The Impact of Air Pollution on Public School Achievement

John "Hans" Gilderbloom, Ph.D., Isaiah Kingsberry, Gregory D. Squires,
Charlie Zhang, Ph.D. and Ellen Slaten, Ph.D.

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ABSTRACT

This article examines the health impacts of air pollution on educational achievement in one of the most polluted cities in the U.S.: Louisville, Kentucky. It examines the impacts of pollution on educational achievement. In Louisville, students attending elementary schools located near chemical factories were two to four times more likely to have health problems such as asthma, chronic obstructive pulmonary disease (COPD), and lung or heart disease than those living in other areas of the city, according to the Centers for Disease Control and Prevention. Yet little research has been performed on the impacts that toxic air pollution has on student achievement in elementary schools.

We compared ten public elementary schools located near chemical factories in the western Louisville neighborhood known as "Rubbertown" to ten elementary schools furthest away in wealthy east side of Louisville with the least exposure to toxic air. Our conclusions contradict the disinformation provided by the Louisville Air Pollution Control District. Our data indicates that: 1) air pollution has gotten a lot worse, not better, in Louisville, according to the U.S. Environmental Protection Agency's (EPA) risk screening environmental indicator; and 2) the quantities of toxic air that mostly minority school children are exposed to is 12 times higher than the mostly non-minority elementary schools elsewhere in the city. Consequently, reading, mathematics, attendance, and suspensions are far worse in schools near the polluting factories. Teacher retention in schools located in areas with high levels of air pollution is problematic, with one out of five leaving these schools every year as opposed to one out of 20 leaving schools in areas with less toxic healthier air quality.

INTRODUCTION

This study examines how highly polluted neighborhoods impact educational achievement. Empirical evidence has long supported the idea that poor air quality has adverse impacts on public health. In fact, it was this knowledge that initially prompted the Clean Air Act in the United States [1]. These effects can be exacerbated by living in close proximity to higher levels of air pollution. While multiple variables affect the quality of life for the groups discussed, air pollution appears to be a key component.

Impact of Air Pollution on Educational Performance

Air pollution is an environmental issue that leads to adverse health effects, affecting everyone in the community. The negative impact of air pollution on school children is an urgent problem that has not been effectively recognized. The early cognitive and biological development of children makes them more vulnerable than adults to air pollution. Studies have indicated that neighborhoods or schools close to hazardous waste sites are associated with lower levels of educational attainment, lower socioeconomic status, and a larger population of minority residents [2]. The few studies that have examined the relationship between air pollution and educational achievement have found alarming correlations of increased levels of pollutants with lower levels of intelligence quotient (IQ) and test scores [3-6].

The less time a child spends in school, the less opportunity there is to learn and receive help with academic skills. Air pollution can impact a child's health throughout the year, causing increased illness-related absenteeism [2]. Fatigue and respiratory illnesses are health effects caused by air pollution that have direct impacts on illness-related absenteeism. Research in the states of Texas, Maryland, and Nevada found that higher levels of air pollution were positively associated with absenteeism [7-9].

The relationship between air pollution and educational performance needs to be further studied, both within cities and neighborhoods, to better understand its impacts on absenteeism and educational achievement. Exposure to air pollution appears to adversely affect the brain and has been associated with decreased cognitive function in adolescents [2,10]. Longitudinal research has measured annual air pollution levels, cumulative air pollution, and short-term air pollution. The research has found statistically significant correlations with cognitive outcomes on reading and mathematics tests for children in kindergarten through the eighth grade. Studies have found a significant and inverse relationship between annual ozone measures and lower mathematics test scores in third grade students [2]. Greater exposure to air pollutants lengthens the effects they have on the body and the developing minds children [10]. Different air pollutants adversely affect the brain in various ways. For example, lead and methylmercury have been recognized as developmental neurotoxins and are associated with lower IQ [2]. A child's ability to stay focused in the classroom can lead to improved educational performance [3,6]. The thalamus is the part of the brain responsible for relaying motor and sensory skills, as well as regulating sleep and alertness. Air-borne particulate matter when inhaled by children has negative effects on thalamic volume [10].

Education can improve an individual's social mobility including the ability to access better quality neighborhoods. It is important factor for individuals hoping to improve their future opportunities. However, education alone does not determine physical health nor directly protect people from environmental hazards. Locally defining the problems of environmental degradation and their solutions will better address a range of social problems such as the years of projected life lost compared to average life expectancy.

While the majority of peer reviewed research suggests that air pollution has a negative impact on learning, there are other studies arguing that air pollution is not correlated with certain aspects of the educational process [8]. One study found that only a marginally significant trend in absenteeism was related to pollution levels in Maryland [6]. However, Maryland is among those U.S. states with the highest air quality and ranks in the nation's top 20th percentile; Kentucky ranks in the bottom 20th percentile in air pollution [11].

