter with aerodynamic diameter $\leq 10 \mu\text{m}$
SES	socio-economic status
Si	silicon
SO ₄ ⁼	sulfate
Ti	titanium
TRI	Toxic Release Inventory
TSP	total suspended particles
U.S. EPA	United States Environmental Protection Agency
V	vanadium
Zn	zinc

Abstract

Background: Growing evidence indicates that toxicity of fine particles (PM_{2.5}) differs by chemical component. Exposure to components may differ by population.

Objectives: We investigated whether exposures to PM_{2.5} components differ by race/ethnicity, age, and socio-economic status (SES).

Methods: Long-term exposures (2000-2006) were estimated for 215 US census tracts for PM_{2.5} and 14 PM_{2.5} components. Population-weighted exposures were combined to generate overall estimated exposures by race/ethnicity, education, poverty status, employment, age, and earnings. Population characteristics for tracts with and without PM_{2.5} component monitors were compared.

Results: Larger disparities in estimated exposures were observed for components than for PM_{2.5} total mass. For race/ethnicity, whites generally had the lowest exposures. Non-Hispanic blacks had higher exposures than whites for 13 of the 14 components. Hispanics generally had the highest exposures (e.g., 152% higher than whites for chlorine, 94% higher for aluminum). Young persons (0-19yrs) had levels as high as or higher than other ages for all exposures except sulfate. Persons with lower SES had higher estimated exposures, with some exceptions. For example, a 10% increase in the proportion unemployed was associated with a 20.0% increase in vanadium and an 18.3% increase in elemental carbon. Census tracts with monitors had more non-Hispanic blacks, lower education and earnings, and higher unemployment and poverty than tracts without monitors.

Conclusions: Exposures to PM_{2.5} components differed by race/ethnicity, age, and SES. If some components are more toxic than others, certain populations are likely to suffer higher health burdens. Demographics differed between populations covered and not covered by monitors.

Introduction

Concepts of environmental inequality and environmental justice refer to larger health burdens from environmental stressors for some populations than others. The U.S. Environmental Protection Agency (U.S. EPA) uses “environmental justice” to refer to “fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies,” (U.S. EPA 2010) and notes that such conditions reflect not only adverse consequences, but lack of positive environmental, health, economic, or social benefits (U.S. EPA 2011a). The earliest studies of environmental justice focused on proximity to potentially harmful locations (e.g., incinerators) (Chavis and Lee 1987; U.S. General Accounting Office 1983).

In addition to more recent studies on proximity (Chakraborty et al. 2011; Maantay 2007; Maantay et al. 2009; Mohai and Saha 2007; Pastor Jr. et al. 2001), many other types of environmental justice issues have been researched (ALA 2001; Brown 1995; Mohai et al. 2009; Waller et al. 1999). Procedural inequities could affect remediation of hazardous sites regarding priority for cleanup, time from identification of hazards to remediation, and degree of remediation; or for regulatory actions such as industry fines (Carruthers 2007; Lavelle and Coyle 1992). Adverse health outcomes may be used as a marker for environmental justice concerns, such as blood lead levels (Peters et al. 2011), which are higher for non-Hispanic black than non-Hispanic white children (CDC 2005) or asthma, which in 1995 had a prevalence of 67.4 per 1,000 population for blacks and 56.2 per 1,000 population for whites (NIH 1999). Some populations may have a different health response to environmental conditions, meaning that a given level of exposure could have a larger impact on some groups than others (Bell and

Dominici 2008; Grineski et al. 2010; Zanobetti and Schwartz 2000). This effect modification could be related to genetics, baseline health status, access to health care, psychosocial hazards, or other factors (Bell et al. 2002; Clougherty 2010; Clougherty and Kubzansky 2009; Cory-Slechta et al. 2010; Couch and Coles 2011; Gee and Payne-Sturges 2004; Glass et al. 2009; McEwen and Tucker 2011; O'Neill et al. 2003; Ren et al. 2010; Samet and White, 2004; Son et al. 2012; Zanobetti et al. 2000).

Whether some populations face higher exposures to contaminants than other populations is another type of environmental justice. Here we examine this type of environmental justice concern with respect to chemical components of airborne particulate matter with aerodynamic diameter $\leq 2.5\mu\text{m}$ ($\text{PM}_{2.5}$). $\text{PM}_{2.5}$ is associated with numerous adverse human health impacts, especially cardiopulmonary responses (Pope and Dockery 2006). The majority of health studies on particles have estimated effects of total $\text{PM}_{2.5}$ mass without regard to chemical composition, and U.S. EPA's standard for particles is based on total mass. However, chemical structure varies widely, such as larger contributions to $\text{PM}_{2.5}$ of nitrate in the western U.S. and sulfate in the eastern U.S. (Bell et al. 2007). Growing scientific evidence indicates that some $\text{PM}_{2.5}$ components or sources are more harmful than others (e.g., Ito et al. 2011; Lippmann et al. 2006; Ostro et al. 2007 and 2008; Peng et al. 2009). The true toxicity of different parts of the particulate mixture is unknown, but is a critical research need (HEI 2001; NRC, 2004).

