
Reading, writing, and toxics: children's health, academic performance, and environmental justice in Los Angeles

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Abstract. A significant body of previous research on environmental justice has demonstrated a disproportionate burden of environmental hazards on low-income and minority residents. In this paper we evaluate spatially indexed data on estimated respiratory and cancer risks associated with exposures to ambient air toxics to show that children of color in the Los Angeles Unified School District suffer potentially disparate health impacts, and that disparities in environmental risks may be associated with diminished school performance—even after controlling for socioeconomic and demographic covariates that generally explain much of the variation in student scores. Remediating environmental health risks in distressed neighborhoods could, therefore, improve both health and human capital.

Introduction

For many years researchers and activists in the environmental justice movement have argued that communities of color are disproportionately exposed to various forms of environmental risks. Although some critics have suggested that the evidence from studies conducted both on regional and on national scales is inconclusive, studies focused on Southern California have consistently demonstrated a positive relationship between minority presence and environmental hazards—even after controlling for other demographic and land-use covariates that should explain hazard location (Boer et al, 1997; Pulido et al, 1996; Sadd et al, 1999). Perhaps this seeming environmental inequity explains why the region has become a hotbed of environmental activism: community organizations have, for example, forced the local air quality district to tighten rules on facility air emissions in minority communities, and most recently led a campaign that prompted a major utility company to abandon plans to site a power plant in an area already overburdened by air pollution (Clifford, 1997; Cone, 2000; Martin, 2001).

Recently, various community actors in Southern California have taken up the question of school location and environmental hazards, leading to a series of dramatic controversies and policy changes. For example, construction on the Belmont Learning Complex, a new, state-of-the-art school designed to relieve overcrowding in a largely Latino immigrant neighborhood in Los Angeles, was halted when it was made public that the school site was a former oil field with active methane gas leaks and soil contaminated with carcinogenic compounds. Partly because the district had actually been forewarned of the problem and had gone ahead with construction anyway,

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a scandal ensued that eventually led to the firing of the incumbent superintendent (Anderson, 2000).

The charged political atmosphere around schools and the environment has led to a new sense of caution on the part of public officials. When traces of arsenic were discovered in a kindergarten area in a school built over a landfill, the Los Angeles Unified School District (LAUSD) commissioned a study that concluded that the levels were higher than normal but not dangerous, and so recommended continued monitoring. In May 2001 a public meeting was held with a crowd of 500 parents, teachers, and children worried that reported cancer cases and asthma were resulting from the contamination. To the surprise and delight of the assembled activists, the district chief facilities officer announced that the preliminary recommendation of more monitoring would be ignored and US \$7.2 million would be spent to excavate and remove contaminated soil (Cardenas, 2001).⁽¹⁾

Because both of these incidents have occurred in the context of schools serving disproportionately Latino student bodies, many have suggested that environmental racism has played a role in the pattern. As it turns out, preliminary research in the district appears to support the claim of racial disproportionality in exposure: for example, indices of estimated lifetime cancer risk and respiratory hazards associated with cumulative exposure to over 148 ambient air toxics are positively correlated with Latino and other minority presence in Los Angeles schools, even after controlling for other neighborhood characteristics that might explain this pattern (Pastor et al, 2002). However, critics of the environmental justice movement, such as Foreman (1998) and Bowen (2001), have begun to question whether observed racial disparities in exposures to environmental hazards are truly consequential for human health and well-being. Foreman, for example, has suggested that the focus on race and the introduction of a discrimination framework to understand the patterns is intended more to contribute to the building of a new political movement than to the development of good science and environmental policy.

In this paper we take up the theoretical and empirical challenges posed by the critics in the context of a particular study of race, health, and learning. We first offer a brief overview of the quantitative empirical work on environmental inequity, focusing particularly on the results for our general study area in Southern California. We propose a conceptual framework for understanding how social and environmental inequality can negatively impact a crucial community asset—human capital. We suggest that one way to examine this framework empirically is to assess the relationship between demographic disparities in environmental hazard exposures and associated health risks among Los Angeles schoolchildren, with a focus on the attendant effect on school performance.

To test the relationship between learning and environmental hazards, we combine data on school demographics, academic performance, and indicators of environmental hazards, such as proximity to Toxic Release Inventory (TRI) emissions and estimated respiratory risks associated with concentrations of outdoor air toxics for the area encompassing the LAUSD. We find that environmental hazard indicators are associated with diminished school-level academic performance even after controlling for key explanatory variables, such as percentage of students on free lunches, teacher quality, and percentage of English learners. Delineating safe areas for schools and cleaning up problems at existing schools could therefore contribute to improving the academic

⁽¹⁾ Interestingly, in September 2001, lead-contaminated soil was discovered at the Avalon School (also predominantly Latino and in the nearby Long Beach, CA, school district). This also prompted temporary relocation of the school until cleanup can be completed, suggesting that local politicians are wary of accusations of environmental inequity.

achievement of inner-city schoolchildren and possibly enhance the human capital potential of vulnerable communities. Challenging environmental racism could, in short, have serious positive consequences that go beyond movement building and aid in a longer term effort to craft a more positive future for communities and children already facing serious obstacles to achievement and economic success.

Environmental inequality, health, and human capital: the state of the debate and a conceptual framework

The issue of environmental justice has given rise to a vibrant and often contentious body of research. Whereas early studies, including the landmark examination of hazardous-waste landfills by the United Church of Christ (1987), found evidence of disparities in the distribution of potentially hazardous facilities, some researchers have argued that there are insignificant racial differences on a national scale after controlling for income and other covariates that could account for the location of environmental disamenities (Anderton et al, 1994a; 1994b). Yet other studies indicate that environmental disparities by race to exist at a national level, and further suggest that at least some of these ethnic differences are caused in part by discriminatory siting (Been, 1994; 1995; Been and Gupta, 1997). In a recent nationwide statistical study, Lester et al (2001) found evidence supportive of the environmental inequity hypotheses which holds across several different specifications; the result is all the more striking because the researchers were initially quite skeptical and were expecting to refute the claims of many environmental justice proponents.