Impact of Air Pollution on Infant Health

Air pollution is potentially more damaging for infant children. While much research on the fetal origins hypothesis centers on how undernutrition, disease, and maternal health habits create lasting effects in newborns, a growing body of literature shows the links between proximity and exposure to air pollution and adverse health effects in the fetus [12].

Studies have confirmed the links between fetal exposure to pollution and higher infant mortality rates [13,14]. There are also established links between a reduction in environmental carbon monoxide and a reduction in instances of low birth weight [7,15]. Infants born weighting less than 5.5 lbs. (2.5 kg) often suffer from early sickness or infections and may have development issues as they grow older [16,17]. Each of these studies supports the notion that the proximity of a pregnant mother to higher levels of air pollution can adversely impact the health of the newborn child. These effects can take place in seemingly healthy babies later in life. Past research has also shown that prenatal exposure to a variety of types of air pollution negatively affects non-health endpoints later in life, such as academic test scores and economic outcomes [18]. Further work illustrates that adult non-health endpoints are affected as well. Both lower labor force participation and lower earnings are correlated with greater exposure to pollution at birth [19,20].

LOCAL IMPACT OF AIR POLLUTION

According to ProPublica, there are more than 1,000 places in the U.S. in which deadly toxins are released into the atmosphere by industries; an estimated 250,000 people living in these environmental hot spots likely have higher levels of cancer risk than the EPA deems acceptable [21]. Louisville, Kentucky is just one example of a city with a high rate of toxin emissions; we should be concerned about other places as well, particularly southern states, where there are fewer regulations on pollution.

City of Louisville officials often mention the metropolitan area’s clean air; an assertion unsupported by available evidence. One of the impacts that has not been explored is the effects of air pollution on the children attending Louisville’s elementary schools, the primary focus of this study.

Rubbertown: America’s Most Polluted Neighborhood

Rubbertown is a local moniker for an area in the far western corner of Louisville, located in Jefferson County, Kentucky. It is located on a large strip of land adjacent to the Ohio River that has 11 large chemical which are responsible for over 40% of Jefferson County’s air emissions. The history of Rubbertown is tainted with industrial accidents and unfortunate environmental devastation affecting workers in the area. There is a consensus that those who work in Rubbertown’s chemical factories face both dangerous and deadly environmental hazards. The LGE Mill Creek electric (1,465 MW) plant, operating since 1972, is located several miles south of Rubbertown and consumes about 4.8 million tons of coal annually. It has scrubbers to remove sulfur dioxide yet emits other types of hazardous air pollutants. Admitting to past emissions issues, LGE plans to install fabric filters or baghouses for all four coal-fired generating units to reduce particulate, mercury, sulfuric acid emissions and other hazardous air pollutants but intends to keep using coal.

Industrial accidents in Rubbertown have been severe and resulted in numerous worker deaths throughout the years. Several historic events highlight the tragedies of Rubbertown [22]. In 1961, approximately 1,000 residents were evacuated from a nearby neighborhood as a cloud of acrid gas formed from the former Stauffer Chemical Company. In 1965, an accident occurred resulting in the deaths of 12 workers who died from explosions and fires rolling through the DuPont synthetic rubber plant; there were at least 37 other injuries. In 1985, a tank explosion killed three workers at Borden Chemicals, and in 2001, an explosion at Carbide Industries killed two workers. Twentysix former B.F. Goodrich workers have died from liver cancer. A Public Broadcasting Service documentary, *Trade Secrets,* in 2001 on the chemical industry brought national attention to workers in Louisville's chemical plants who were dying prematurely [23]. These workers had disintegrating bones in their hands and up to 60 non-naturally occurring chemicals in their bodies. There are similar health impacts for residents who may not work in Rubbertown but who live nearby.

A Louisville Metro health report in 2013 noted that residents living in the poorest neighborhoods adjacent to the chemical industry park have much lower life expectancies—in certain cases over 10 years shorter than the average area resident [24]. This report analyzed cancer rates by local zip codes and found that rates of common forms of cancer are significantly higher in the Rubbertown zip codes. They also determined that people living in these zip codes have a 45% higher chance of contracting lung cancer and a 31% higher chance of getting colorectal cancer.

METHODOLOGY AND STUDY FOCUS

The methodology of our study was multifaceted. We performed an exhaustive and thorough search of information sources to ensure that the data we used was complete. Using the data available, we performed a two-group comparison. We researched the top ten elementary schools' assignment boundaries with the worst and best risk screening environmental indicator (RSEI) ratings [25]. We then used quantitative data to perform a simplified and multivariant regression analysis using a set of data from 82 JCPS elementary schools. Using the information from the comparative assessments and the regression analysis, we drew our key conclusions which were supported by the methodology. The study focuses on determining the impacts of air pollution on student health and education in elementary grades.