A recent study reported that non-Hispanic blacks and those >64yrs had higher $\text{PM}_{2.5}$ exposures than other U.S. population subgroups (Miranda et al. 2011). As the chemical structure of particles is likely to affect its toxicity, we investigated exposures to selected $\text{PM}_{2.5}$ chemical components under the hypothesis that exposures would differ based on race/ethnicity, age, and

socio-economic indicators, and that differences in exposures to PM_{2.5} components would be larger than differences in exposure to PM_{2.5} total mass.

Methods

We estimated population-level exposures for different groups (e.g., race/ethnicity) to PM_{2.5} and 14 PM_{2.5} components measured by U.S. EPA's national monitoring network: sulfate (SO₄²⁻), nitrate (NO₃⁻), ammonium (NH₄⁺), organic carbon matter (OCM), elemental carbon (EC), sodium ion (Na⁺), aluminum (Al), calcium (Ca), chlorine (Cl), nickel (Ni), silicon (Si), titanium (Ti), vanadium (V), and zinc (Zn). These components were selected because they contribute $\geq 1\%$ to total PM_{2.5} mass for yearly or seasonal averages, and/or have been associated with adverse health outcomes in previous studies including mortality, heart rate, heart rate variability, and low birth weight (Bell et al. 2007 and 2009; Dominici et al. 2007; Franklin et al. 2008; Huang et al. 2007; Lippmann et al. 2006; Ostro et al. 2007 and 2008; Rohr et al. 2011; Wilhelm et al. 2012).

Daily air pollution measures were obtained for 2000-2006 (U.S. EPA 2011b). Pollutant monitors were matched to U.S. census tracts, which are geographic units representing small subdivisions of a county and are the smallest spatial unit for which demographic variables of interest were available. Tracts from the 2000 Census were designed to have an optimal population of 4,000 (range 1,500-8,000) and to follow government boundaries (e.g., county), geographic features (e.g., rivers), or other identifiable features (e.g., roadways), where possible. The median land area of 2000 Census tracts in the continental U.S. was 5.06 km².

Census tracts in the continental U.S. were included in our analysis if they had PM_{2.5} component monitors in operation for ≥ 3 yrs with ≥ 180 days of observations during the study

period. Results were based on 219 monitors in 215 census tracts. Land use near monitors was 43% residential, 34% commercial, 8% industrial, 8% agricultural, and 4% forest.

We calculated long-term averages for each pollutant and 2000 Census tract with a monitor for that pollutant. If multiple monitors were present for the same pollutant in a single tract, we averaged daily monitor values within a tract, and then averaged daily values to generate long-term averages. The population and area of census tracts varied. The average distance between a census tract's centroid and monitor was 2.3km (standard deviation 4.9km, median 0.8km, maximum 46.7km).

For each census tract, we considered population characteristics (U.S. Census, 2000):

- *Race*: Population self-identified as non-Hispanic white, non-Hispanic black or African American, non-Hispanic Asian, Hispanic, or other (SF1.P08)
- *Educational attainment*: Those ≥ 25 yrs with less than a high school degree or equivalent, high school degree or equivalent, or some college (SF3.P37)
- *Poverty*: Those in poverty using Census-defined poverty levels (SF3.P87)
- *Unemployment*: Those ≥ 16 yrs who were unemployed, employed, or not job seekers (SF3.P43)
- *Age*: 0-19, 20-64, or ≥ 65 yrs (SF1.P12)
- *Earnings*: Average annual earnings of those ≥ 16 yrs with earnings (SF3.P84)
- *Total population*: (SF1.P08)

We excluded census tracts with populations ≤ 100 ($n=1$, for tract with population=1). For each population characteristic and category (e.g., race/ethnicity: Hispanic), we estimated the average exposure to each pollutant for that group in the U.S. as a whole by weighting levels in each census tract by the population as:

$$Y_i^k = \frac{\sum_{j=1}^J P_{ij} x_j^k}{\sum_{j=1}^J P_{ij}} \quad [1]$$

where Y_i^k = national average estimated exposure to pollutant k for persons with characteristic i (e.g., Hispanic)

j = number of census tracts with pollutant data ($J=215$)

P_{ij} = number of persons with characteristic i in census tract j

x_j^k = concentration of pollutant k for census tract j

This provides an estimate of average exposure for each pollutant and population group, accounting for population size and pollutant levels in each census tract. In addition, we performed univariate regression to estimate differences in exposure to PM_{2.5} and each component according to census tract characteristics (e.g., percent unemployed), which are expressed as the percent change in exposure compared to overall mean levels associated with a 10% increase in a given population characteristic.