In general, however, the literature on environmental justice research has yielded mixed results—depending on the region of the country under study (Baden and Coursey, 1997; Bowen et al, 1995; Ringquist, 1997; Stretesky and Hogan, 1998; Szasz and Meuser, 1997; US EPA, 1992). We have argued elsewhere that such regional variation is to be expected and that the region is actually the geographic scale of most interest and relevance for testing environmental disparity: industrial clusters are often rooted in regional economies and thus the equity question is that of how the social costs of such industries are distributed within the regions that host them (Sadd et al, 1999). Our own studies of the Southern California region, which has some of the worst air quality in the country, have consistently found a disproportionate burden borne by people of color in the location of toxic treatment, storage, and disposal facilities (TSDF), TRI facilities,⁽²⁾ and toxic air releases (Boer et al, 1997; Sadd et al, 1999). In a more recent effort, we tested and found that the lifetime cancer risk associated with cumulative exposure to ambient air toxics was unequal by race—even when one accounted for income, local land use, and other factors generally deemed relevant to local air-pollution levels (Morello-Frosch et al, 2001).

The fact that these and other studies have tended to look at cross-sectional variations in exposure have led to the suggestion that the location of environmental disamenities in minority neighborhoods merely reflects market choice: minorities may have chosen to congregate in polluted areas because they are lower rent (see, for example, the critique by Bowen, 1999). To get at this issue, we recently conducted a unique and very detailed historical study on the timing of TSDF siting (Pastor et al, 2001). The results, derived through a series of multivariate models which included two-stage least squares estimates to control for simultaneous processes, suggest that the problem in Los Angeles County has been the siting of facilities

⁽²⁾The TRI includes emissions estimates from large industrial facilities which are required to report to the US Environmental Protection Agency this information under the Emergency Planning and Community Right-to-Know provisions of the Superfund Amendments and Reauthorization Act (SARA) of 1986.

in minority neighborhoods and not simply a market-induced move of members of these minorities into lower rent, already polluted, areas.

With the racial disparity demonstrated across a range of hazards, and the timing issue tackled in the context of one in which dating is possible, some critics of environmental justice (Bowen, 1999; 2001; Foreman, 1998) have begun to suggest that too little is known about actual risks and thus the differences in environmental exposure may not, in fact, be that significant. Foreman, in particular, has also argued that the activist focus on company-induced hazards, such as toxic storage and disposal facilities, has led to a deemphasis on other epidemiological factors, or even individual behavior with regard to smoking or drinking; in his view, political targeting is taking precedence over health. He goes on to argue that too much time is spent on emotive issues and not enough on gauging actual impact or health consequences. Bowen is more circumspect, arguing for caution in policymaking because of worries that new policy initiatives, poorly informed by research, might bring unintended consequences.

As it turns out, with a few exceptions, the ability of researchers to link the presence of potentially hazardous facilities or environmental pollution conclusively with adverse health effects has remained frustratingly elusive (Institute of Medicine, 1999). The reason is partly that confirming or disputing the risk–illness connection generally requires detailed epidemiological studies that are difficult and expensive to mount; one recent exception is a correlational study by researchers at University of California at Los Angeles and University of Southern California who linked ambient air pollution to a higher risk of birth defects in Southern California (Ritz et al, 2002). As the research moves forward at a pace slow enough to respond to the flags of methodological caution, activists worry that many communities may be getting sick.

One way to get at this issue of consequences with the available aggregate data may be to shift focus slightly. In virtually all previous environmental justice research, including our own, the focus has been on the location of hazards and potential pollution exposures relative to where people live—and many of the implicit medical models are normed against adult males. However, increasing scientific evidence suggests that children may be more susceptible to the effects of environmental pollution than adults because of fundamental differences in their physiology, metabolism, and absorption and exposure patterns, suggesting that effects might show up first and most dramatically in this sector of the population (see Crom, 1994; Guzelian et al, 1992; Kaplan and Morris, 2000; Parkinson, 1996). Partly because of this research, Executive Order 13045, issued in 1997, directs federal agencies to consider the particular vulnerability of children to environmental health risks. Certain childhood diseases (for example, respiratory illnesses such as asthma) have become an increasingly significant health problem (Leikauf et al, 1995; Mannino et al, 1998) and hazardous air pollutants (HAPs) or air toxics could be aggravating these conditions (Burg and Gist, 1998; Leikauf et al, 1995; Ware et al, 1993). And although children are certainly affected by these threats in their home and neighborhoods, they spend much of their day in schools—and these schools may or may not be located in the communities where they live, particularly given magnet programs and cross-town busing in major urban areas like Los Angeles.

Anecdotal, epidemiological, and exposure studies do, in fact, suggest potential short-term and long-term health effects among school children from outdoor and indoor air pollutants (Gilliland et al, 1999; Guo et al, 1999; Jedrychowski and Flak, 1998; National Environmental Trust, 2000; Schettler et al, 1999; 2000; Van Vliet et al, 1997), potentially hazardous facilities (Ginns and Gatrell, 1996; Gomzi and Saric, 1997), and pesticides (Northwest Coalition for Alternatives to Pesticides, 2000; US General Accounting

Office, 1999).⁽³⁾ That these patterns have given rise to popular concern is demonstrated in the title of a recent publication put out by one activist organization, the Center for Health, Environment and Justice: *Poisoned Schools: Invisible Threats, Visible Actions* (CHEJ, 2001).

What, however, are the potential consequences of such environmental hazards for other measurable outcomes? Certainly, adverse health outcomes are one issue and numerous community groups have expressed concern about ‘cancer clusters’ that have affected youth as well as adults. But childhood respiratory problems have also been associated directly and indirectly with lower academic performance (Bener et al, 1994; Fowler et al, 1992). In some communities, parents have complained of diminished school performance among their children because of health effects associated with outdoor and other pollution (Diette et al, 2000; Kaplan and Morris, 2000; Perera et al, 1999). The growing sense is that there may be a link between disparate levels of air pollution and differences in human-capital formation and realization.

Unfortunately, actual scientific information on the exposures and public health impacts of air pollution among children at school is generally sparse, and few researchers have focused on environmental inequalities among children (Friedrich, 2000; Kraft and Scheberle, 1995; Stephens, 1996). Moreover, the theoretical frameworks used to approach the problem are generally quite sparse, consisting of specifications of functional relationships between variables that are poorly placed in a broader model of how socioeconomic and institutional forces create a range of environmental health risks to diverse communities, which in turn determine inequalities in community susceptibility to environmental hazards (Morello-Frosch et al, 2002; Pulido et al, 1996).

