

Drinking Water Quality in Seattle Public Schools: A Case of Environmental Equity

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Abstract

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The Flint water crisis brought national attention to the issue of toxicity in water sources that previously had been presumed safe. However, despite the widespread public outcry over the discovery of lead contamination in water, a significant amount of uncertainty remains around the quality and safety of publicly sourced drinking water throughout the United States. This research investigates the water-quality testing reports of the Seattle Public School District's (SPS) Water Quality Program to answer two important questions: (i) What is the current state of drinking water quality in Seattle's public schools? (ii) Does the district's water quality represent an environmental justice problem in addition to a water quality problem? This research tests the hypothesis that the drinking water quality of Seattle's public schools is not as safe as presumed

by the City of Seattle's record of compliance with the federal Lead and Copper Rule, and that factors that determine improvements in water quality reflect larger patterns of societal inequities.

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1. Introduction

The Safe Drinking Water Act (SDWA) requires the EPA to set and oversee implementation of standards for drinking water quality of all public water systems (Safe Drinking Water Act, 1996). However, those standards only apply to the suppliers of water, often local public utilities. As end-users of public water, schools are not required by the SDWA to test the quality of their water, since that testing happens at the source before being piped to school buildings. When water is pumped through aging and corrosive pipes—however clean it may be at the source—risk of contamination and exposure to toxic chemicals can increase substantially. The situation in Flint highlighted just how little is known about the quality of drinking water in the U.S., challenging the assumption that locally sourced water is inherently safe for consumption. The uncertainty around school drinking water quality is of especially great concern given the vulnerability and sensitivity of children to toxic exposures like lead (EPA Office of Water, 1999). Furthermore, children spend a significant portion of their day at school, essentially compounding potential environmental risks with longer periods of exposure to those contaminants of concern. On a macro-scale, national coverage of water contamination has increased, including the discovery of elevated levels of lead and copper in the tap water of schools in Portland, Oregon, Chicago, Illinois, Washington, D.C., and numerous other cities throughout the country. However, mass media attention of these water crises has not translated into data—or transparency about the lack of data—regarding the quality of drinking water in all schools across the United States. Recognizing the importance of student health and the deficiency of information on school environmental risk, the Seattle Public School District adopted and implemented a water quality testing program in late 2003 in an effort to fill the

information gap and prioritize safe drinking water quality in public schools (SPS Drinking Water Quality Program, 2017). This research provides an in-depth analysis of the water quality data from this program, the results of which are expected to contribute to a growing body of environmental equity studies focused on school-level exposure risks, and provide insight into how socioeconomic status influences the exposure of children to lead in school drinking water.

1.1 Seattle Public Schools Water Quality Testing Funding

Public school funding models in the United States vary from state to state. In Washington, school districts are funded through four major sources: state revenue (primarily collected through taxes), local levies, federal revenue, and a number of miscellaneous sources such as grants from government or private sectors (Seattle Public Schools, 2016: 41). Funds are allocated among school districts based on each district's financial plan as outlined through yearly fiscal budgets. The Seattle Public School District develops budgets for four separate governmental "funds", or fiscal entities: a General Fund, Associated Student Body (ASB) Fund, Debt Service Fund, and Capital Projects Fund (Seattle Public Schools, 2016: 45; School Apportionment and Financial Services, 2015: 27). It is within this last group, the Capital Projects Fund, that the Seattle Water Quality Testing Program operates.

The Capital Fund supports the construction, renovation, and maintenance of SPS educational facilities, and receives the majority of its financial backing from local, voter-approved capital levies (Seattle Public Schools, 2016: 45; School Apportionment and Financial Services, 2015: 200). Subsumed within the Risk Management budget of this Fund, the SPS Water Quality Testing Program is financed primarily through the Building, Technology and

Athletics (BTA) levies, which are placed on the ballot every six years (Seattle Public Schools Drinking Water Quality Improvement Program, 2007: 17). Rather than distributing BTA revenue among individual schools, the District uses these levies to fund water quality testing and necessary remediation of all schools every three years as prescribed by a long-term policy developed by the SPS School Board's Policy and Legislative Committee at the inception of the Water Quality Testing Program.

Of the three largest school districts in Washington State (Tacoma, Spokane, and Seattle), the Seattle Public School District is the only one with a consistent and established water-quality testing program. In 2009, the Washington State Board of Health adopted rule WAC 246-366A Environmental Health and Safety Standards for Primary and Secondary Schools, also known as the "School Rule," requiring school districts to monitor health risks including lead contamination in school water (Washington State Legislature, 2015). However, due to lack of funding, the rule has yet to be implemented. While the Seattle Public School District has adequate financial backing to support its Water Quality Testing Program, in the absence of state support, many school districts are not as well-funded. This heavy reliance on levies—which, by nature, generate less revenue in poorer areas—to fund basic student welfare needs not only represents a major equity concern within the state, but threatens the survival of the SPS Water Quality Testing Program as well.

On January 5, 2012 the state Supreme Court ruled that Washington was in violation of the state Constitution for its failure to adequately fund basic public education (*McCleary v. State of Washington*, 2015). The state's use of funding formulas that only cover a portion of actual school operation costs has required districts to increasingly rely on local levies to supplement the

lack of state support. The legislature has steadily adjusted the original levy limit of 10% to increase the amount of local levy revenue that school districts can collect. Though the existing levy limit is now 28%, the Seattle Public School District is grandfathered in at a 36.97%. However, since the Court ordered the legislature to fully fund public education by 2018, many of these adjustments are scheduled to end the same year. Furthermore, the state has yet to fulfill its obligation to provide a plan for full school compensation reform by April 2017. Despite the passing of an 18-month levy cliff extension, SPS still faces a \$50 million shortfall for the 2017-2018 school year, which will inevitably force them to make budget cuts (Seattle Public Schools Financial Services Division, 2017). The lack of a federal or state mandate for schools to test their water quality, combined with growing budget deficits and forecasted levy limits, creates an insecure future of the SPS Water Quality Testing Program.