Whereas the above analysis investigates whether some groups have higher exposures than others among areas with monitors, we further contrasted population characteristics between census tracts with and without monitors for PM_{2.5} or components. We calculated population characteristics for census tracts with and without monitors and performed univariate logistic regression to estimate the percent increase in the probability of a census tract having a monitor with a 10% increase in each population characteristics. This investigates whether some populations are better covered by the existing monitoring network than others.

Results

Exposures among children and young adults (0-19yrs) were as high or higher than exposures in other age groups for PM_{2.5} and all components except sulfate, which was highest among those ≥ 65 yrs (see Figure 1 for relative differences in exposures and Supplemental Material Table S1 for average exposure estimates according to age). For example, those <20yrs had levels 7.0% higher than adults (20-64yrs) for zinc and 6.2% higher for Ca. Older persons (≥ 65 yrs) had lower exposures than other adults (20-64yrs) for most pollutants, with exception of similar levels of PM_{2.5} (<1% differences) and higher estimated exposures to ammonium, sulfate, and zinc.

Non-Hispanic whites had the lowest estimated exposures for 11 of 14 components (see Figure 2 for relative differences in exposures and Supplemental Material Table S2 for average exposure estimates according to race/ethnicity). Hispanics had the highest estimated exposures for 10 of the 14 components, and were tied with African-Americans for the highest estimated exposure to vanadium. Levels for Hispanics were higher than non-Hispanic whites for 12 of the 14 components (e.g., 152% higher for chlorine, 94% for aluminum). Sulfate levels for Hispanics were 22% lower than for non-Hispanic whites. Estimated exposures were higher for African-Americans than whites for 13 of the 14 components (e.g., 43% higher for zinc, 25% for vanadium). African-Americans had the highest average exposure levels for ammonium, sulfate, and zinc, and the lowest estimated exposure to nitrate. Asians had higher estimated exposures than whites for most components considered (e.g., 103% for chlorine, 69% for vanadium, 64% for nickel), but had the lowest estimated exposures of any race/ethnicity group for PM_{2.5}, ammonium, and sulfate.

In general, persons with lower socio-economic status (SES) had higher estimated exposures, based on indicators of education, unemployment, poverty, and earnings (see Figure 3 for relative differences in exposures and Supplemental Material Tables S3 and S4 for average exposure estimates according to SES indicator). Those with less than a high school education had higher estimated exposures to PM_{2.5} and all components than those with college education (e.g., 6.2% higher PM_{2.5}, 29% higher zinc, 20% higher chlorine), and higher estimated exposures than those with a high school degree for PM_{2.5} and all components except sulfate. Estimated exposures were $\geq 10\%$ higher among those without a high school education compared to those with college education for aluminum, calcium, chlorine, EC, silicon, titanium, vanadium, and zinc.

PM_{2.5} exposures for unemployed persons were 2.3% higher than employed persons (Figure 3 and Supplemental Material Table S3). The unemployed has higher levels than employed persons for 13 of the 14 components (e.g., 11% higher for vanadium, 9.5% for zinc). Those in poverty had exposures 3.0% higher than those above poverty for PM_{2.5}, and higher exposures for 11 of the 14 components, at $\geq 10\%$ for aluminum, calcium, chlorine, EC, silicon, titanium, vanadium, and zinc. Those in the lowest earnings category had 18% higher aluminum and 16% higher silicon exposures than those estimated for the highest earnings category, but 26% lower levels of nickel.

Table 1 shows estimated percent differences from overall mean census tract exposure levels with a 10% increase in individual population characteristics. For example, a 10% increase in the proportion of the population that was Asian was associated with 53.5% higher levels for chlorine, 50.0% for vanadium, and 45.0% for nickel. Census tracts with a higher percentage of Asians also had higher levels of EC and nitrate, and lower levels of sulfate. A 10% increase in

the proportion of Hispanics was associated with significantly higher levels of 11 components and lower levels of sulfate. For example, an additional 10% of the population that is Hispanic was associated with increases of 18.2%, 25.4%, and 21.3% in aluminum, chlorine, and nickel, respectively. Increases in age, unemployment, education, poverty, and earnings at the census tract level also were associated with differences in exposures. For example, a 10% increase in the proportion of the population without a high school degree was associated with increases of 19.1% in zinc and 12.2% in vanadium.

Supplemental Material, Table S5 compares populations of the 215 census tracts with monitors used in this study and the 64,413 tracts without monitors. In addition, 286 tracts have component monitors that did meet our inclusion criteria (e.g., sampling duration). Tracts with monitors for components had higher percentages of non-Hispanic blacks (20.5%) than tracts without monitors (13.5%). The tracts with monitors had lower SES based on education (25.5% with <high school education versus 20.8% in tracts without monitors, 44.3% with college versus 50.1%), unemployment (8.64% versus 6.47%), poverty (19.9% versus 13.4%), and earnings (39.6% with earnings <\$50,000/yr versus 33.9% in tracts without monitors). Results from univariate logistic regression indicate that a 10% increase in the population that is non-Hispanic black is associated with a 10.3% increase in the probability that a census tract has a monitor (Supplemental Material Table S5). The same increase in the population (10%) for those with less than a high school education, unemployed, in poverty, or with earnings <\$15,000/yr is associated with a 22.6%, 41.2%, 39.2%, and 37.6%, respectively, increase in probability of a census tract having a monitor.