One effort at a broader framework, originally developed by Morello-Frosch et al (2002), is depicted in figure 1 (over). The framework illustrates how patterns of social inequality, segregation, and discrimination can interact with community capacity to shape patterns of economic and regional development. The interaction of these institutional and structural processes of inequality in income and power ultimately places additional environmental stress on communities of color through the placement of potentially hazardous facilities, transportation corridors, and pollutant exposures through various media (Hamilton, 1995). The adverse effects of these intersecting processes can be observed through specific public health outcomes, which ultimately erode community-based human capital. This, in turn, can lead to a further diminishing of community economic capacity or ‘human capital’, plunging communities into a sort of vicious circle of despair and decline. One dimension of that decline in human capital might be found in the public school system in terms of educational achievement, the focus of this study.

Data and methods

To assess whether, in fact, exposure to environmental hazards and potential respiratory risks may impact one indicator of human capital—school performance—we decided to explore the relationship between school educational outcomes and environmental hazard and health-risk indicators. The universe for this paper is the LAUSD, the second most populous school district in the USA, enrolling over 700 000 students as of Fall 1999, and covering 704 square miles. Using standard geographic information system (GIS) procedures, we geocoded all LAUSD school locations and matched them to land-use data showing actual school footprints,

⁽³⁾ Many of these studies have been conducted in other countries and it is unclear whether or not their results can be meaningfully generalized to children in the United States.

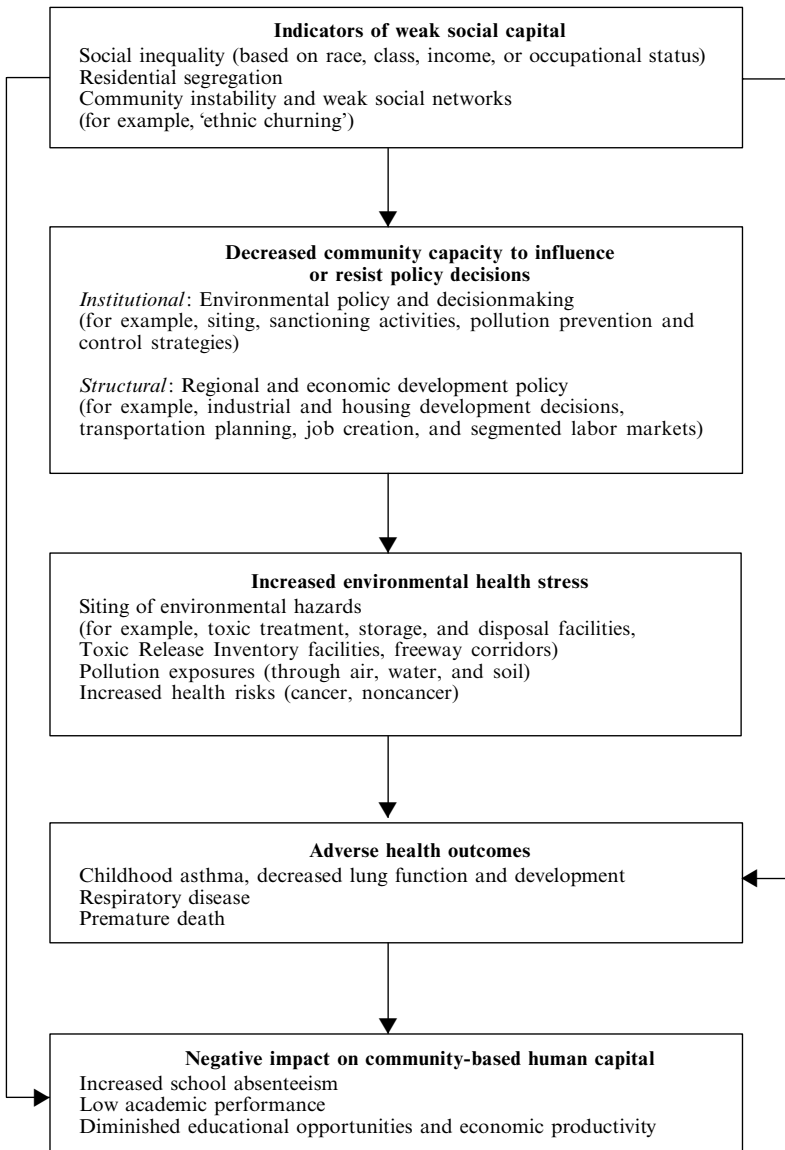


Figure 1. Environmental inequality and community-based human capital.

and then joined this spatial information to tract-level information on environmental hazards and air quality.⁽⁴⁾

The specific environmental hazard indicators used were: (1) the point locations of emission facilities from the 1997 TRI, provided by the US EPA⁽⁵⁾ with locations verified for accuracy (Sadd et al, 1999); and (2) tract-level estimates of respiratory risk associated with exposure to 148 ambient air toxics both from mobile and from

⁽⁴⁾ Demographic information on race and income from the 1990 Census (Summary Tape Files 1 and 3) (US Bureau of the Census, 1992) and 1993 land use for the study area from the Southern California Association of Governments (1999) was used to establish the nature of environmental inequity between schools, which is discussed elsewhere (see Pastor et al, 2002).

⁽⁵⁾ Obtained at US Environmental Protection Agency website <http://www.epa.gov/tri/tridata/tri97/>.

stationary sources. Whereas the TRI dataset is familiar to researchers in this field, the respiratory-hazard index merits explanation. It is derived by combining modeled estimates of concentrations of ambient air toxics with corresponding toxicity data that are relevant to respiratory effects. Exposure data were derived from a modeling analysis undertaken by the US EPA's Cumulative Exposure Project (CEP), which estimated long-term average concentrations of 148 air toxics for every census tract in the contiguous United States for 1990 (US EPA, 1998). Emissions data used in the model take into account large stationary sources (such as TRI facilities), but go beyond the TRI in the inclusion of small area service industries and fabricators (such as dry cleaners, auto body paint shops, and furniture manufacturers) and mobile sources (such as cars, trucks, and aircraft). The modeling algorithm takes into account meteorological data, and simulation of atmospheric processes (see Morello-Frosch et al, 2000; Rosenbaum et al, 1999; 2000).