2. Literature Review

2.1 Health Effects of Lead Exposure

The Seattle Public School District's (SPS) Water Quality Testing program sets its standard for maximum allowable lead levels in school water at 10 parts per billion (ppb). This measure is a more stringent standard than the one imposed by the Environmental Protection Agency (EPA), which sets the action level for lead at 15ppb, and recommends sources be removed from schools at 20ppb (United States Environmental Protection Agency, 2017). However, the concept of a lead standard is inherently misleading, as there is no proven safe level of lead exposure. In July 2016, the American Academy of Pediatrics (AAP) released a policy statement detailing the dangers of childhood lead toxicity, and provided evidence-based

guidelines for managing increased lead exposure in children. In this document, the AAP advised the EPA to “revise downward the allowable levels of lead in house dust, soil, paint, and water to conform with the recognition that there are no safe levels of lead” (AAP Council on Environmental Health, 2016: 11). In accordance with this understanding, they recommended that state and local governments take steps to “ensure that water fountains in schools do not exceed water lead concentrations of 1ppb” (AAP Council on Environmental Health, 2016:11). Thus, neither the SPS nor the EPA has a Water Quality standard sufficient to protect the health of children, according to the relevant medical professionals.

While lead exposure can adversely affect all people, the risks are especially significant for children. Not only do children absorb more lead than adults when exposed, but their brains and nervous systems are particularly sensitive to lead-induced damages (Learn About Lead, 2017). The effects of childhood lead exposure vary across a wide range of intensity. Exposure levels as low as 10 micrograms per deciliter (ug/dL), where distinctive symptoms do not manifest, have been associated with decreased intelligence (often measured by IQ) and impaired neurobehavioral development (CDC, 1991; Davis and Svendsgaard, 1987; Mushak et al., 1989; Needleman and Gastonis, 1990), as well as decreased growth (Schwartz et al., 1986; Bornschein et al., 1986; Shulka et al., 1989) and hearing problems (Schwartz and Otto, 1987). Since lead can accumulate in our bodies over time and stored in our bones, some studies have examined the effects of lead in children’s teeth. A 1990 study found that dentine lead levels above 20 parts per million in the teeth of first and second graders were subsequently associated with a “seven-fold risk of not graduating from high school, a six-fold risk of having a reading disability, deficits in

vocabulary, problems with attention and fine motor coordination, greater absenteeism, and lower class ranking” (CDC, 1991; Needleman et al., 1979).

Higher levels of exposure (≥ 380 ug/dL) can result in comas, seizures, and even death (Learn About Lead, 2017; CDC, 1991). Some studies have even found relationships between childhood lead exposure and crime levels in adulthood. In 2007, Nevin found a strong association between preschool blood lead levels and subsequent incarceration trends and murder rates across the United States (Nevin, 2007). Similarly, Stretesky and Lynch found an association between lead exposure and violent behavior and homicide rates (Stretesky and Lynch, 2001). These results serve as evidence of the long-term implications of any level of childhood lead exposure, both for a child’s academic success and overall quality of life.

2.2 Environmental Equity

The rise of a burgeoning environmental justice movement has shed light on the existence of environmental inequalities throughout the United States. Among the core tenets of this movement lies the fundamental principle that “all people and communities are entitled to equal protection of environmental and public health laws and regulations,” (Bullard, 1994) regardless of race, color, national origin, or income (EPA, 1999). Though a substantial body of literature provides evidence of the inequitable distribution of environmental risk that disproportionately affects poor and minority communities (Brown, 1995; Bryant, 1995; Mohai, 1996), scholars debate the importance that class and race each bear in predicting these inequities.

Two widely referenced studies from the 1980s both document race as the predominant factor in toxic waste sitings (Brulle et al, 2006; United Church of Christ, 1987; United States General Accounting Office, 1983). Further investigations beginning in the 1990s build upon

these findings. Following their 1990 Conference on Race and the Incidence of Environmental Hazards at the University of Michigan, Bryant and Mohai conducted a meta-analysis of 16 studies that examined the influence of race and class on environmental risk. Of the nine studies in their analyses where both race and class were examined, six demonstrated a stronger association between race and exposure to environmental hazards (Bryant and Mohai, 1992). Subsequent explorations of the determinants of environmental inequities have revealed similar findings, whereas others have cited income as a more powerful predictor (Evans and Kantrowitz, 2002). Still others have found significance in both factors (Brown, 1995; Szasz and Meuser, 1997), highlighting a fundamental shortcoming of the race versus class debate in environmental justice literature.

Critics argue that the mixed results of these studies demonstrate the danger in assessing the predictive power of race and class separately (Pulido, 1996; Downey, 1998;). These two factors are highly intertwined in the United States (Downey and Hawkins, 2008), and thus consideration of each in isolation fails to capture this connection. Rather than focusing on the influential power of the two indicators together, the race-versus-class debate “implies that the one factor that is found to be ‘right’ has to be so at the expense of the other” (Downey, 1998: 774).

Beyond the limitations of the race-versus-class debate, existing environmental justice literature often has a narrow spatial scope, focusing on environmental hazards and pollution as they relate to the homes or communities in which people live (Pastor et al, 2002). While people are inarguably affected by environmental risk exposure in the places in which they reside, children in particular spend significant portions of their day in school. Several studies explore

environmental inequities related to children (Friedrich, 2000), and even childhood exposure to lead (Kraft and Scheberle, 1995; Zahran et al, 2009). However, research that investigates exposure to these risks at the level of schools is only beginning to emerge (Mohai et al, 2011; Pastor et al, 2002; Pastor et al, 2006; Samson, 2012). The sources of potential environmental hazards in schools are seemingly infinite, ranging anywhere from noise, to mold, to particulate matter, to airborne and waterborne metals. Given the lack of local and federal policies to monitor school environmental health (Samson, 2012), underlying disparities in environmental risks within schools are often not perceived and therefore go unaddressed.

Considering the shortage of literature focused on school environmental equity and the need for further understanding of the sources of environmental risk exposure for children, this research seeks to contribute to the growth of the field through its analysis of inequitable lead exposure in the drinking water of Seattle's public schools. In an effort to avoid the pitfalls of the race versus class debate within prevailing literature, this study will examine environmental equity concerns primarily through socioeconomic status, while including an assessment of its relationship to the racial demographics of each school.

2.3 Socioeconomic Status

A wide range of literature exists on how to operationalize socioeconomic status (SES) in education research and childhood development studies. SES is broadly defined as an indicator of one's access to valued commodities like wealth, power, or status (Mueller & Parcel, 1981; Sirin, 2005). While conceptualizations of the term vary, scholars largely agree that SES is comprised of three key variables: 1) family income, 2) parental education level 3) and parental occupation

(NAEP, 2012; Hauser, 1994; Duncan and Featherman, 1972). However, despite general consensus on the core composition of SES, there remain disparate views on how to measure each of these components in primary research. An examination of prevailing literature reveals the numerous methodologies for operationalizing SES, and the associated complexities of doing so with the constraints of ambiguous guidelines, and often missing or incomplete data.