Attendance boundaries, sometimes known as school catchment areas, define the geographic extent served by a local school for the purpose of student assignments. According to the EPA's RSEI data, many are near Rubbertown's chemical factories, liquor distilleries, and other industrial plants. Using the RSEI data expands and strengthens our argument as it shows a pattern of uneven development in multiple minority and low-income neighborhoods across Louisville. Reliable and verifiable EPA, Centers for Disease Control and Protection (CDC), and Jefferson Country Public Schools (JCPS) data compared the quality of educational performance in elementary schools in heavily polluted neighborhoods to those in eastern Louisville [26]. Notice in Figure 1 (all Figures and Tables are found in Appendix A) the heavy concentration of chemical factories, coal burning factories, and liquor distilleries that are located near elementary schools in western Louisville. Conversely, the 10 elementary schools furthest away from these plants in eastern Louisville show very little air pollution.

JCPS operates 172 public schools with approximately 96,000 students as of 2022. Table 1 shows the demographic comparisons between the 10 least polluted schools and the 10 most polluted schools. Geographic information system and spatial analysis methods were used to assign REEI measures to each school based on spatial relationships assigned by the EPA. All of this data is publicly available. The schools located in areas with the poorest air quality (see Table 2) have student enrollments that are 75% less white and 250% more African American than their counterparts in areas where the schools have better air quality.

There are large economic gaps between the groups; as an economic proxy we used the free and reduced lunch programs. The schools in locations with poor air quality had an average of 46.3% of the students on reduced fee lunch programs; schools in locations with better air quality averaged 86.2% on reduced fee lunch programs. The demographic differences between levels of air quality in school zones tell a story about the long-lasting impacts of apartheid in Louisville that left minority and low-income communities powerless to prevent the endangerment of their neighborhoods by toxic industrial air pollution.

Data Sources

Pollution data was obtained from the EPA's publicly available (RSEI) gridded model [8,27]. The RSEI model uses the toxic release inventory (TRI) data reported by individual polluting facilities to estimate the risks of exposure to toxic emissions across the U.S. provided in an 810 m by 810 m grid format (roughly a half square mile). This publicly available data was spatially joined and averaged over the JCPS schools. The model considers the volume of chemical emissions weighted by the potential harm that the pollutants pose to humans.

Under the Emergency Planning and Community Right-to-Know Act of 1986, the EPA is required to annually collect and make publicly available information about industrial management of toxic chemicals [28]. To complete this, industrial facilities handling toxic waste are required to report on the quantities, composition, and management of their toxic wastes. Toxicity is calculated by assessed dosage and exposure at which harmful health effects, such as cancer, reproductive and developmental toxicity, neurotoxicity, and other forms of acute illness, threaten those exposed. This is further weighted by the strength of evidence as framed by the EPA guidelines for carcinogenic risk assessments [29]. It scales chemical toxicity as "0" for chemicals with no or inadequate evidence of toxicity to a weight of "1" for chemicals with sufficient evidence proving harmful exposure. For each school district, an average RSEI hazard score was generated by averaging the value of grids that overlapped school assignment zones.

Two Group Comparison

RSEI is a model that helps collect and explore data on toxic substances from industrial factories, specifically, the toxic chemicals released, together with factors of each chemical's relative toxicity and potential human exposure. Table 2 shows the air pollution profiles of the areas in Jefferson County where 10 schools (Group A) are located in areas with the lowest air quality and the 10 schools (Group B) located in areas with the best air quality. The results of student's *t*-test were used to determine the statistical significance of differences between the two groups.

When outdoor air quality is poor, it is introduced into the schools through the ventilation systems. When not in school, students continue to be exposed to the polluted air in their neighborhoods. Students attending the Group A schools located in areas with lowest air quality are 35 times more likely to be exposed to environmental toxins. They have an average of 76,714 pounds of air-borne toxins, while students attending the Group B schools, located in areas with the best air quality, have an average of 2,185 pounds of toxins. RSEI scores are designed to be comparable; a score 35 times higher than another indicates that there is a potential risk that is 35 times higher. Looking at the RSEI Scores in Table 2, which takes considers the estimated population in a grid cell, students in the Group A schools located in areas with lowest air quality have a risk of exposure to air-borne toxins that is 73 times higher than the risk of exposure the students in the Group B schools located in areas with the best air quality. Of those toxins, some are known carcinogens and others are considered to be detrimental to human health. The differences are alarming to learning and overall student health. The data also show that pollution levels are significantly increasing, which is contrary to the claims of the local air pollution control district which claims the air is improving [30].

Exposure to high levels of air pollution impacts learning ability with half the elementary students near Rubbertown factories unable to read or perform mathematics at proficiency levels comparable to schools located in areas with the best air quality which is dramatically higher. Student absenteeism is three times higher, and suspensions are 14 times higher in the Group A schools located near Rubbertown as compared to those in the Group B schools located in areas with the best air quality. Children with headaches, asthma, stomach aches, trouble breathing, and poor sleep have difficulties maintaining focus in the classroom.