Discussion

To our knowledge, this is the first study of how exposures to PM_{2.5} components may differ by population for race/ethnicity, age, and SES. An earlier study examined PM_{2.5} from diesel sources and hexavalent chromium based on individual-level exposure estimates in California, finding higher exposures to both for persons who were younger (<7 versus >80yrs), less educated (< high school versus college), or non-white (Marshall, 2008). Previous studies investigated this issue for other pollutants, including PM_{2.5}. U.S. counties in the lowest quantile of air quality had a higher fraction of non-Hispanic blacks and persons in poverty than counties in the highest quantile of air quality for PM_{2.5} and ozone (Miranda et al. 2011). In the same study, the 20% of counties with the worst air quality had more persons >64yrs for PM_{2.5} and more <5yrs for ozone. Areas with or adjacent to parks in Los Angeles, California had higher nitrogen dioxide (NO₂) and PM_{2.5} levels for low SES or high minority neighborhoods (Su et al. 2011). In the U.S., Hispanic, African-American, or Asian/Pacific Islander women had higher air pollution exposures during pregnancy than white mothers, after adjusting for education and other factors, based on an air pollution index that incorporated levels of particulate matter with aerodynamic diameter $\leq 10\mu\text{m}$ (PM₁₀), ozone, carbon monoxide, NO₂, and sulfur dioxide (Woodruff et al. 2003). In that study, lower education was associated with higher pollution levels, after adjustment for race/ethnicity. In Hamilton, Canada, total suspended particles (TSP) levels were higher in census tracts with more Latin-Americans or fewer Asian-Canadians, with no observable trends between TSP and black-Canadians, after adjustment for SES (Buzzelli and Jerrett, 2004). In the same area, TSP levels were higher in census tracts with higher dwelling values and lower income (Jerrett et al. 2011).

In Tampa, Florida, blacks, Hispanics, and those in poverty resided in neighborhoods closer to Toxic Release Inventory (TRI) sites, whereas whites resided closer to air pollutant monitors (Stuart et al. 2009). In California, census tracts within a mile of TRI facilities had higher fractions of minorities, especially Latinos, lower rates of home ownership, and lower incomes (Pastor Jr. et al. 2004). In Orange County, Florida, Hispanic or black children were more likely to live or attend school near TRI sources than white children (Chakraborty and Zandbergen 2007). In regions of West Virginia, Louisiana, and Maryland, African-Americans lived closer to TRI sites than whites (Perlin et al. 2001).

Our estimates are consistent with these overall trends, indicating the highest $PM_{2.5}$ exposures for non-Hispanic blacks, the least educated, the unemployed, and those in poverty. However, overall differences were small in magnitude, with the largest difference at 9.9% higher for non-Hispanic blacks than whites. We estimated larger disparities for exposures to $PM_{2.5}$ components than $PM_{2.5}$. Whereas $PM_{2.5}$ levels for those without a high school education were 6.2% higher than those with college, zinc levels were 29% higher. Unemployed persons had 2.3% higher $PM_{2.5}$ than employed persons, but 11% higher levels for vanadium. Similarly, estimated differences among race/ethnicity, earnings, or age categories were larger for many components than for $PM_{2.5}$. The directions of the associations were different among components. For example, those in the lowest earnings category (<\$15,000/yr) had higher levels than those earning \geq \$50,000/yr for seven components (18% higher for Al), and lower levels for seven components (26% lower for Ni).

We used community-level exposures for census tracts. More precise measures would incorporate spatial heterogeneity (Peng and Bell 2010), as well as daily activity patterns, indoor exposures (e.g., environmental tobacco smoke), inhalation rates, and occupational exposures at

the individual level. Many of these factors (e.g., occupation) may differ by population.

Exposures were estimated from ambient monitors, and thus do not reflect the personal exposures of all individuals within the census tract.

This research does not disentangle demographic characteristics of race/ethnicity, education, unemployment, poverty, and earnings; and many population characteristics co-vary (see Supplemental Material, Table S6 for correlations). For example, race, education, earnings, and poverty were correlated. Future work could examine patterns in population characteristics in relation to PM_{2.5} component exposures and such patterns related to community factors such as urbanicity, property values, etc.

Only 215 census tracts had PM_{2.5} component monitors meeting the inclusion criteria, covering 0.3% of the population. The monitor coverage hinders ability to fully investigate equity issues, especially for rural populations, which likely have different characteristics. As population demographics and chemical composition of particles differ dramatically by region (Bell et al. 2007), the geographical distribution of monitors could affect results. In this study, 37% of monitors were in the South (defined by U.S. Census regions), 27% in the Midwest, 19% in the West, and 17% in the Northeast. Future research may consider alternative methods of estimating exposure, such as air quality modeling and satellite imagery (Anderson et al. in press; Bell 2006; Boldo et al. 2011; Fann et al. 2012), to estimate exposures for a larger population.