Each of the aforementioned components of SES measures one's access to distinct types of capital (Coleman, 1988): human capital, financial capital, and social capital. Education measure's access to human capital, as it paves the road to information and knowledge gain, shaping "future occupational opportunities and earning potential" (Ross and Wu, 1995; Adler, 2002). Income measure's access to financial capital, as it reflects one's ability to purchase valuable commodities and resources, like food, housing, health care, and recreation. Finally, occupational status measure's social capital, as occupation often plays a large role in building social connections, and thus acts as an indicator of social prestige (Bradley, 2002).

All of the forms of capital mentioned above inarguably influence childhood wellbeing in a number of ways, from academic achievement to health; and while social scientists tend to agree that education, income, and occupation together produce the most accurate representation of SES, there remains a lack of consensus on a number of critical questions that must be considered when determining how to incorporate these variables into a comprehensive reflection of SES (Bradley, 2002; Krieger, 1997). The first of these questions concerns the dilemma of whether to measure individual indicators of SES, or to rely on a composite measure of SES where several variables are weighted and combined to produce an index or single score. Some researchers give preference to certain components over others, choosing to focus on the measurement of what

they consider to be stronger indicators of SES (Wright, 1993). Still others use indices or composites like Duncan's Socioeconomic Index (Duncan, 1961) and the Hollingshead Socioeconomic Index of Social Prestige or Position (Hollingshead, 1958) that measure key SES variables together (Shavers, 2007). The list of methodologies employed over the past 50 years is inexhaustible and are often chosen contextually at the researchers' discretion.

The second point of contention concerns the question of how to operationalize the chosen individual or composite variable. Income, education, and occupation are all complex components of SES, and can thus be captured through a number of different mechanisms. For example, elements of income include, but are not limited to, unemployment compensation, disability, wage earnings, dividends, food stamps, child support, alimony, welfare, investments, and pensions (Krieger, 1997; Entwisle et al, 1994). All of these sources reflect manners through which an individual or household receives financial capital. Education can be operationalized through a focus on either maternal or paternal educational attainment, or that of the head of household (Entwisle et al, 1994). Occupation represents a similarly diverse construct, which can be operationalized by employment status (working for pay, part-time, or full time), possession of a job, or actual occupation held (NAEP, 2012). As demonstrated, the elements of each of the core components of SES are seemingly infinite, yet it is impossible to realistically include every aspect without a limitless amount of time and money. Furthermore, reliable data is often not readily available or easily accessible, and thus researchers must determine what they consider the optimal method for operationalizing SES within existing constraints.

Since SES reflects access to various forms of capital, some researchers choose to focus on a single indicator that measures multiple SES components. One such indicator frequently used

to measure childhood SES is that of student eligibility for free and reduced lunch. “Students from families with incomes at or below 130% of the poverty level are eligible for free meals. Those with incomes between 130% and 185% of the poverty level are eligible for reduced-price meals” (Sirin, 2005). Eligibility for free and reduced price lunch (henceforth referred to as FRPL) through the National School Lunch Program is considered a proxy for SES as it functions as an indicator of a child’s access to social and economic resources.

In the context of both education and childhood development studies, researchers have to decide whether to measure childhood SES at the school or neighborhood level, as both units of analysis have significant effects on a child’s wellbeing (Sirin, 2005; Caldas & Bankston, 1997; Brooks-Gunn, Duncan, & Aber, 1997; Krieger, 1997). School-level SES is typically measured by the proportion of students who are eligible for free and reduced-priced lunch, as previously described (Sirin, 2005; NAEP, 2012). On the other hand, neighborhood SES captures the conditions of a child’s surroundings, and can provide insight as to how the community in which a student resides affects their access to various forms of capital. Neighborhood units are often categorized by the US Bureau of Census at three levels of varying size: the census tract, census block-group, and census block (Krieger, 1997; US Department of Commerce).

There are notable limitations when using either school and neighborhood-level SES measurements. School-level SES as measured by FRPL eligibility is not always fully representative of those who qualify for it, as not all families of children who are eligible apply for it (Entwisle & Astone, 1994). This issue often arises with older students. Furthermore, measuring SES through a single variable like NSLP eligibility excludes other important components of SES like parental education or occupational status. Neighborhood SES, on the

other hand, can measure a number of SES attributes related to income, educational attainment, and occupation. However, issues arise when choosing census-defined neighborhood boundaries. Census tract neighborhoods are typically more heterogeneous in makeup than block-group or block boundaries. Homogeneity within neighborhoods is usually desired in measures of SES as it can “reveal otherwise hidden pockets of poverty and affluence” (Krieger, 1997). While block data most successfully distinguishes between areas of higher and lower SES, relatively little data is provided at this level. This leaves the block-group as the optimal neighborhood unit of analysis, which on average measures 1500 residents. However, block-group data is obtained through the American Community Survey 5 year estimates, which does not reflect changes in block-group neighborhoods within each 5-year period.

Recognizing the strengths and limitations of both individual versus composite SES indicators, and commonly used school and neighborhood SES measurements, for the purposes of this research student eligibility for free and reduced lunch aggregated at the school level will be used as a measure of the SES of the community each school serves. The rationale for doing so are fourfold: 1. For one, the unit of analysis for this study are schools, and thus SES data provided at the school level will prove most representative. 2. While FRPL eligibility does not always fully capture all students who are in fact eligible for free and reduced-price lunch, the problem typically arises with older students, and this research focuses specifically on younger student populations. 3. Though neighborhood characteristics significantly affect childhood wellbeing and can influence overall student SES, it is difficult to differentiate between those aspects which are a part of student SES and which are simply highly correlated to overall SES. Furthermore, not all children attend school in the neighborhood in which they live, and thus

relying on measures of neighborhood SES presents the possibility of ecological fallacy whereby inferences about students within a school are made by assumptions from data gathered from a surrounding neighborhood. 4. While the use of an index or composite that measures each core component of SES would be ideal, information on every SES variable is not provided by schools within the Seattle Public School District. Implementation of survey methods could provide a means to collect this missing data at the school level. However, time and money constraints limits this research to the use of existing data. Furthermore, questionnaires soliciting information like income and education level from families and students often have low response rates.