We take these data one step further by calculating a respiratory-hazard index associated with outdoor air toxics exposures in which we divide pollutant-concentration estimates by their corresponding reference concentration (RfC) to derive a hazard ratio. An RfC for chronic respiratory effects is defined as the amount of toxicant below which long-term exposure of the general population of humans, including sensitive subgroups, is not anticipated to result in any adverse effects (Dourson and Stara, 1983). The actual respiratory-hazard ratios for each pollutant in each census tract were calculated from the following formula:

$$HR_{ij} = \frac{C_{ij}}{RfC_j},$$

where HR_{ij} is the hazard ratio for pollutant j in tract i , C_{ij} is the concentration in $\mu\text{g m}^{-3}$ of pollutant j in census tract i , and RfC_j is the reference concentration for pollutant j in $\mu\text{g m}^{-3}$. An indicator of total respiratory hazard was calculated by summing together the hazard ratios for each pollutant in order to derive a total respiratory-hazard index:

$$HI_i = \sum_j HR_{ij},$$

where HI_i is the sum of the hazard ratios for all pollutants (j) in census tract i . This measure assumes that multiple subthreshold exposures may result in an adverse health effect. The methods for deriving a respiratory-hazard index comply with recommendations for conducting screening-level noncancer risk assessments for multiple pollutants under the Superfund Guidance, California's AB2588 'Hot Spots' Guidelines, and the US EPA's Chemical Mixtures Guidelines (CAPCOA, 1993; Morello-Frosch et al, 2000; US EPA, 1986a).

Cancer-risk estimates were derived by use of inhalation unit risk (IUR) estimates, which are a measure of carcinogenic potency for each pollutant (US EPA, 1986b). Cancer risks for each pollutant in each census tract were derived with the following formula:

$$R_{ij} = C_{ij} \times IUR_j,$$

where R_{ij} is the estimate of individual lifetime cancer risk from pollutant j in census tract i , C_{ij} is the concentration of hazardous air pollutant j in $\mu\text{g m}^{-3}$ in census tract i , and IUR_j is the inhalation unit risk estimate, or cancer potency, for pollutant j in $(\mu\text{g m}^{-3})^{-1}$. The cancer risks of different air toxics were assumed to be additive, and were summed together in each census tract to estimate a total individual lifetime cancer risk in each tract.

School-level information was taken from a state database which records the Academic Performance Index (API). Mandated by the State of California under the Public Schools Accountability Act of 1999, the API is a summary score of school performance based on the Stanford 9 achievement test given as part of the state's testing program; we specifically used the results for the test administered in Spring 1999 because this was the first year it was used and it is the set of observations closest in timing to the data we have on cumulative exposure and TRI proximity. In order to contextualize measures of school performance, the state includes in this database a limit set of school-level variables, including student demography, a proxy for poverty, a measure of teacher quality, and other related factors. Because such measures have been shown in other research to have an effect on school performance, we make use of those additional variables in our regressions below, linking them to the tract-level information on our hazard and risk measures.

Results

We begin by reviewing the general issue of environmental inequities faced by schoolchildren in the LAUSD; as this was explored by us in a previous paper (Pastor et al, 2002), we confine our attention here to the main points before considering the impacts on school performance. As it turns out, those census tracts that are within the LAUSD boundaries and actually contain schools are more likely to be located near potentially hazardous facilities, such as TSDFs and TRIs, than are within-district tracts that do not host a school. When we look at the schools themselves, the data suggest that minority students, especially Latinos, are more likely to bear the burden of attending a school near potentially hazardous facilities, and also face higher cumulative cancer and noncancer health risks associated with outdoor air toxics exposures (see figure 2).

Of course, the immediate question is whether this is simply a manifestation of other, underlying, factors. To investigate, we conducted a multivariate analysis in which four dependent variables—estimated cancer and respiratory risks associated with ambient air toxics, and the likelihood of being in close proximity to either TSDF or TRI facility—were regressed on the proportion of minority students within a school, as well as tract-level characteristics such as industrial land use, population density, median household income, and the rate of homeownership. Results showed that the proportion of students of color at a school site was a consistently significant factor for predicting risk estimates and facility location, even after controlling for the other socioeconomic and land-use variables; the result held even when we controlled for the percentage of minority persons living in the neighborhood, suggesting that the

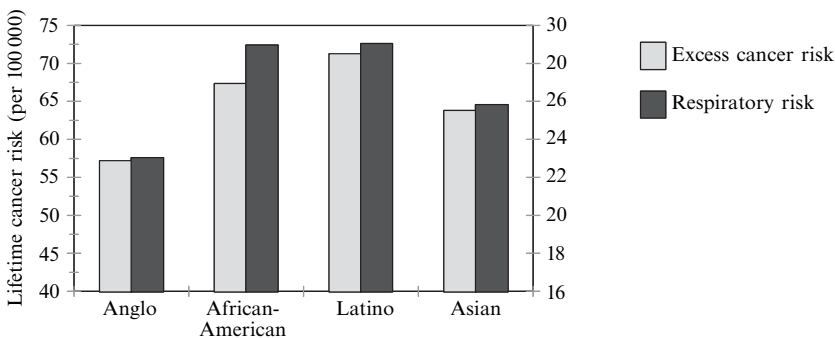


Figure 2. Cancer and respiratory risks for schoolchildren by race, Los Angeles Unified Schools District.

result correlating risk for, and color of students does not merely reflect the already demonstrated disparities in exposure by residence.

In this paper, we attempt to assess the relationship of these ambient air pollution levels with learning outcomes. To explore this, we borrowed from fairly standard models of 'educational production functions' (Hanushek, 1986). Several important caveats are in order. We do not have individual student performance data, but rather the API score for the entire school that is used by the state for ranking purposes (Koretz, 1997). As a result, we are in the tradition of those studies that focus on aggregate performance rather than in those that look at individual student performance (Bickel and Howley, 2000; Fowler and Walberg, 1991). However, as Bickel and Howley note, such school-level studies are increasingly common because of the way in which states and school districts have focused on the school as the unit of accountability (Powers, 2001).

