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School-based exposure to hazardous air pollutants and grade point average: A multi-level study

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ABSTRACT

The problem of environmental health hazards around schools is serious but it has been neglected by researchers and analysts. This is concerning because children are highly susceptible to the effects of chemical hazards. Some ecological studies have demonstrated that higher school-level pollution is associated with lower aggregate school-level standardized test scores likely, related to increased respiratory illnesses and/or impaired cognitive development. However, an important question remains unexamined: How do school-level exposures impact individual children's academic performance? To address this, we obtained socio-demographic and grades data from the parents of 1888 fourth and fifth grade children in the El Paso (Texas, USA) Independent School District in 2012. El Paso is located on the US-side of the Mexican border and has a majority Mexican-origin population. School-based hazardous air pollution (HAP) exposure was calculated using census block-level US Environmental Protection Agency National Air Toxics Assessment risk estimates for respiratory and diesel particulate matter (PM). School-level demographics were obtained from the school district. Multi-level models adjusting for individual-level covariates (e.g., age, sex, race/ethnicity, English proficiency, and economic deprivation) and school-level covariates (e.g., percent of students economically disadvantaged and student-teacher ratio) showed that higher school-level HAPs were associated with lower individual-level grade point averages. An interquartile range increase in school-level HAP exposure was associated with an adjusted 0.11–0.40 point decrease in individual students' grade point averages (GPAs), depending on HAP type and emission source. Respiratory risk from HAPs had a larger effect on GPA than did diesel PM risk. Non-road mobile and total respiratory risk had the largest effects on children's GPA of all HAP variables studied and only mother's level of education had a larger effect than those two variables on children's GPA. The five school-level demographic indicators were only weakly associated with GPA. The study findings indicate the need for regulations on school siting and adjacent land uses to protect children's environmental health.

1. Introduction

Nearly 600 million children attend primary school worldwide, yet little attention is paid to school-based environmental health hazards confronting them (Legot et al., 2010; Pastor et al., 2002; Sampson, 2012). The problem of environmental hazards in and around schools is serious (Rudnai et al., 2012; Wargo, 2004). For example, in the US, a significant portion of the top 100 polluting facilities for developmental toxics are located in close proximity to multiple schools (Legot et al., 2010). Children are highly susceptible to the effects of chemical hazards because of heavy exposures (i.e., they consume more air and food per unit of body weight than do adults), biologic sensitivity associated with early growth and development, and their long future lifetimes as early insults can manifest in adult diseases (Perera, 2008). The World Health Organization has published guidelines for integrating environmental considerations into school siting policies (Wargo, 2004), as has the United States Environmental Protection Agency (USEPA) (Environmental Protection Agency, 2014). Because these guidelines are designed to inform voluntary decision-making only, there is no enforcement component. The lack of enforcement is reflected in the fact that only 10 US states actually prohibit school siting near environmental health hazards (Gaffron and Niemeier, 2015).

One documented consequence of school-based exposure to environmental health hazards is a reduction in children's aggregate standardized test scores. Subpar academic performance at a young age can have lifelong impacts on a child's developmental trajectory and life chances, including lower economic and educational attainment in adulthood. Statewide in California (USA),

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hazardous air pollutant (HAP) risks were negative and statistically significant predictors of lower standardized test scores adjusting for school demographics in OLS regression models (Pastor et al., 2006). A more recent study in Sacramento, California found a similar association between school-level PM2.5 and aggregate academic performance (Gaffron and Niemeier, 2015). Outside of California (Pastor et al., 2004, 2006), researchers have examined similar questions in Baton Rouge, Louisiana (USA) based on school proximity measures to Toxic Release Inventory (TRI) facilities. They found that a school's proximity to these industrial facilities was significantly and negatively associated with lower aggregate standardized test scores, controlling for a host of relevant school-level covariates (Legot et al., 2011; Lucier et al., 2011; Scharber et al., 2013). Another study found a similar pattern in Michigan (Mohai et al., 2011).

While documenting a disturbing pattern, this extant literature is limited by ecological study designs. Results obtained solely from aggregate (or ecological) data should not be used for making assumptions about associations at the individual level; doing so commits the ecologic fallacy (Beale et al., 2008). By design, these ecological studies have also neglected factors known to influence children's academic achievement at an individual-level, like mothers' education and family economic status, which confounds reported findings. While ecologic study designs are appropriate when little is known about the association under study, they are less appropriate for examining school-level pollution and academic performance, given the ecologic evidence now available (Currie et al., 2009; Gaffron and Niemeier, 2015; Legot et al., 2010; Lucier et al., 2011; Mohai et al., 2011; Pastor et al., 2002, 2004, 2006; Scharber et al., 2013).