3. Methods

This study examined all schools of the Seattle Public School District (SPS) involved in the district's Water Quality Testing Program. Schools in which 50% or more of building water sources¹ were tested for lead contamination in at least three separate years were included in the analyses. While the program tests for other contaminants of concern, including copper, cadmium, and iron, this study looked exclusively at lead contamination. Reasons for lack of testing data in schools included building closures and the construction of new buildings.^{2,3} The Drinking Water Policy adopted by the SPS School Board calls for reoccurring testing of the water in each school

¹ Water source refers to any mechanism through which water is provided within a school building, categorized by the Water Quality Testing Program as bubblers (drinking water fountains), sinks (faucets), sink/bubbler combinations, or main service entries.

² A t-test was performed to measure whether schools with very little testing data (fewer than 3 testing years) had statistically different socioeconomic status (SES) from schools with 3 or more years of testing data. At a 95% confidence level, the results revealed a p value of .2028, indicating that schools with less than 3 years of testing data do not have statistically different socioeconomic status from schools with 3 or more testing years. These findings support the conclusion that the exclusion of schools with little testing data does not introduce any systematic bias into the analyses or reveal additional equity concerns.

³ See Appendix for list of schools not included in the analyses.

at least every three years (SPS School Board, 2012). Thus, since its inception in 2004, the Water Quality Testing Program has tested some schools on more than three occasions. Therefore, water quality data for the first, middle, and last testing years of each school were analyzed to ensure a comprehensive assessment of the relationship between the dependent variables and independent variables. Dependent variables that were analyzed included percentage of water sources tested, percentage of sources that failed the SPS Water Quality Standard for lead, and percentage of sources that failed the health standard for lead as recommended by the American Academy of Pediatrics. Independent variables of focus included socioeconomic status, school building age, and presence of galvanized steel in school water piping. All testing years in which 50% or more of water sources were tested were included in the longitudinal analysis.

In the first section of the analyses, patterns of lead contamination in the drinking water of SPS schools as they correspond to household income were mapped for both the middle and last testing years using Geographic Information Systems (GIS). Data on 2010 median household income was retrieved from the American Community Survey (ACS) of the United States Census Bureau. This data represents the most current available estimates of median household income at the neighborhood level. Census data was not used on the regression analyses as the unit of analysis for this research was that of schools, not communities or neighborhoods. However, maps were created to visually display spatial trends in the variables of interest (Figures 1 and 2).

In the second step of the analyses, associations between the dependent variables (SPS lead standard failures, AAP health recommendation failures, and percentage of sources tested) and independent variables (socioeconomic status, building age, and presence of galvanized steel) were investigated through multiple linear regression analyses for three cross sections: the first

(table 2), middle (table 3), and last water quality testing years of each school (table 4a). Two additional dependent variables were regressed in the last cross section: the slope coefficients of the percentage of sources that failed SPS lead standards for all testing years, and the slope coefficients of the percentage of sources that failed AAP health recommendation standards for all testing years (table 4b).⁴ Calculated slopes for each school included every year in which more than 50% of water sources were tested to measure improvement in water quality over time.

A separate multiple regression was performed for each operationalization of socioeconomic status at the school level (percentage of FRPL, a binary variable for FRPL, and a binary variable for Title I status), and building age (first construction year, and year of the last building renovation or addition) so as not to confound the variables. The independent variable of interest for this equity study was socioeconomic status, however building age and the presence of galvanized steel were included as control variables. The multiple regressions reveal the joint influence of socioeconomic status, building age, and galvanized steel on the prevalence of water sources that violate program and health standards for lead. The results are reported in a series of tables in the next section.

4. Data

4.1 Lead Levels in School Drinking Water and Building Water Sources

Data on lead levels for every tested source of a school from 2004 to present are reported in yearly summary reports available on the program's website. Each report provides the lead level of every tested source at first draw and after a thirty second flush. "First draw" refers to the

⁴ Changes in the percentage of sources tested over time were also examined. Results revealed very few schools with a statistically significant trend. Out of 78 schools analyzed, 23 had R² values over .65.

initial water to come out of a source after a period of inactivity. A 30-second flush is a testing protocol in which the water is allowed to run for 30 seconds prior to taking a sample. This study only used first-draw data in the analyses, as it best captures water quality amid the intermittent nature of water use in schools.⁵ All sources that exceeded 10ppb were coded as SPS water-quality standard failures, while all sources that exceeded 1ppb were coded as AAP health recommendation failures. Each source has a fixture identification number that corresponds to its location and type. However, as fixture IDs are not listed in numerical order, each fixture was tallied to obtain the total number of existing water sources in each school. The number of water sources tested each year were then totaled to determine the percentage of water sources tested, percentage of SPS standard failures, and percentage of AAP health recommendation failures.

4.2 Socioeconomic Status Data

School socioeconomic status for each corresponding testing year was operationalized in three ways: 1) percentage of students who obtained free and reduced priced lunch (FRPL); 2) a binary variable in which schools with FRPL percentages higher than the median of all schools for a given testing year were assigned a 1, and those that fell at or below the median were assigned a 0; 3) a binary variable based on a school's Title I status for a given testing year, where Title One schools were assigned a 1, and non- Title I schools were assigned a 0.⁶ Data on FRPL

⁵ According to the Washington State Department of Health, lead levels in school drinking water can increase as water sits overnight in between school days, during weekends, or vacations when schools are not in operation. <http://www.doh.wa.gov/Portals/1/Documents/Pubs/331-255.pdf>

⁶ Title I, Part A is a federally funded program whereby financial assistance is provided to states and school districts to help support at-risk students. Funding for each state and school district is determined by their relative poverty compared to other states and school districts, measured by data from the Census Small Area

percentages were obtained from yearly school report cards through the State of Washington Office of Superintendent of Public Instruction (OSPI).⁷ Data on each school's yearly Title I status were obtained from the Seattle Public School District's Adequate Yearly Progress List⁸ through the State of Washington OSPI as well.

While this study recognizes the influence of race and ethnicity on exposure to environmental hazards, as evidenced from prevailing environmental equity literature, the exclusion of these factors in the regression analyses is due to the fact that they are highly correlated to socioeconomic status. This study examined the correlation between SES (operationalized as the percentage of students receiving FRPL), race (operationalized as the percentage of non-white students in schools), and ethnicity (operationalized as the percentage of Transitional Bilingual English Language Learners in schools). The Pearson correlation coefficients for the percentage of FRPL and percentage of Non-White students range from .9416 to .9519 from 2004 to 2008. The correlation coefficients for the percentage of FRPL and percentage of Transitional Bilingual (English Language Learners) range from .7928 to .8052 for the same period of time. The strength of these correlations has remained consistent since the inception of the Water Quality Testing Program, and so it is treated as a constant in the analyses.