Assessing Academic Differences

Academic success was assessed using the results of state testing and absenteeism rates. The Kentucky Performance Rating for Educational Progress (KPREP) is a standardized state test administered by the Kentucky Department of Education to assess student academic achievement. Elementary students are administered the KPREP exam annually to assess mathematics and reading skills. The reading and mathematics exams for elementary students are given to students in grades 3-5. Students in grades 4 and 5 take a writing skills exam as well. In addition, students in grade 4 take a science exam while those in grade 5 takes a social studies exam. Our assessment of academic differences studies elementary students from grades 3, 4 and 5 [31].

Over half of the elementary students in the Group A schools located near Rubbertown factories read at the novice level; only one-sixth of students share the same score in the Group B schools located in areas with the best air quality (Table 3). Moreover, there are three times more students who scored at the novice level in the reading section of the KPREP in the Group A schools located compared to the Group B schools. Students are much less likely to achieve distinguished scores in polluted schools. Nearly one-fourth of students in the least polluted schools scored in areas with poor air quality.

Similarly, the results of the mathematics scores mirror the reading scores (Table 4). Over half of the students in the Group A received the lowest score (novice) on the mathematics section of KPREP versus a small fraction of students in Group B schools. Further, just 4% of students in the Group A schools received a score of distinguished while one-fourth of students in the Group B schools scored at this level. Moreover, the mathematics scores were nearly twice as high for the students in the Group B schools compared to the Group A schools. Nearly one-fifth of teachers in the Group A schools leave the following school year versus; less than 5% leave the Group B schools.

Chronic absenteeism rates were used to assess academic performance. Chronic absenteeism is defined by JCPS as students who attended school for at least 10 days but no less than 90% of full-time equivalency. Chronically missing school can make it difficult for students to complete course work. It may be impacted by medical absences caused by chronic asthma attacks and other illnesses. Students attending the Group A schools located in areas with lowest air quality had a chronically absent rate that was three times the rate of students from Group B schools located in areas with the best air quality (Table 5). Nearly one quarter of the students from Group A schools missed 10% or more of the school year. Student suspension rate in the Group B schools was 1 for every 100 students, but 15 per 100 students in the Group A schools. Future research may seek to isolate medical absences from delinquency for more reflective results. Racial demographics are provided by JCPS and expressed via the proportion of Black students.

Regression Analysis

Using a simplified linear regression analysis, we used data from all 82 elementary schools in Jefferson County Public Schools with school zone pollution levels and compared five outcomes for JCPS: mathematics and reading test performance, absenteeism, suspensions, and teacher retention (see Table 6). Although detailed socio-economic data from JCPS was unavailable, we used a proxy variable (participation in school lunch program) as a measure of income. In the regression analysis, the two specific measures of school performance, air pollution and school lunch program participation, were measured against the five dependent variables: reading, mathematics, absenteeism, suspensions, and teacher retention.

Due to RSEI hazard levels being skewed towards larger values with pollution values growing exponentially as we near TRI facilities, the logarithm of RSEI hazard scores were used as the independent variable. The logarithm linear regression showed statistical support that pollution is significantly correlated with elementary education achievement. A logarithmic linear analysis was performed and the five key dependent variables were determined to be statistically significant at the p-value <.05. Pollution's impact on both reading and mathematics scores explained about half of the variation. Chronic absenteeism, suspensions and teacher retention were all statistically significant. These equations showed that pollution is statistically significant and potentially contributes to deficient in learning, the number of suspensions, rates of absenteeism, and poor teacher retention.

A multivariate regression was performed using standardized pollution and school lunch rates as independent variables against the same dependent variables of novice scores, chronic absenteeism, suspensions, and teacher retention (see Table 7). For KPREP reading and mathematics, lunch rates and pollution were both found to be statistically significant in modelling test scores with lunch rates being only slightly elevated in explanatory power than pollution. For chronic absences, pollution and lunch rates were significant explanatory variables; however, absences were nearly twice as sensitive to lunch rates as to air pollution. Suspensions were not well modeled by the inclusion of reduced cost lunch participation rates, yielding a low standardized coefficient of only 0.3 and a large $p = 0.759$, while pollution correlated significantly with suspension rates. This is a potentially important finding which suggests that either behavioral issues and/or the administration of punishments are more closely correlated with the development of toxic industries than the income of their parent. Conversely, teacher retention was weakly correlated with pollution levels, producing a $p < 0.10$, while reduced lunch program participation was significantly correlated at a 0.05 alpha level. Still, both correlated negatively with teacher retention with participation in reduced cost school lunch programs being slightly more explanatory than pollution levels.