The important question as to how school-level exposures impact individual children remains unexamined. Individual children have not been studied in the literature likely because of data limitations. Standardized test scores aggregated at the school level are relatively easy to acquire from public sources, whereas academic performance measures and personal characteristics for individual children are more difficult to obtain. The use of individual-level data in a study examining school-level pollution also necessitates a more complex statistical approach, e.g., multilevel modeling (Raudenbush and Bryk, 2002), than the OLS regression models used in previous studies examining school-level pollution.

Improving on prior school-level studies, we employ a multilevel modeling approach which allows us to examine the effects of school-level covariates (e.g., level of air pollution at the school, percent of children qualifying for free/reduced price meals) and individual-level control variables (e.g., mother's education) on an individual-level outcome (i.e., child's grade point average [GPA]) for the first time. We do so by integrating primary survey data on El Paso, Texas (USA) school children, school data from the El Paso Independent School District (EPISD), and geographically fine-scale hazardous air pollutant (HAP) data from the USEPA. We answer the following research question: What is the effect of outdoor HAPs surrounding school sites on attending students' GPAs, accounting for individual-level covariates and school-level demographics?

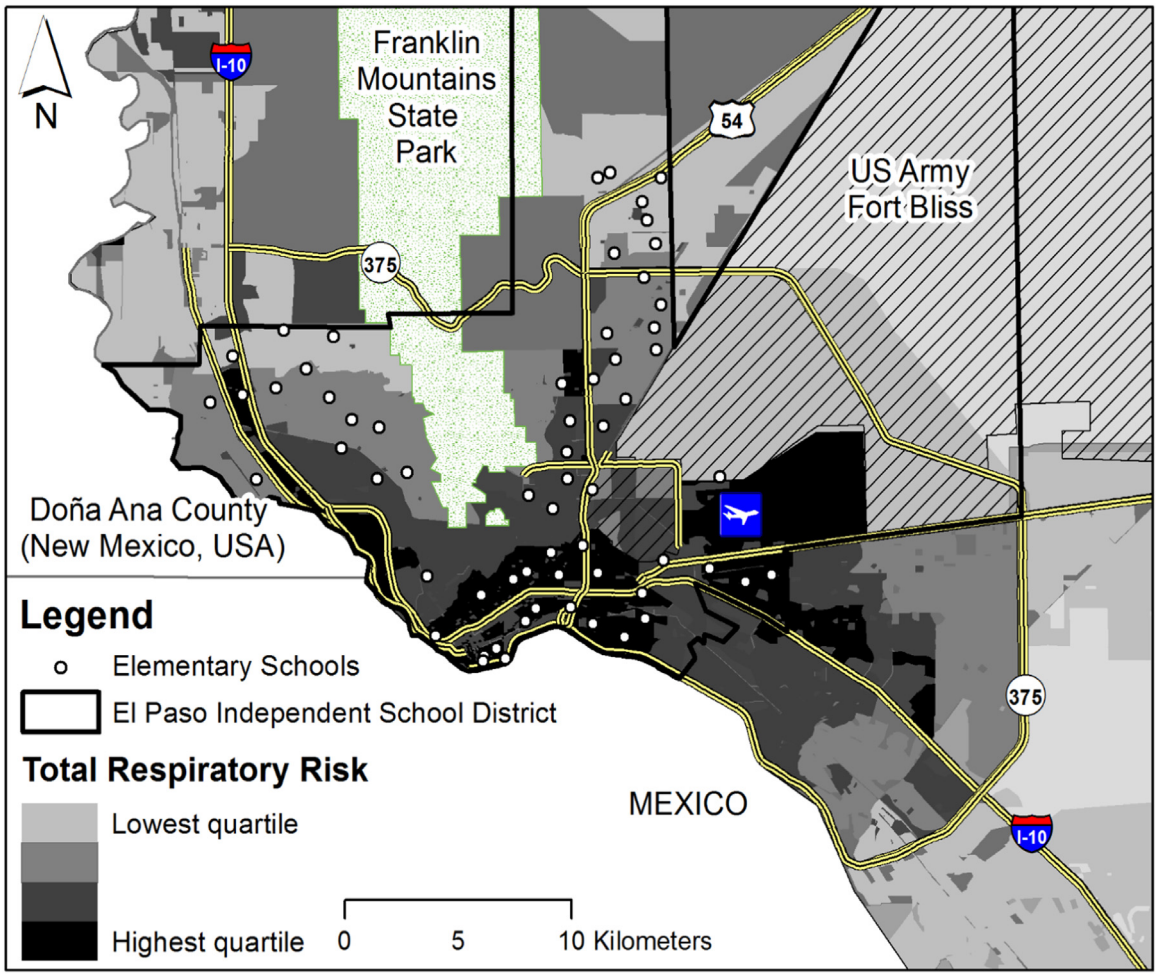

Fig. 1. Study Area and Elementary Schools in El Paso, TX.