Results show that populations potentially at risk for higher exposures to components do not appear to be underrepresented in areas with monitors compared to areas without monitors. This contrasts with a study finding that U.S. counties without sufficient monitoring for PM_{2.5} and ozone had fewer non-Hispanic blacks, Hispanics, and persons <5yrs, and a higher percentage of persons >64yrs (Miranda et al. 2011). Our findings may differ due to use of census tracts

(median land area 5.06km^2 , standard deviation 571km^2) rather than counties (median land area 1582km^2 , standard deviation 3375km^2), and because of differences between monitoring networks for $\text{PM}_{2.5}$ and PM_{10} components. Other studies have also shown links between population characteristics and monitoring networks. In São Paulo, Brazil, areas with higher SES were more likely to have PM_{10} and ozone monitors (Bravo and Bell 2010).

Additional challenges in this area of research include the choice and interpretation of SES indicators, as true SES relates to historical conditions, full sources of income and access to resources beyond official earnings, neighborhood-level SES, insurance, access to health care, use of health care systems, and social networks (Bell et al. 2002; O'Neill et al. 2003). The interpretation of SES indicators can vary by region or sub-culture. Subjective measures of SES include factors such as satisfaction with position, comparison to peers, and perception of financial security. Perceived and actual SES may differ, and can have different trends by population (Brown et al. 2008). Traditional measures of SES (e.g., income, education) can be supplemented with subjective social status measures, which in some cases may be more closely linked to health outcomes than conventional measures (Dennis et al. 2012; Singh-Manoux et al. 2003).

The 14 $\text{PM}_{2.5}$ chemical components investigated here were selected because they contribute $\geq 1\%$ to $\text{PM}_{2.5}$ total mass and/or were found to be potentially harmful to health in earlier studies. However, the full health impacts of various particle mixtures, and the identities of the most harmful components or set of components, are unknown. A further complication is that all components come from multiple sources, although some components are more strongly linked to some sources than others (e.g., nickel and vanadium from oil combustion, sulfate from coal combustion, silicon from road dust).

A growing body of scientific literature, including epidemiological and toxicological studies, indicates health associations with various PM_{2.5} chemical components (U.S. EPA 2009). For example, results of toxicological studies using animal models and human cell cultures suggest the possibility of adverse respiratory effects for zinc (Gerlofs-Nijland et al. 2007; Wu et al. 2003 and 2004), aluminum (Graff et al. 2007), vanadium (Veranth et al. 2007), sulfate (Riley et al. 2005), and nitrate (Huang et al. 2003). Animal models have shown associations with cardiovascular outcomes, such as for zinc (Bagate et al. 2004 and 2006). As additional information becomes available on which chemical components and related sources are most harmful, future studies could examine how such exposures differ by population.

Conclusions

Our estimates suggest differences among populations in PM_{2.5} component exposures. However, exposure differences may only partly determine whether health impacts from these pollutants are greater in some population groups than others. The actual difference among groups for health burdens from PM_{2.5} or its components depends not only on the distribution of exposure, but whether effects are modified by population characteristics. In other words, whereas this study shows that some populations have higher exposures than others, a separate issue is whether a given exposures results in the same health response across populations. Methods for risk assessment are needed to assess different effects of environmental exposures across populations and communities, incorporating temporal and spatial connections among risk factors in real-world settings (Schwartz et al. 2011).

Our findings highlight the need for additional research to understand health responses to complex pollutant mixtures, as opposed to effects of individual pollutants. Advances in this field

of research are further complicated by inadequate data on multiple pollutants, limitations in methods, and exposure assessment (Dominici et al. 2010). However, this work takes a step towards that goal by providing information on differences in exposures that can be used to inform future studies investigating differential health impacts from PM_{2.5} components and the particulate mixture.

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Table 1. Percent increase in long-term average exposure per an additional 10% increase in population with that characteristic