We began the analysis by building a base regression in which a school's performance index, or API score, was a function of the percentage of children receiving free school lunches (see Krueger, 1999; Orfield, 1997), the percentage of teachers with emergency credentials (a proxy for teaching quality) (Darling-Hammond, 2000), and the percentage of students who are learning English.⁽⁶⁾ We also introduced a measure of school size; the research on whether school size has an impact on academic performance is reviewed in Fowler (1995) and the general pattern suggests a negative effect, with the general notion being that smaller schools can more easily offer students individual attention.⁽⁷⁾ We also introduced a measure of student mobility (the number of students who are new to the school that year) because of the notion that continual changes in school registration could produce lower performance.⁽⁸⁾ Interestingly, class size, the subject of recent heated debate between a series of researchers and policy-makers (see Hanushek, 2000; Krueger, 2000), did not have a significant impact on the school score; although we tested to find this out, we excluded it from the regressions presented here because of the statistical insignificance.

The statistical literature on student performance also suggests that parents' educational background matters greatly (see Hanushek, 1992). Unfortunately, these data are imperfectly collected in the API, with the average school receiving a less than 60% response rate to queries regarding parents' education. The lack of responses in some schools means that the sample was reduced when this variable was introduced, and for all schools it does reduce the reliability of this measure. As it turns out, excluding the API-provided parents' education measure (which ranks the level from 1 to 5 depending on parents' average number of years of schooling) did not affect the pattern of our other results, but the variable is highly significant and so we introduced it in a second round of regressions.

⁽⁶⁾ English proficiency impacts the overall API scores, which are not adjusted for this variable. The underlying exams used to calculate the API are administered in English because of the passage in California of the 1998 statewide initiative that limits bilingual instruction and testing.

⁽⁷⁾ Bickel and Howley (2000) also conclude that district size matters to performance (as do Fowler and Walberg, 1991); because we are focusing on one district, this is not a concern for us. Also, the focus on a single district allows us to sidestep the problem of intraclass correlations (which occur when the units are schools within districts with districts as a separate variable).

⁽⁸⁾ The 1999 API database measure of mobility does not include students who are new to the district; such students were excluded from the API scores altogether, presumably on the grounds that their performance would reflect the efforts of other districts. Thus, the mobility measure is just for intradistrict transfers. Although this presents measurement problems in Los Angeles, where a significant number of students are immigrants and may be very recent arrivals, there is little that can be done given the data at hand. Moreover, given our attempt to look at the impact of location, there is some rationale for excluding scores for those who have recently arrived in the overall area.

We also introduced a variable indicating the percentage minority (or non-White) students in the school. Although this may tend to bias against finding an impact from environment hazards [because of the high correlation between our risk measures and the racial/ethnic makeup of the student body (see Pastor et al, 2002)], such a variable could capture unexplained differences between White and non-White student performance (see Krueger, 1999). As it turns out this is a significant variable, although it seems to be picking up some of the residual—and given the acknowledged disparity by race in exposure to air releases, we are concerned that its inclusion is simply mirroring the differentials in risk. In addition, in one run, we introduced a dummy variable for whether the school has a year-round or traditional academic calendar. Research on the effects of a year-round calendar on student achievement is somewhat equivocal. Whereas proponents have argued that there is a positive effect, presumably because shorter breaks between sessions facilitate retention, others question the validity of many of the positive studies—which have been sponsored by the National Association for Year-Round Education (Harp, 1993; Naylor, 2001). Other studies indicate that when year-round programs are adopted solely to alleviate overcrowding, education improvement is not significant (Weaver, 1992). The dependent and all nondummy variables were entered as natural logarithms, both to reflect diminishing returns and for reasons of standardization.

Of course, the main variables of concern for this exercise are environmental. Given that the health–school-performance literature has stressed the link via respiratory problems, such as asthma (see Austin et al, 1998; Bener et al, 1994; Fowler et al, 1992; Lenney, 1997; Maier et al, 1998; Spee-van der Wekke et al, 1998), we focus on two measures that might capture this: the presence of a TRI facility within one mile of the tract containing the school; and respiratory-hazard estimates associated with cumulative ambient air toxics exposures in the tract containing the school in question.

Although we have discussed the respiratory estimates above, it is important to note here that our attention to the TRI facilities is confined to those reporting air releases of chemicals listed under the EPA's 33/50 Program⁽⁹⁾, a voluntary pollution-prevention initiative designed to reduce by half the releases and transfers of seventeen high priority toxic substances during the period between 1988 and 1995 (US EPA, 1994). Most of the chemicals listed in the 33/50 Program are also carcinogens (either known or suspected). In 1997 TRI facilities reported air releases totaling 2346.4 tons in the study area; of this total, 15.5% were chemicals in the 33/50 Program. Our decision to focus on TRI facilities in the 33/50 Program follows the lead of the EPA which chose these high-volume industrial pollutants based on concern about their environmental health impacts and their potential for reduction through pollution-prevention efforts.

We start the analysis with figure 3, which shows the average API scores along two dimensions: (1) for those schools within one mile of a TRI facility releasing chemicals listed in the 33/50 Program and those not within one mile of such facilities: and (2) for schools ranked by lowest respiratory hazard to the highest respiratory hazard associated with ambient air toxics, with the risk groups each reflecting one third of all schools. As can be seen, the differences are fairly dramatic: schools proximate to TRI facilities with 33/50 Program chemical releases exhibit a 16% gap from those not proximate to such facilities, whereas schools located in tracts with the highest estimated respiratory hazard have a performance differential of about 20% compared with schools located in tracts with the lowest risk level. This 20% differential is sizeable, roughly matching the average difference between the bottom third and middle third of

⁽⁹⁾ Summary at US Environmental Protection Agency website http://www.epa.gov/tri/programs/other_federal.htm.