CONCLUSION

Horace Mann, a Massachusetts educator, famously wrote in 1848, "Education, then beyond all other devices of human origin, is the great equalizer of the condition of men—the balance wheel of social machinery" [32]. While many have used education as for upward mobility, providing equal educational opportunity remains a major challenge. At the K-12 level, reliance on property taxes to fund public schools, tracking systems, and the resources wealthy parents can provide (SAT preparation tutorials, summer travel, music lessons, etc.) all bring social and societal inequities into the schools. The same dynamics are operative in institutions of higher education. They are manifest in legacy and development admissions (i.e., children of prospective donors have preference), early admissions programs requiring students confirm admission decisions prior to knowing the status of financial aid, and unpaid internships.

School policies often fail to fully consider the context in which schools operate. As education historian Jean Anyon once asserted: "… to solve the systemic problems of urban education, we need not only school reform but reform of these public policies as well" [33]. While this has long been known, what has not been recognized is the contribution of air pollution to inequities in education. This study focuses on Louisville, Kentucky but Louisville is not unique. Air pollution and its many costs are widely understood to be major challenges to the nation's metropolitan areas even if local officials often publicly minimize the extent or costs. These data demonstrate that toxic air pollution in Louisville has negative impacts on children's ability to learn, behave appropriately. It reduces rates of teacher retention. Yet the Air Pollution Control District final report claims that the "air is cleaner than ever" and that the air is not harmful to health [30].

This reveals deep injustice in regard to pollution and socio-economic inequality. Those who can afford to move to neighborhood schools with less polluted air tend to do so; those who cannot afford to move or desire to live in predominantly minority neighborhoods are faced with the consequences of living with toxic air pollution.

The larger point is that the neighborhoods in western Louisville (including just south of west Louisville), which include more than 62,000 residents of which 75% are Black, would benefit from tougher regulation of pollution. This would not only improve children's learning but also allow home values to increase, reducing the costly abandonment of homes, stimulating greater investment in homes and businesses, reducing medical costs and reducing crime with greater livability and homeownership. Why can't minority communities have equal justice and fairness when it comes to air quality? Our data provides strong evidence that toxic air pollution negatively impacts educational achievement.

Reducing air pollution will help change the lives of the economically disadvantaged, providing them with better educational opportunities. One solution to solving the inner-city educational crisis: expanded and tougher regulation of the city's toxic pollution, which is worse than nearly every other city in the nation. Another possible but costly solution is to relocate polluting factories far away from residential areas and public schools. Air pollution is costly to human lives and some forms create high levels of greenhouse gases. Pollution is not the only factor creating these challenges, but it is one that city leaders have often ignored.

In the words of Larissa Lockwood, Director of Clean Air at Global Action Plan, "Children have the right to breathe clean air [34]. As our Clean Air Day research showed, air pollution doesn't just affect a child's health, but can also affect their working memory and hence their ability to learn. To safeguard the future of our children's health and educational potential, we need to work together to take urgent actions […] to eliminate harmful pollutants."

The first step to resolving any problem is to describe it. When a nine-year old girl in London is declared dead from air pollution, it makes us wonder how many more children are also being harmed [35]. As London's Mayor Sadiq Khan stated, "Toxic air pollution is a public health crisis, especially for our children. Ministers and the previous Mayor have acted too slowly in the past, but they must now learn the lessons from the coroner's ruling and do much more to tackle the deadly scourge of air pollution in London and across the country." It makes us wonder how many other children are also being harmed. This research indicates that exposure to high levels of air pollution also impact the educational performance of young children.

OPPORTUNITIES FOR FUTURE RESEARCH

This is exploratory research using publicly available data which provides preliminary but fairly significant (statistically and otherwise) evidence on the impact of air pollution on educational achievement. Using this research study, we ask JCPS to provide additional information to enable us to asses student achievement scores. This data would consider achievement scores by gender, race, gender, socioeconomic status, housing tenure (renter or homeowner), one or two parents in the household, educational levels, and students' eligibility for free or reduced cost lunch. Further research should seek data in which the interschool socio-economic variability may be assessed in conjunction with academic achievement to further isolate the impact of wealth on academic achievement from pollution.

In the future we hope to explore the impact of low proficiency scores. A 2012 study found a strong correlation between low reading proficiency scores and decreased high school graduation rates [36]. More alarming are the strong connections between low literacy skills and incarceration rates which require further study. For example, 85% of all juveniles who interface with the juvenile court system and more than 60% of all prison inmates are functionally illiterate [37].