Income Poverty Estimate. Funding is then allocated among schools based on the number of low-income students in attendance, measured by eligibility for FRPL.

<http://k12.wa.us/TitleI/pubdocs/CensusDataandFreeandReducedPriceLunch.pdf>

⁷<http://reportcard.ospi.k12.wa.us/Summary.aspx?domain=AYP&schoolId=100&reportLevel=District&yrs=2010-11&year=2010-11>

⁸<http://reportcard.ospi.k12.wa.us/AYPList.aspx?domain=AYP&schoolId=100&reportLevel=District&yrs=2010-11&year=2010-11>

4.3 Building Age

School building age was included as a control variable to account for the potential influence of aging, corrosive pipes on the presence of lead in school drinking water. Many schools in the Seattle Public School District have undergone numerous renovations since their original construction date, many of which date back to the early 1900s. Some of the original buildings are still standing, while others have been completely demolished, or else had sections of the school renovated or torn down. The building age of each school was thus operationalized in two ways: 1) the year in which the current school building was initially constructed; 2) the year of the last renovation or addition to the building. Construction and renovation years were assigned numerical indicators, where construction or renovations that took place in the year 2017 were assigned a 0, with each preceding year coded in ascending numerical order (i.e. 2016 was assigned a 1, 2015 a 2, and so on). Data on school building age were obtained through the Seattle Public Schools Building for Learning Archives.⁹ Any data missing from these archives were obtained through individual school websites.

4.4 Presence of Galvanized Steel

The SPS Water Quality Testing Program lists the plumbing piping materials of each school at the top of every water quality testing report. Given the corrosive nature of galvanized pipes and subsequent higher risk for lead contamination, the presence of galvanized steel was included as a control variable as well. A binary variable was used for this control in the analyses,

⁹ <http://www.seattleschools.org/cms/One.aspx?portalId=627&pageId=14818>

where schools with piping containing galvanized steel were assigned a 1, and schools without galvanized piping were assigned a 0.

4.5 Demographic Data: Race and English Language Proficiency

Student demographic data were obtained through yearly school reports published on the Seattle Public School District website. Racial composition is reported in these documents as a percentage of the total student population classified by the following categories: Native American, Hispanic, Black, Asian/Pacific Islander, and White. Starting with the 2010-2011 school year, these classifications are broken down further into the following categories: American Indian/Alaskan Native, Hispanic/Latino of any race(s), Black/African American, Asian, Native Hawaiian/Other Pacific Islander, Two or More Races, and White. The percentage of Transitional Bilingual students¹⁰ is also identified in each report. This demographic data was included in the analyses to discern the scope of potential environmental inequities related to SPS water quality as they pertain not only to socioeconomic status, but to race and ethnicity as well.

5. Results

5.1 Spatial Analyses

The maps below compare the percentage of SPS standard violations (Figure 1) and AAP standard violations (Figure 2) in both the middle and last testing years. The geographic location

¹⁰ The Washington State Transitional Bilingual Instruction Program (TBIP) serves children who comes from homes where the primary language is other than English. Eligible pupils as defined by Section 28A. 180. 030 of the TBIP are considered those “whose English language skills are sufficiently deficient or absent to impair learning.” <http://apps.leg.wa.gov/rcw/default.aspx?cite=28A.180&full=true>

of the violations of SPS schools are displayed relative to neighborhood socioeconomic status (operationalized as median household income). Red circles represent schools with predominantly low SES (operationalized as a binary variable of FRPL), while green circles represent non-disadvantaged schools with higher student SES. Circles increase in size with the greater percentages of violations.

The spatial analyses illustrate that lead is, in fact, present throughout the entire school district. While the concentration of green-versus-red circles demonstrate a clustering of higher SES-student populations in the northern half of the district and lower-SES student populations in the southern portion, lead violations span all geographic regions, regardless of student SES. Furthermore, this clustering of schools with lower-SES student populations in the south correlates with lower household median income at the neighborhood level. Though geographic divisions between the rich and the poor are signs of historical gentrification, the distribution of wealth within the boundaries of the Seattle Public School District has further implications on childhood lead exposure in schools. Though the percentage of school lead violations of both SPS and AAP standards are spread throughout the district, there are notably fewer schools with no violations in the south. Figure 1 shows that the number of schools in the southern portion of the district with zero SPS standard violations actually decreases between the middle and last testing year (Fig.1), while Figure 2 shows an increase in the number of schools with zero AAP violations in the northern portion of the district over the same time period (Fig. 2). This indicates that lower-SES students residing in the south have fewer options to attend a school in or near their neighborhood without school drinking water lead violations. While violations of varying size are scattered geographically among schools of low and high SES, students residing in the

northern portion of the district have greater access to school alternatives that do not have any lead violations (Fig. 1 and Fig. 2).

Figure 1- SPS Violations in Middle and Last Testing Years

Seattle Public Schools Exceeding 10ppb Lead in Water (middle testing year)

Seattle Public Schools Exceeding 10ppb Lead in Water (last testing year)