Population	PM _{2.5}	Al	NH ₄ ⁺	Ca	Cl	EC	Ni	NO ₃ ⁻	OCM	Si	Na ⁺	SO ₄ ⁼	Ti	V	Zn
Age															
<20yrs	2.69	16.0*	6.47	19.0*	-0.82	-1.37	7.50	17.7*	-0.84	12.3*	0.28	-1.46	7.27	5.00	19.5
20-64	-5.00*	-11.2	-11.3*	-14.7*	7.89	3.69	14.4	-14.2*	3.32	-7.48	6.54	-6.37	-3.18	15.0	-27.2*
>65	3.07	-11.9	6.24	-11.8	-11.3	-3.41	-38.1*	-10.2	-3.81	-10.9	-11.1	13.1*	-8.64	-33.9*	7.47
Race/Ethnicity															
White	-1.37*	-4.93*	-1.02	-5.61*	-8.13*	-5.35*	-10.0*	-2.20	-2.72*	-4.08*	-4.01*	-0.27	-4.77*	-8.89*	-6.71*
African-American	1.88*	-0.39	1.95*	0.32	-2.08	2.93*	2.50	-2.92	1.89*	-0.64	0.46	4.22*	0.23	2.22	6.10
Asian	-2.92	-5.76	-8.40	4.97	53.5*	20.3*	45.0*	19.8*	4.69	-5.47	29.9*	-18.3*	16.8*	50.0*	-5.41
Hispanic	0.13	18.2*	-0.18	16.7*	25.4*	7.17*	21.3*	12.9*	3.04*	15.9*	8.47*	-7.39*	13.2*	16.7*	4.73
Other	-16.4*	8.33	-36.5*	31.0	84.2*	23.3*	72.5*	18.4	16.8	10.8	23.3	-59.4*	16.8	52.2*	63.4
Education															
< High school	4.69*	8.30*	5.26*	13.3*	11.5	9.55*	7.50	5.66	5.14*	8.04*	3.64	4.31*	9.77*	12.2*	19.1*
High school	2.34	-11.1*	7.34*	-15.7*	-19.8*	-5.38	-26.9*	-7.43	-4.66	-10.4*	-12.8*	12.5*	-13.9*	-20.6*	5.07
College	-3.55*	-2.36	-5.21*	-4.26	-2.08	-4.62*	2.50	-1.63	-2.03	-2.36	1.03	-5.96*	-2.50	-2.22	-13.4*
Unemployed	4.63	13.5	3.10	13.9	22.4	18.3*	16.9	10.3	12.0*	12.6	3.72	-2.52	15.2*	20.0*	22.0
Poverty	2.16*	7.31*	-0.69	9.89*	9.39	8.78*	11.3	-2.14	7.15*	6.19*	3.24	0.17	7.95*	8.89*	11.2
Earnings															
<\$15,000/yr	0.07	10.4*	-3.73	10.1*	3.63	3.12	-8.13	-2.45	5.30*	10.4*	0.09	-3.77	8.64*	-1.67	5.14
\$15,000-\$29,999	2.61	-3.37	4.59	-6.61	-8.65	3.81	8.13	-2.74	1.24	-3.82	-1.30	7.15*	-2.50	-4.44	6.99
\$30,000-\$49,999	-1.55	-17.2*	4.49	-18.8*	-8.4	-10.5*	-15.0	2.43	-11.7*	-17.0*	-4.05	5.04	-18.0*	-7.78	-7.88
≥\$50,000	-1.21	-10.8	2.38	-6.79	3.25	-3.75	20.6	6.19	-6.07	-10.8	3.15	0.21	-7.05	11.1	-12.2

Note: This table provides the percent increase in exposure level, evaluated at the mean (Table 1) for a 10% increase in population characteristic of a census tract.