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AUTHOR BIOGRAPHIES

John "Hans" Gilderbloom is a professor in the University of Louisville (UofL) graduate Planning, Public Administration, Sustainability, and Urban Affairs program. He is a former professor of economics in the College of Business at the UofL, where he directed the Center for Sustainable Urban Neighborhoods for 30 years. His research in sustainability, health, housing, and green renewal has appeared in eight books, 63 scholarly journals, 30 chapters in edited books, 11 monographs plus opinion pieces in the *Wall Street Journal, Washington Post, Los Angeles Times, New York Times, Chicago Sun-Times, San Francisco Chronicle*, *Courier-Journal*, and *USA Today* magazine. He won the UofL Presidential medal for distinguished research. Dr. Gilderbloom earned as one of the top urban thinkers according to an international survey by Planetizen. Dr. Gilderbloom was recognized by the American Sociological Association for a lifetime achievement award for Urban and Community studies. Email: john.gilderbloom@louisville.edu.

Isaiah Kingsberry is a graduate research assistant at the UofL department of geography and geosciences. A Woodford R. Porter Scholar recipient and National Science Foundation research participant, Isaiah's research aims to understand the gaps between our physical and experienced environments. He earned his master's degree in geography in 2022. Email: Isaiah.kingsberry@louisville.edu.

Gregory D. Squires is a research professor and professor emeritus in the department of sociology at George Washington University. He has served as a board member, consultant or advisor to several government and non-profit organizations including the Consumer Advisory Council of the Federal Reserve Board, Housing and Urban Development's Office for Fair Housing and Equal Opportunity, National Association of Insurance Commissioners, U.S. Commission on Civil Rights, Social Science Advisory Board of the Poverty and Race Research Action Council, Fair Housing Task Force of the Leadership Conference on Civil and Human Rights and several others. He is currently a community development columnist for *Social Policy*. Email: squires@gwu.edu.

Charlie Zhang, is a professor at the department of geographic and environmental sciences, University of Louisville. He is an urban geographer with research interests and expertise in crime

mapping, school segregation, environmental pollution, and health disparities. Dr. Zhang's publications have appeared in premier academic journals including *Environmental Pollution, Environmental Research*, *Environmental Science and Technology*, *Exposure & Health*, *Journal of Exposure Science & Environmental Epidemiology*, *Journal of Rural Health*, *Journal of Urban Affairs,* and *Urban Geography*. Email: c.zhang@louisville.edu.

Ellen Slaten holds a Ph.D. in sociology from the University of Texas at Austin. She previously worked in the Department of Psychiatry at The University of Texas Health Science Center at San Antonio, where she coordinated several federally funded research projects, including a study of family caregivers for people with HIV/AIDS and a study of people with psychiatric illnesses who were in a supported employment program. Dr. Slaten also served as the evaluator for an HIV/AIDS education program for mental health providers. She evaluated proposals for the Texas Workforce Commission and recently joined Neighborhood Associates as a colleague. Email: ellen.slaten@gmail.com