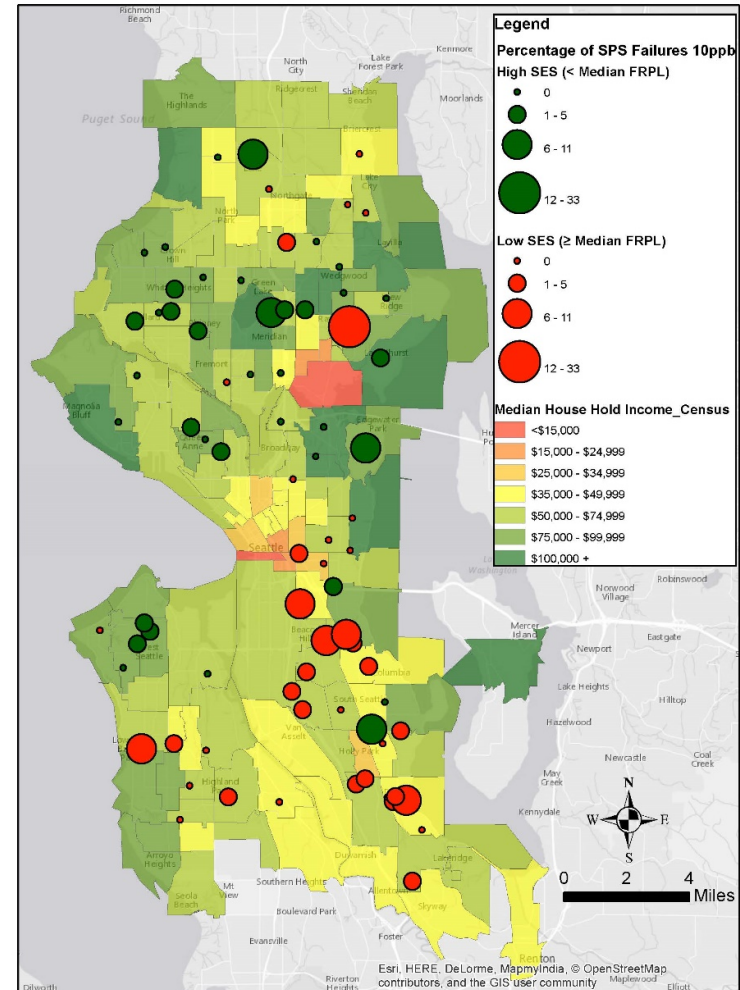
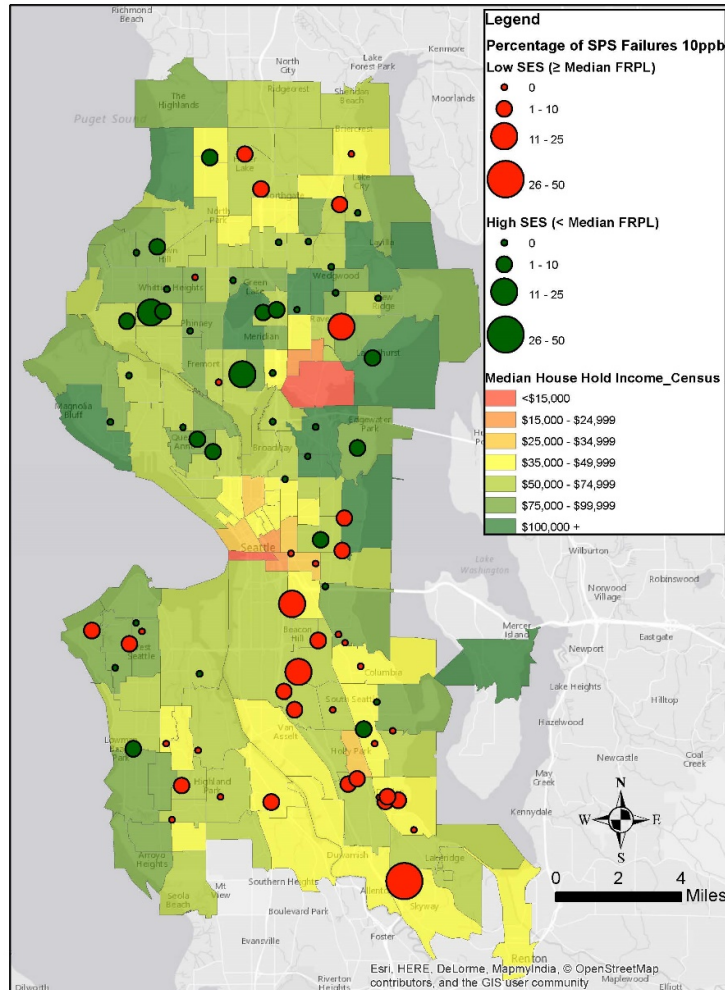
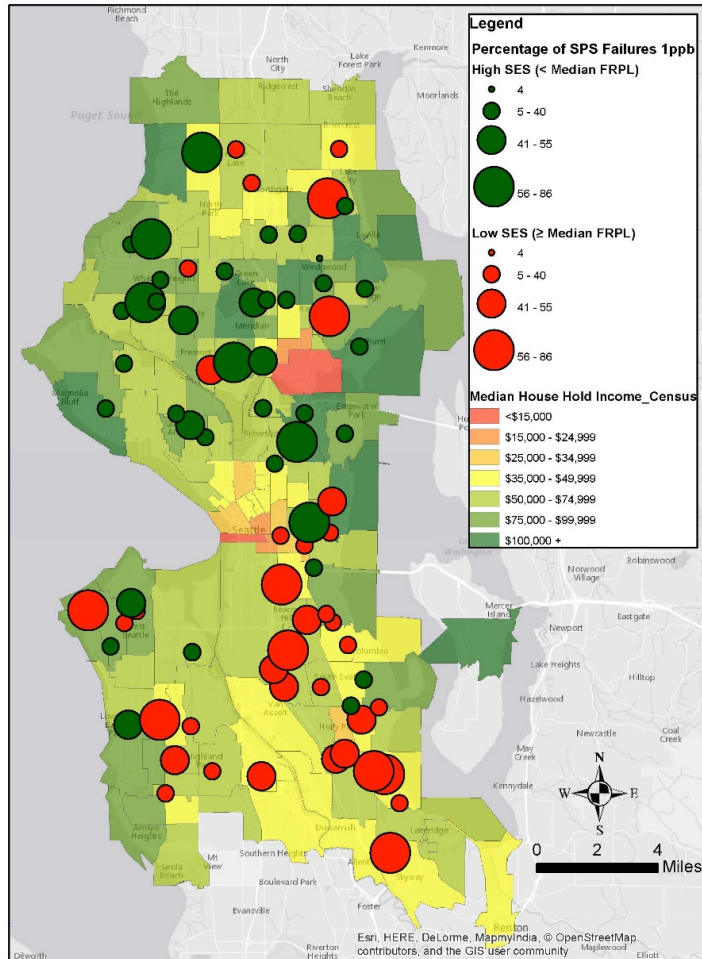
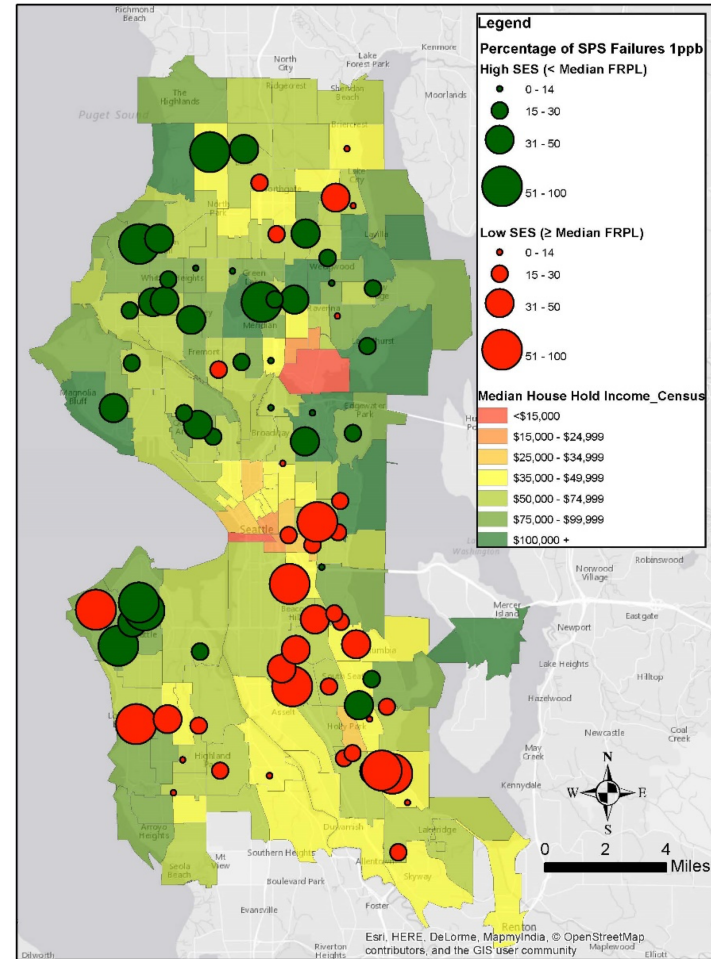