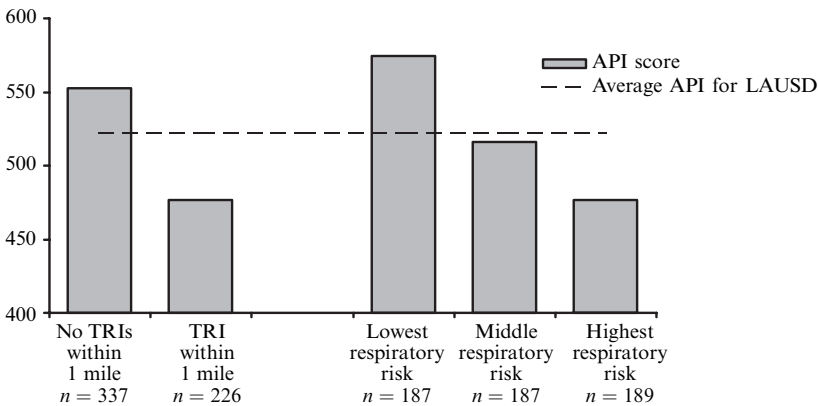


Figure 3. School-level academic performance index (API) score by environmental hazard (Toxic Release Inventory—TRI) category ($n = 563$ schools) for Los Angeles Unified Schools District (LAUSD).

schools in terms of academic performance.⁽¹⁰⁾ Figure 4 (over) shows the geographic pattern when the respiratory risk levels (once again, by thirds) are compared with quartiles of school performance; the visual correlation is striking.

Of course, many other variables are correlated with the differences in academic performance observed in figures 3 and 4. Table 1 (over) reports the results from multivariate regression analysis that tease out the separate impacts of several variables by specifying four possible models (a–d). Models a and b include our base specification, which includes the percentage of children receiving free lunches, the percentage of teachers with emergency credentials, the percentage of students who are English learners, school size, student mobility, and our two different environment variables. Every variable is significant and signed as expected. Models c and d include the average education level of the parents: as expected, this covariate is highly significant. Most other coefficients decrease in these models, but remain statistically significant; in particular, the decline in coefficient size for the environmental variables is quite modest.

Table 2 (page 284) shows the expansion of our statistical model, introducing the proportion of minority children in the school as an independent variable (models a and b). The environmental coefficients decline slightly, although their statistical significance remains at the 0.01 level. For models c and d we introduce a measure for year-round operation of a school. This variable is important for two reasons: first, our school-size measure is derived from the number of students and all year-round schools necessarily have more students; second, there is some debate within the education literature regarding the positive or negative impacts of departing from the traditional academic calendar. As can be seen, the variable is negative and significant although it is hard to tease out which of the two effects dominates.

What difference would it make if it were ensured that all schools were located in areas without potentially hazardous emission facilities and with lower respiratory risks associated with air pollution? Certainly, the changes needed to improve school outcomes in minority and other communities should include what is by now a familiar litany of measures: reducing family poverty, improving teacher quality, reducing class size,

⁽¹⁰⁾ These are unweighted averages, for ease of use. In the actual regressions, all observations are weighted by school population, with adjustments made when we enter parent education to account for the fact that not all schools reported this variable.

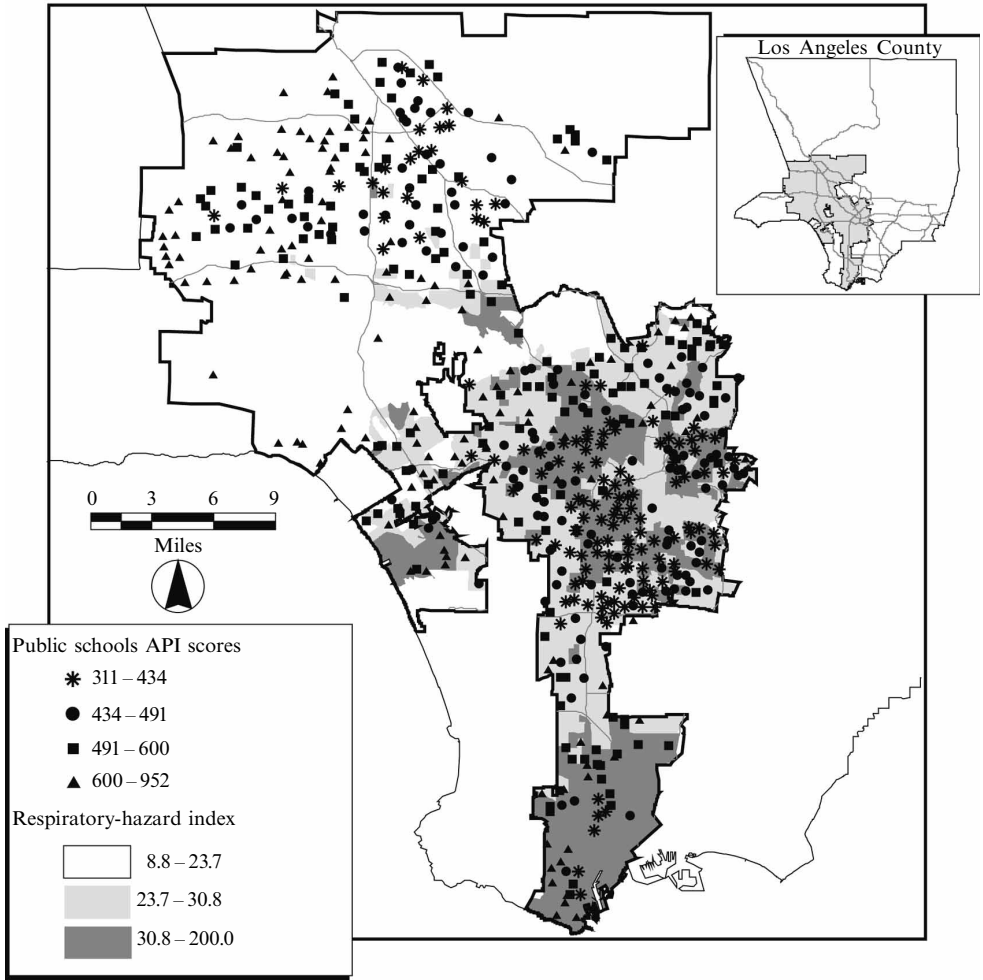


Figure 4. Public school academic performance index (API) and estimated cumulative respiratory risk from ambient air toxics exposure, Los Angeles Unified School District.

enhancing language acquisition, and the like. Nevertheless, environmental remediation might be of use in improving student academic performance and health.