APPENDIX A

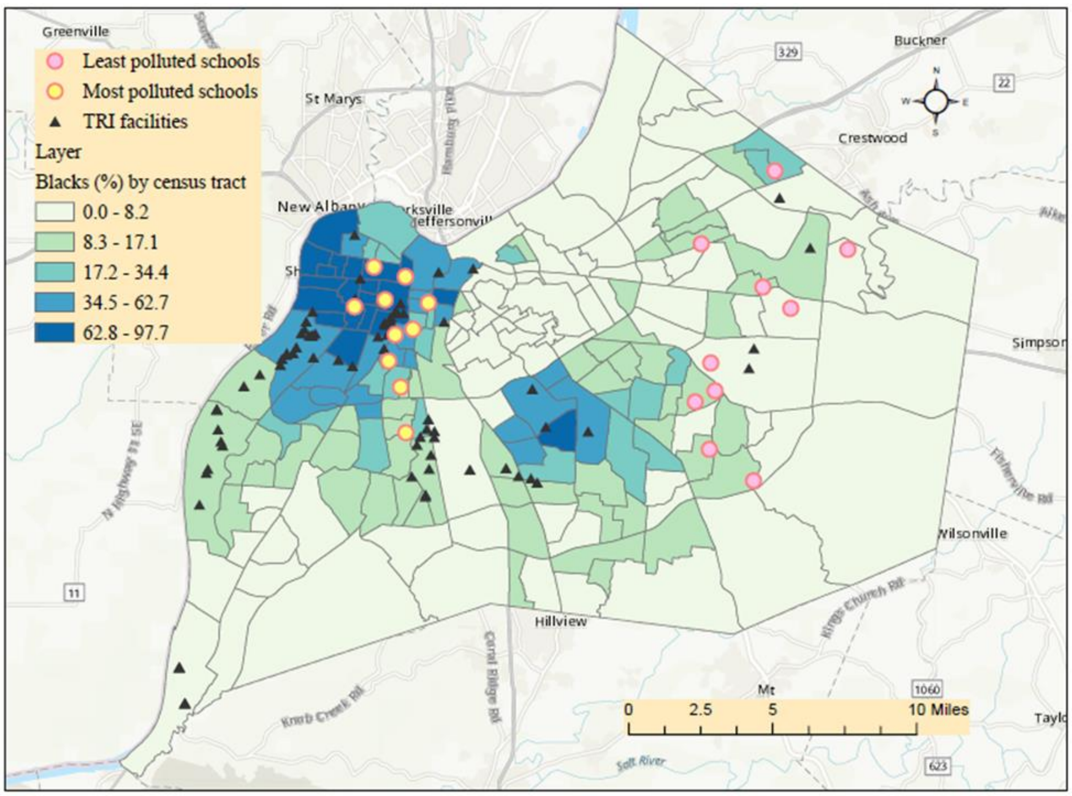

Figure 1. The 10 most and least polluted elementary school attendance zones in JCPS (source: CASCADE JCPS Data Portal and EPA's risk screening environmental indicator 810m x 810m micro-gridded data).

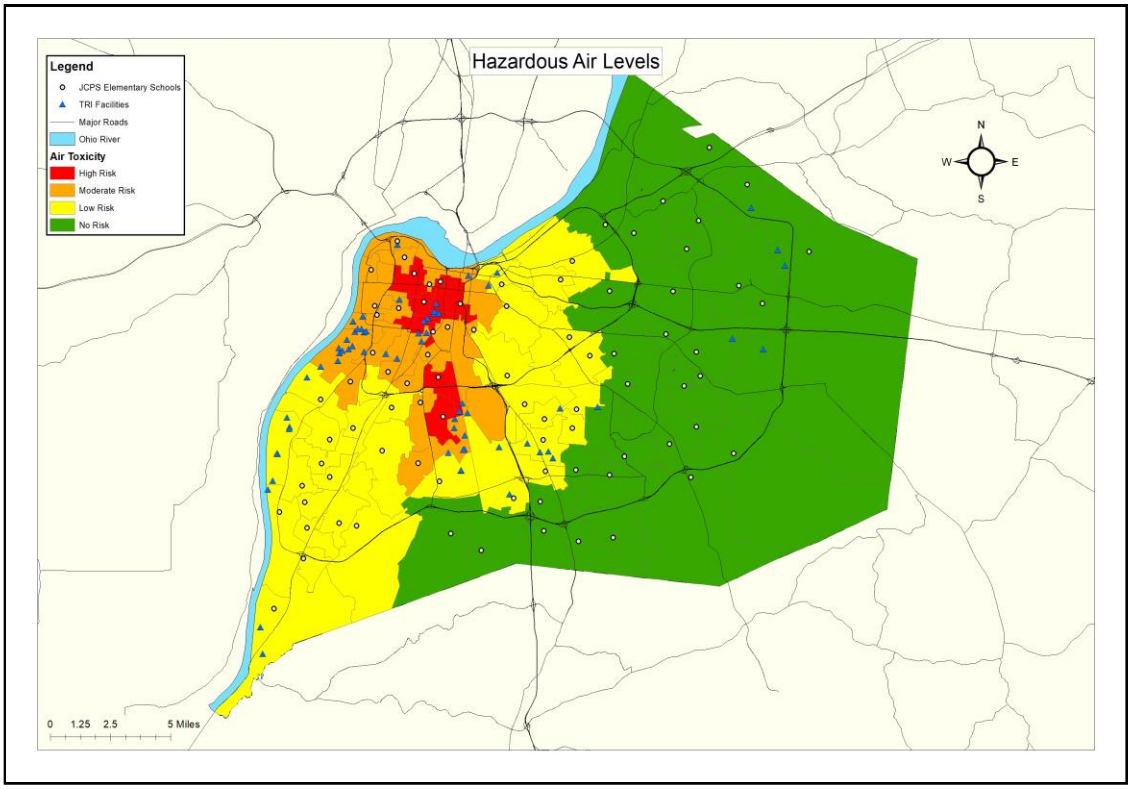

Figure 2. Map of JCPS public elementary school locations and hazardous air levels in Jefferson County (Source: CASCADE JCPS Data Portal and EPA's risk screening environmental indicator 810m x 810m micro-gridded data.)

Table 1. Demographic comparisons between most and least polluted schools in the JCPS district (source: CASCADE JCPS Data Portal [26]).

Groups	*Statistics*	*% Black*	*% White*	*% Hispanic*	*% Other*	*Free/reduced lunch rate*
A. 10 least polluted schools	Mean	18.4	54.8	13.0	11.	46.3
	Std. dev.	8.7	13.7	8.7	1.2	16.4
B. 10 most polluted schools	Mean	65.5	15.5	10.1	7.4	86.2
	Std. dev.	18.4	10.7	7.2	2.8	4.5
Mean difference		47.1	-39.3	-2.9	-3.7	39.9
Student *t*-test	*p*-value	< 0.001	< 0.001	0.429	0.002	< 0.001

Table 2. Risk screening environmental indicator pollution profiles for most and least polluted schools in the JCPS district (source: CASCADE JCPS Data Portal and EPA's risk screening environmental indicator 810m x 810m micro-gridded data.)