Figure 1- AAP Violations in Middle and Last Testing Years

Seattle Public Schools Exceeding 1ppb Lead in Water (middle testing year)



Seattle Public Schools Exceeding 1ppb Lead in Water (last testing year)



5.2 Multivariate Regression Analyses

The key variable of interest in this study was socioeconomic status and its relationship with water quality in schools. While the statistical models control for other variables that could also influence the presence of lead contamination in school drinking water, they are not discussed explicitly in this discussion. The first testing period did not reveal any statistically significant relationships between socioeconomic status and water quality in the Seattle Public School District (Table 2). **Numbers reflect regression coefficients (p values are in parentheses).**

Table 2: The impact of SES on Seattle Public Schools Water Quality, 1st water testing period

Dependent variables in columns, independent variables in rows

	Testing Frequency; % of water sources tested			Water quality; % of sources violating SPS water quality standards for lead			Water quality; % of sources violating AAP health recommendation standards for lead		
% FRPL	-.0002 (.9972)			-.0278 (.8158)			.0822 (.4148)		
Binary SES		-.0002 (.9932)			-.0487 (.4319)			.0071 (.8918)	
Title 1			.0240 (.4586)			-.0301 (.6349)			.0128 (.8111)
1st Construction Year	.0002 (.6956)	.0002 (.6974)	.0002 (.6312)	-.0003 (.7574)	-.0004 (.6851)	-.0004 (.7396)	.0005 (.5807)	.0004 (.6476)	.0004 (.6415)
Last Renovation/ Addition Year	-.0017 (.0563)	-.0017 (.0552)	-.0016 (.0735)	.0026 (.1302)	.0025 (.1402)	.0025 (.1432)	.0021 (.1495)	.0019 (.1793)	.0020 (.1747)
Presence of Galvanized Steel	-.0096 (.7854)	-.0096 (.7863)	-.0131 (.7100)	.0624 (.3664)	.0658 (.3400)	.0668 (.3379)	.0685 (.2402)	.0684 (.2442)	.0670 (.2572)

The middle testing period revealed statistically significant positive relationships between socioeconomic status (SES) and water quality in the Seattle Public School District (Table 3). A marginally statistically significant relationship was found between the percentage of water sources that failed the SPS water quality standards for lead and percentage of FRPL ($\beta=.0433$, $p=.1066$), while a statistically significant association was found between the percentage of water sources that failed SPS standards and SES operationalized as a binary variable ($\beta=.0277$, $p=.0571$). A significant positive relationship was also found between the percentage of sources that failed AAP health standards for lead and two of the three operationalizations of SES: the percentage of FRPL ($\beta=.2249$, $p=.0074$), and FRPL reported as a binary variable ($\beta=.1004$, $p=.0293$).

Table 3: The impact of SES on Seattle Public Schools Water Quality, 2nd (middle) water testing period

	Testing Frequency; % of water sources tested			Water quality; % of sources violating SPS water quality standards for lead			Water quality; % of sources violating AAP health recommendation standards for lead		
% FRPL	-.0116 (.7637)			.0433 (.1066)			.2249 (.0074)		
Binary SES		-.0209 (.3184)			.0277 (.0571)			.1004 (.0293)	
Title 1			.0125 (.5864)			.0186 (.2479)			.0675 (.1864)
1st Construction Year	-.0005 (.2248)	-.0005 (.2183)	-.0004 (.2849)	-.0002 (.4046)	-.0003 (.3272)	-.0002 (.4166)	-.0003 (.6881)	-.0005 (.5106)	-.0004 (.6337)
Last Renovation/ Addition Year	-.0014 (.0161)	-.0014 (.0139)	-.0014 (.0202)	.0008 (.0452)	.0008 (.0462)	.0008 (.0494)	.0024 (.0515)	.0023 (.0694)	.0023 (.0743)
Presence of Galvanized Steel	.0051 (.8295)	.0040 (.8662)	.0059 (.8028)	-.0041 (.8015)	-.0033 (.8354)	-.0046 (.7813)	-.0640 (.2077)	-.0631 (.2213)	-.0675 (.1999)
Note: Numbers reflect regression coefficients (p values are in parentheses)									

The last testing period revealed a marginally statistically significant relationship between SES operationalized as a binary variable and the percentage of water sources that failed SPS water quality standards for lead ($\beta=.0155$, $p= .1288$) (Table 4a).