For example, applying the coefficient from the first of our models (which includes the largest sample), we find that cleaning up the air so that a school would have the mean figure for the lowest, rather than the highest, of the respiratory-risk categories depicted in figures 3 and 4, would yield an estimated performance boost of over 10%.⁽¹¹⁾ Such a boost in scores would allow a school to meet the growth targets for the API for two years—and thus earn financial bonuses—as designated under California’s Public Schools Accountability Act. One should be cautious as these are cross-sectional estimates. In fact, scores seem to be rising over time without significant

⁽¹¹⁾ We use the coefficient derived prior to entering the percentage minority because of our concern that conflation in that specification (because of inequity in exposure) may be artificially reducing the independent impact of the environmental variables. Using the coefficients from table 2 would reduce the estimated impact described here, but would swell the explanatory power for the rest of racial differential referred to in the second half of the paragraph.

Table 1. Impact of demographics and environmental hazard variables on academic performance scores. Dependent variable: academic performance index, 1999; log coefficients, with *t*-test scores shown in parentheses.

	Model a	Model b	Model c	Model d
<i>School demographics</i>				
Percentage of children receiving free school lunches	-0.172 (-10.385)***	-0.158 (-9.270)***	-0.121 (-7.675)***	-0.109 (-6.783)***
Percentage of instructors with emergency credentials	-0.058 (-6.886)***	-0.060 (-6.911)***	-0.057 (-7.130)***	-0.057 (-7.126)***
Percentage of children who are English learners	-0.088 (-9.129)***	-0.093 (-9.620)***	-0.046 (-4.735)***	-0.051 (-5.153)***
Number of students in school	-0.054 (-7.685)***	-0.055 (-7.841)***	-0.040 (-5.963)***	-0.041 (-6.146)***
Mobility: percentage of students in that school for first time	-0.032 (-3.039)***	-0.035 (-3.247)***	-0.048 (-4.929)***	-0.051 (-5.127)***
Average educational level of parents			0.259 (10.839)***	0.260 (10.882)***
<i>Environmental Hazards</i>				
Dummy for TRI 33/50 facility ^a within 1 mile	-0.062 (-6.069)***		-0.051 (-5.125)***	
Respiratory risk in tract for air		-0.084 (-5.700)***		-0.067 (-4.940)***
<i>F</i> -value	201.0***	198.9***	224.0***	223.0***
Adjusted <i>R</i> ²	0.681	0.679	0.742	0.741
number of schools	563	563	545	545

***significant at the 0.01 level.

^a TRI 33/50 facility—facility releasing substances covered by the Toxic Release Inventory (TRI) and included in the 33/50 Program.

changes in the underlying independent variables—partly because accountability can bring increased effectiveness in teaching strategies and particularly because instructors begin ‘teaching to the test’. However, the results still imply that environmental remediation could accelerate the improvement.

To look at this a different way, we attempted to account for the various factors that might explain the roughly 20% mean difference between white and African-American academic performance in the API sample.⁽¹²⁾ The decomposition procedure was done in two ways. The first and simplest involved use of the coefficients as elasticities (given the double-log specification), determining the percentage change in the dependent variable from variations by race in the independent variables, and then scaling that estimated change against the estimated racial gap in API scores. The second method involved setting up separate regressions for each group, and then using the within-group coefficients while sequentially altering the independent variable for minorities to the values for Anglos in order to simulate the effect of a change in school conditions; in this case, the calculation is on the log values themselves, but the overall accounting

⁽¹²⁾ Technically, we do not have the actual individual scores and so cannot calculate the ethnic differences per se; instead, we are simulating this by multiplying the weight value for the number of students against the percentage of any particular ethnic group in the school in question, and thus we are in essence calculating the aggregate impact on the school from such changes. A similar procedure was used by Ragosa (2001) in an official API report posted on California’s Department of Education website; it also shows about a 20% differential in White and African-American APIs—in that case, at the statewide level.

Table 2. Impact of demographics and environmental hazard variables on academic scores. Dependent variable: academic performance index, 1999; log coefficients, with *t*-test scores shown in parentheses.

	Model a	Model b	Model c	Model d
<i>School demographics</i>				
Percentage of children receiving free school lunches	-0.036 (-1.898)*	-0.032 (-1.649)*	-0.037 (-1.982)**	-0.032 (-1.740)*
Percentage of instructors with emergency credentials	-0.048 (-6.249)***	-0.050 (-6.300)***	-0.048 (-6.289)***	-0.049 (-6.344)***
Percentage of children who are English learners	-0.057 (-6.066)***	-0.060 (-6.271)***	-0.047 (-4.920)***	-0.050 (-5.130)***
Number of students in school	-0.027 (-4.091)***	-0.028 (-4.423)***	-0.021 (-3.260)***	-0.023 (-3.411)***
Mobility: percentage of students in that school for first time	-0.046 (-4.922)***	-0.047 (-4.991)***	-0.045 (-4.848)***	-0.045 (-4.828)***
Average educational level of parents	0.214 (9.061)***	0.218 (9.196)***	0.187 (7.814)***	0.195 (8.065)***
Percentage of children who are minority	-0.243 (-7.217)***	-0.236 (-6.852)***	-0.240 (-7.261)***	-0.239 (-7.040)***
Dummy for year-round schooling			-0.049 (-4.605)***	-0.045 (-4.053)***
<i>Environmental hazards</i>				
Dummy for TRI 33/50 facility ^a within 1 mile	-0.039 (-4.223)***		-0.038 (-4.27)***	
Respiratory risk in tract from air		-0.045 (-3.345)***		-0.035 (-2.627)***
<i>F</i> value	221.2***	217.7***	206.4***	200.9***
Adjusted <i>R</i> ²	0.764	0.761	0.773	0.768
Number of schools	545	545	545	545

***significant at the 0.01 level; ** at the 0.05 level; * at the 0.1 level.

^aTRI 33/50 facility—facility releasing substances covered by the Toxic Release Inventory (TRI) and included in the 33/50 Program.

for the impacts for the environmental, poverty, and teacher-quality variables are quite similar (the percentage of English learners is especially strong for Latinos).

In both cases, about one tenth of the Black–White gap can be attributed, according to the model, to the differences in the mean air pollution levels experienced by these respective groups at their schools. This is about one third of the effect explained by the poverty variable, usually the determinant factor, and the explanatory power of the ‘environmental effect’ is only slightly less than that of the teacher-quality variable. Although we do not wish to make too much of this result, partly because of the assumptions required to conduct this procedure, the fact that the magnitude of the effect is similar under several different methods, and that socioeconomic conditions and teacher quality dominate in this aggregate procedure, as in the individual-level literature, suggest that the estimates may be reasonable.