Groups	*Statistics*	*Toxic-weighted pounds*	*RSEI score*	*RSEI score - cancer*	*RSEI score - non-cancer*
A. 10 least polluted schools	Mean	2,184.67	283.50	273.68	16.05
	Std. dev.	454.40	188.01	181.27	11.78
B. 10 most polluted schools	Mean	76,713.80	20,928.62	20,835.75	532.81
	Std. dev.	25,889.49	7,208.18	7,183.85	331.80
Mean difference		74,529.13	20,645.12	20,562.07	516.76
Student *t*-test	*p*-value	< 0.001	< 0.001	< 0.001	< 0.001

Table 3. Kentucky Performance Rating for Educational Progress (KPREP) Reading Performance Comparison (source: CASCADE JCPS Data Portal).

Groups	*Statistics*	*Reading - novice*	*Reading - apprentice*	*Reading - proficient*	*Reading - distinguished*	*Reading - total score*
A. 10 least polluted schools	Mean	16.3	22.9	36.3	24.5	2.7
	Std. dev.	7.6	5.3	3.7	10.5	0.3
B. 10 most polluted schools	Mean	53.7	25.5	16.0	4.8	1.7
	Std. Dev.	12.8	3.9	7.1	4.3	0.3
Mean difference		37.4	2.6	-20.3	-19.6	-1.0
Student *t*-test	p-value	< 0.001	0.233	< 0.001	< 0.001	

Table 4. Kentucky Performance Rating for Educational Progress (KPREP) mathematics performance comparison (source: CASCADE JCPS Data Portal).

Groups	*Statistics*	*Math - novice*	*Math - apprentice*	*Math - proficient*	*Math - distinguished*	*Math - total score*
A. 10 least polluted schools	Mean	15.2	27.9	33.7	23.2	2.6
	Std. dev.	7.3	7.3	5.5	10.4	0.3
B. 10 most polluted schools	Mean	51.8	31.2	13.1	3.9	1.7
	Std. dev.	17.3	5.2	9.3	4.6	0.4
Mean difference		36.6	3.3	-20.6	-19.3	-1.0
Student *t*-test	*p*-value	< 0.001	0.257	< 0.001	< 0.001	

Table 5. Additional performance indicators (source: CASCADE JCPS Data Portal).

Groups	*Statistics*	*Teacher retention (%)*	*Teacher attendance (%)*	*Chronically absent (%)*	*Suspensions (%)*
A. 10 least polluted schools	Mean	94.6	95.0	8.8	1.4
	Std. dev.	5.0	1.0	4.0	1.3
B. 10 most polluted schools	Mean	81.6	94.6	24.2	15.1
	Std. dev.	10.6	0.7	6.5	13.5
Mean difference		-13.0	-0.4	15.4	13.7
Student *t*-test	*p*-value	< 0.01	0.268	< 0.001	< 0.001

Table 6. Results of simple linear regression: RSEI toxic hazard log score, sample of 82 elementary schools in Jefferson County (source: CASCADE JCPS Data Portal and the EPA's risk screening environmental indicator, 810m x 810m micro-gridded data).

Dependent variable	*Coefficients*		*Adjusted R squared*
	Log (RSEI)	*Intercept*	
Reading - Novice (%)	25.443 (p < 0.001)	-70.447 (p<0.001)	0.581
Reading math – Novice (%)	25.377 (p < 0.001)	-71.816 (p < 0.001)	0.498
Chronic absence (%)	10.011 (p < 0.001)	-23.449 (p < 0.001)	0.463
Suspensions (%)	8.560 (p < 0.001)	-29.284 (p < 0.001)	0.286
Teacher retention (%)	-8.786 (p < 0.001)	123.481 (p < 0.001)	0.185

Table 7. Standardized regression, *N*=82 (source: CASCADE JCPS Data Portal and the EPA's risk screening environmental indicator, 810m x 810m micro-gridded data).

Dependent variable	*Coefficients*			*Adjusted R squared*
	Intercept	*RSEI - Pollution*	*Free/Reduced lunch*	
Reading – Novice (%)	32.725 (p<0.001)	6.130 (p < 0.001)	8.333 (p<0.001)	1.720
Reading math – Novice (%)	31.089 (p<0.001)	6.915 (p<0.001)	7.178 (p<0.001)	0.585
Chronic absence (%)	17.147 (p<0.001)	1.718 (p = 0.008)	4.262 (p<0.001)	0.652
Suspensions (%)	5.425 (p<0.001)	3.828 (p<0.001)	0.304 (p=0.759)	0.278
Teacher retention (%)	87.855 (p<0.001)	-2.125 (p=0.104)	-2.865 (p=0.029)	0.223