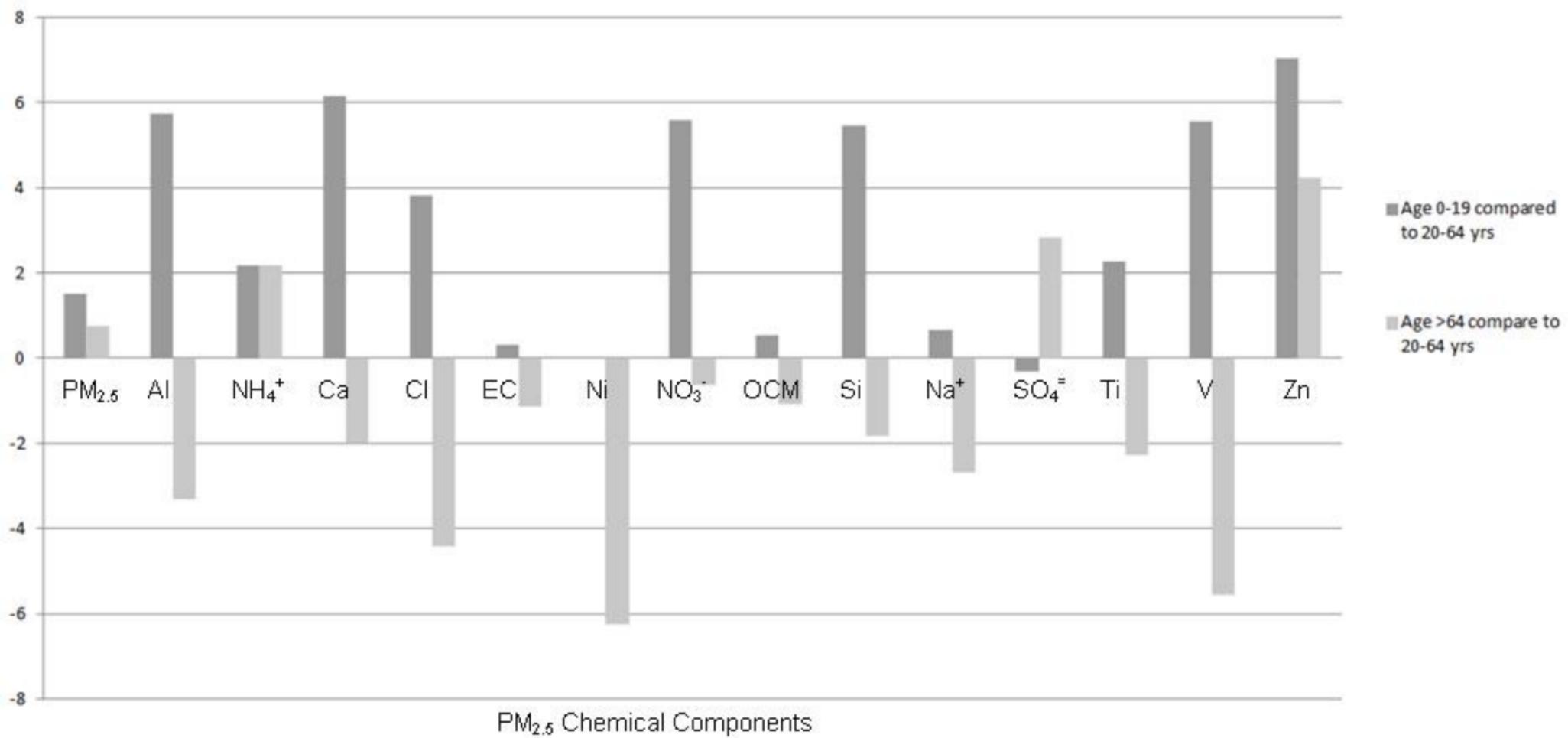
White, African-American, and Asian refer to non-Hispanics. *p<0.05.