Discussion

A key debate in the environmental equity literature has centered on whether or not observed disparities in potential environmental hazards have consequences for public health and other outcomes. In this paper, we have argued that social and environmental inequality can negatively impact community-based human capital. To explore this, we empirically assessed the linkage between community-based human capital and

children's environmental health, comparing school-level academic performance on one hand and proximity to TRI facilities and respiratory risks associated with ambient air toxics on the other. In a reasonably specified set of multivariate regressions, we find that these two indices of environmental hazards have a negative and statistically significant impact on one measure of school performance, the API, even when controlling for the other factors that should explain such performance. Because research also suggests that there is a significant racial disparity in air-pollution exposures among schoolchildren, again controlling for other factors, this is an issue that should concern those in the worlds of environmental justice action, research, and policy, and help to inform future theorizing and research on the topic.

Numerous caveats are in order. First, this study is limited to Los Angeles, making it difficult to generalize the empirical results beyond this area. Second, the measure of school performance that we use in our regressions is unidimensional and cannot capture all aspects of learning and academic performance; although this is a standard and, we believe, valid critique in the education literature, we should stress that the measure does have consequences as state authorities are using the API as a way to gauge outcomes and reward or punish school administrators and teachers.

Third, we employ an aggregate model of school performance rather than an individual-level model of academic achievement; however, such aggregate procedures are increasingly common as parents and policymakers demand school-level accountability and for environmental conditions—which stick with the school even if an individual student moves away—the aggregate level is appropriate. Fourth, we employ a relatively limited set of explanatory variables given our reliance on the aggregate-level API database. On the other hand, we have used all of the variables that were available in the database and made sense for our statistical model (although some covariates, including class size, were eventually eliminated because of their lack of significance). Although the resulting specification is parsimonious, it is important to recall that our objective is not a full model of educational outcomes but, rather, simply an attempt to see if there is any potential impact from local environmental hazards, as a way of spurring future research in this field.⁽¹³⁾

Fifth, although we have established a multivariate association, the causal chain and biological mechanisms between the environment and learning are properly the subject of epidemiological studies; this research merely establishes the plausibility of or rationale for such studies. Sixth, we acknowledge that the results here were obtained via relatively straightforward methods, including a rather limited set of regression specifications; of course, given that this is an initial paper in this emerging field and that the dataset is constrained, such simplicity is required and may, in fact, be a virtue as it allows for further hypothesis testing and development.

Conclusion

Despite methodological caveats, the results of our study should encourage some thinking about the need for strict environmental standards for new schools slated for construction in the post-Belmont era in Los Angeles and elsewhere. Building schools in urban areas may necessarily involve development of brownfield lands or locations near pollution sources (Blume, 2000; Hernandez, 1999). Indeed, with student enrollments spiraling and mounting pressure to ease severe overcrowding in Los Angeles schools, the district is faced with the Herculean task of building over eighty new schools over the next five years (Trotter, 2002). This scenario, which is occurring in urban

⁽¹³⁾ Even with this objective, our tests are more fully specified than, for example, the research undertaken on the determinant of performance of Rhode Island's schools by Cheek et al (2000).

districts across the country, raises challenges for balancing the need to enhance educational opportunities for students in the district, most of whom are students of color, with the need to address legitimate environmental health concerns about siting new facilities. If excess caution stops construction, this will have a negative impact on the educational opportunities and futures of minority schoolchildren. At the same time, any future construction plans should measure and seek to minimize disparities in environmental hazard distributions among minority schoolchildren in the district, particularly given the existing tendency of predominantly minority and poor schools to underperform academically. Administrators, teachers, parents, and students across the USA already face many challenges as they strive to provide quality education to public schoolchildren, and their success may be further compromised by unknown (or unaddressed) environmental hazards.

A positive step in addressing this dilemma is a new requirement that potential sites for new school construction must pass an environmental review by California's Department of Toxic Substances Control (DTSC). Moreover, the US EPA is currently working to develop a Healthy School Environments Assessment Tool that would provide districts, parents, administrators, teachers, and local communities with substantive information and guidance for implementing effective environmental management systems in the context of health and safety issues facing new and existing school sites. This process would establish guidelines encouraging school districts to proceed with caution to ensure that children's environmental health concerns are adequately addressed in siting, construction, and remediation projects. Most important, in order to respond to environmental health and justice challenges facing children in US schools best, these problems must be addressed within the larger context of educational challenges, including meeting academic-performance mandates, reducing school violence, enhancing social support for students and their families, ensuring adequate books and other supplies, and accommodating burgeoning urban student population.

Decisionmakers should recognize that spending scarce resources on education, including environmental remediation, could have positive effects on human-capital formation (through better student academic achievement), as well as on children's environmental health. Indeed, the value of health in improving and sustaining economic prosperity has gained wider attention from policymakers since the publication of the 1993 World Development Report (World Bank, 1993). Specifically, a healthy community, and healthy children in particular, are a critical component for promoting poverty reduction, economic growth, and long-term socioeconomic stability (Seligman et al, 1997; Smith, 1999). Decreasing the incidence of debilitating and chronic diseases or premature mortality association with pollution exposures and other risk factors ultimately reduces the economic losses borne by vulnerable communities, who can least afford them. Indeed, economists and health researchers have demonstrated that the relationship between health on the one hand and human and social capital on the other is by no means unidirectional, but rather dynamic: poverty and low social capital is linked to poor health outcomes. However, the reverse pathway is also valid: poor health also adversely impacts community economic resources (Subramanian et al, 2002). The results from our study represent part of a larger, more complex, web of the relationships between community environmental health and social and economic outcomes.

Although much remains to be debated regarding methodology, theoretical frameworks, and causal pathways, our results support the model that we have offered and constitute one response to the critics of environmental justice research. Environmental inequality, it seems, can have real consequences for children's environmental health and for human-capital formation, by diminishing academic performance and, ultimately,

possibilities for future economic productivity. Indeed, although environmental justice advocates and scholars points out the specific disproportionality involved in the distribution of environmental goods and bads, it is critical to realize that this pattern is part and parcel of a broader problem in contemporary society. Reversing the trend will likely require a return to the implications of the model we presented earlier: building community capacity and political power is one crucial key for children's environmental health, learning, and general well-being.

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