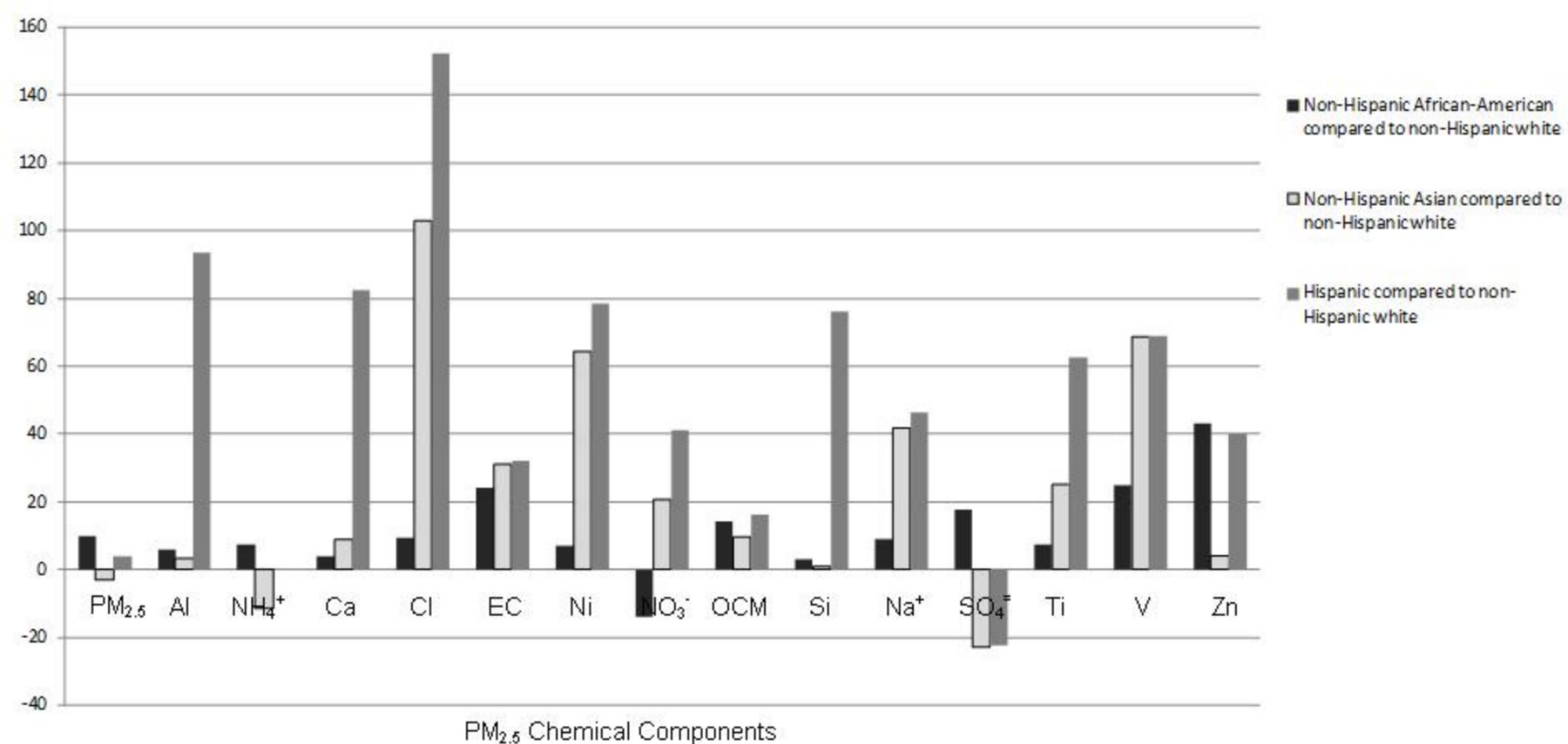
Figure Legends

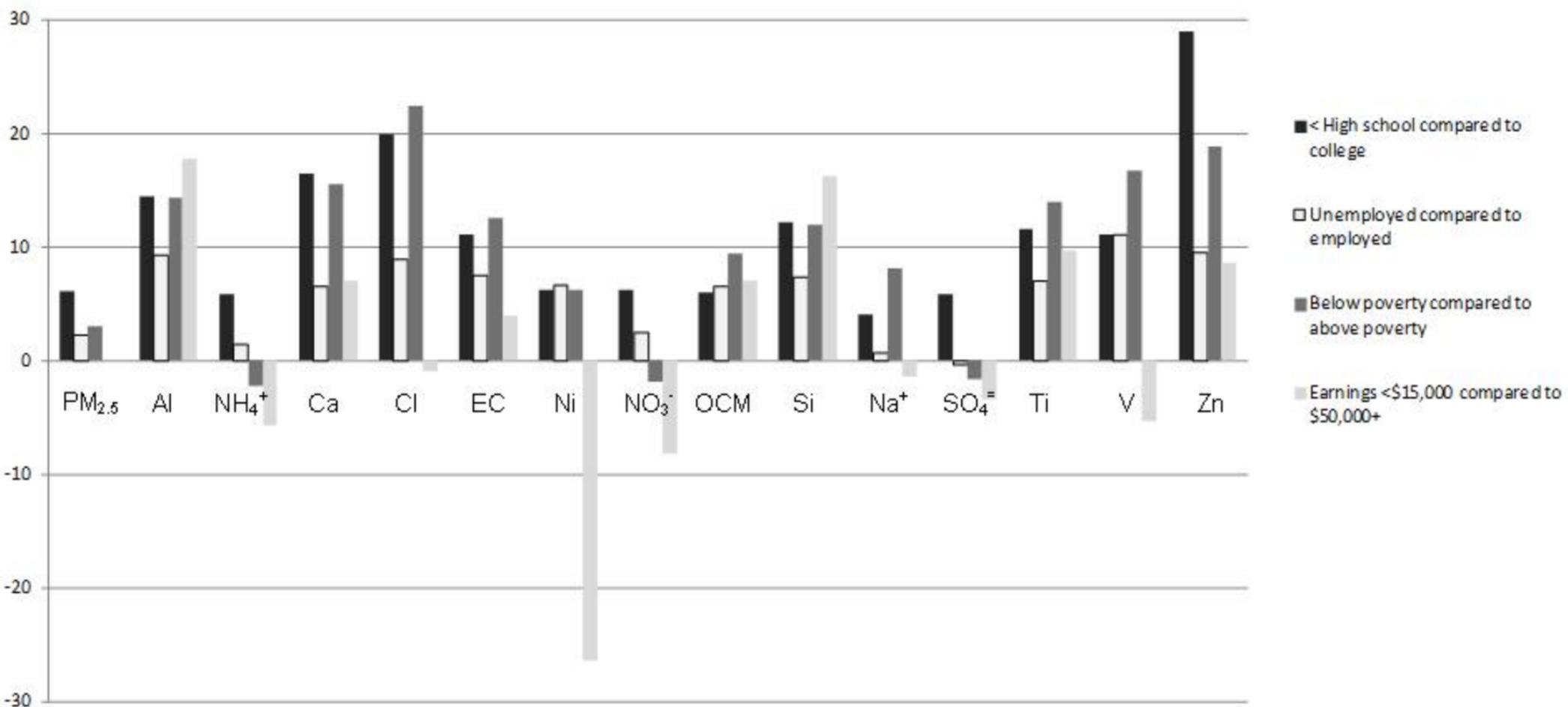
Figure 1. Percentage difference in exposures by age, comparing 0-19 or >64yrs to those 20-64yrs

Figure 2. Percentage difference in exposure by race/ethnicity category, comparing non-Hispanic African-American and non-Hispanic Asian to non-Hispanic white

Figure 3. Percentage difference in exposure by category of socio-economic indicators (education, unemployment, poverty, earnings)







PM_{2.5} Chemical Components