Table 4a: The impact of SES on Seattle Public Schools Water Quality, 3rd (last) water testing period

	Testing Frequency; % of water sources tested			Water quality; % of sources violating SPS water quality standards for lead			Water quality; % of sources violating AAP health recommendation standards for lead		
% FRPL	-.0485 (.1866)			.0234 (.2090)			.0087 (.9146)		
Binary SES		-.0290 (.1502)			.0155 (.1288)			.0090 (.8395)	
Title 1			-.0051 (.8122)			.0143 (.1832)			-.0122 (.7941)
1st Construction Year	0 (.9631)	0 (.8965)	.0001 (.8712)	-.0002 (.2497)	-.0002 (.2171)	-.0002 (.2793)	-.0013 (.1152)	-.0013 (.1126)	-.0013 (.1053)
Last Renovation/ Addition Year	-.0014 (.0163)	-.0013 (.0182)	-.0013 (.0236)	-.0001 (.6598)	-.0001 (.6231)	-.0001 (.6512)	.0004 (.7454)	.0004 (.7439)	.0004 (.7732)
Presence of Galvanized Steel	.0258 (.2580)	.0247 (.2789)	.0259 (.2633)	.0150 (.1961)	.0156 (.1768)	.0143 (.2189)	-.0664 (.1913)	-.0660 (.1935)	-.0656 (.1970)
Note: Numbers reflect regression coefficients (p values are in parentheses)									

Results examining the relationship between the improvement in water quality over time, measured as the percentage of SPS and AAP standard failures (table 4b), are sensitive to the operationalization of the independent variable (SES).

Table 4b: Water Quality Improvement Over Time from 3rd (last) water testing period

	SPS Fail Slopes			AAP Fail Slopes		
% FRPL	0.0162 (.1135)			-.0040 (.7460)		
Binary SES		-.0067 (.2332)			-.0007 (.9181)	
Title 1			-.0105 (.0747)			-.0045 (.5351)
1st Construction Year	0 (.7729)	0 (.6785)	0 (.8499)	-.0001 (.3389)	-.0001 (.3533)	-.0001 (.3111)
Last Renovation/ Addition Year	-.0003 (.0277)	-.0003 (.0360)	-.0003 (.0270)	-.0003 (.1646)	-.0003 (.1721)	-.0003(.1562)
Presence of Galvanized Steel	.0017 (.7896)	.0014 (.8272)	.0022 (.7229)	-.0064 (.4104)	-.0064 (.4077)	-.0006 (.4285)
Note: Numbers reflect regression coefficients (p values are in parentheses)						

6. Discussion

The analyses sought to address two key concerns. First, the study explored whether SPS schools face a problem with lead contamination in their water pertaining to the existence of violations of both SPS and AAP water quality standards measured systematically over a period of 12 years (from 2004-2016). The study further examined whether this problem was improving over time. Second, the analyses investigated whether schools with predominantly poor, minority students were disproportionately exposed to lead in their water. Prevailing environmental equity and health literature suggests that not only are environmental inequities present within many urban schools in the United States, but that the issue of lead contamination is of especially great significance among students given the comparatively higher risks of childhood lead exposure. Amid the growing realization of the prevalence of lead in water throughout the country, this study tested whether the pervasiveness of lead contamination both existed and corresponded to equity concerns in Seattle as well. This hypothesis challenged the assumption that Seattle, a rapidly growing and well-resourced city, would likely be devoid of lead-related health and equity problems. The study found reoccurring violations of both SPS and AAP water quality standards. The spatial analyses revealed a scattering of lead violations of both standards throughout the district, with a greater number of schools with zero violations located in the north and fewer schools with zero violations located in the south. However, results also indicate that the percentage of sources in schools violating both standards is declining over time suggesting the lead contamination problem in SPS school water is improving. In regards to equity concerns, the study found an existing relationship between SES and water quality in SPS schools, indicating that Seattle's more vulnerable student populations are exposed to poorer water quality. The

strength of this association differs with respect to both the operationalization of SES and the stringency of the water quality standard assessed. The strength of this relationship is also greater in the middle testing period than the last testing period.

7. Conclusion

In conclusion, the findings from this study are consistent with prevailing environmental equity literature that cites class and race as powerful predictors in environmental risk exposure. The data presented here indicates that SPS students of lower-socioeconomic status and who are predominantly racial and ethnic minorities, are disproportionately burdened by higher levels of lead contamination in their school drinking water. Furthermore, the results illustrate an equity issue pertaining to access. The spatial analyses revealed that students of lower-SES have less access to schools with zero lead violations than their higher-SES peers in the north. Evidence from this research also indicates that overall water quality in the Seattle Public School District is improving over time. However, given the substantial evidence linking childhood lead exposure to long term, adverse health effects, these findings hold considerable importance for the futures of all children (past and present) who have passed through the Seattle public education system. The hope is that this research will aide in the development of future policy decisions pertaining to the funding of water quality testing and revisions of lead criteria for public schools in the State of Washington.

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Appendix

The sample size for this study included 78 schools. The following information details schools that were excluded from the study due to missing data:

- Arbor Heights was demolished and rebuilt in 2016, and thus only had sampling data from 2016. It was not included in the analyses since it had only been tested one year and thus results could be compared to previous years.
- Cedar Park was built in 1959 and has been leased to an Art Community for the past 30 years. This building has served as an interim site for Olympic Hills Elementary in 2015-2016. Thus in the analyses, water testing data for Olympic Hills Elementary was taken from the Olympic Hills Elementary original school site up until 2015, at which point data was used from the Cedar Park building since that is where the Olympic Hills students were during that year. Cedar Park, however, was not included as a separate entity/school, as there is no school profile report for it, and the only existing water quality testing data is for 2015 (the year Olympic Hills Elementary used the building).
- Fairmount Park only had sampling data from 2014. It was not included in the analyses since it has only been tested one year and thus results could not be compared to previous years.
- Queene Anne Elementary only had sampling data from two years (2008 and 20011). It was not included in the analyses since it had insufficient observations.
- Sand Point Elementary only had samples from two testing years (2011 and 2015). It was not included in the analyses since it had insufficient observations.
- Thornton Creek Elementary School only had sampling data from year 2016. It was not included in the analyses since it had only been tested one year and thus results could not be compared to previous years.
- Van Asselt Elementary School moved to the former African American Academy Building in September 2009. Thus, in this analysis the water sampling data from 2009-present for Van Asselt was taken from the testing reports at the African American Academy Building. The African American Academy building was not included as a school in and of itself though.
- Viewlands Elementary only had sampling data from 2011 and 2014. It was not included in the analyses since it had only been tested two years and thus results could not be compared to previous years.

- Denny Middle School only had sampling data from years 2010 and 2014 It was not included in the analyses since it had insufficient observations.
- SPS closed Meany Middle School 2009, allowing for the Nova Alternative High School and the World School program to move in. Nova has since moved back to its home in the Horace Mann building on E Cherry and the World School will move to an overhauled TT Minor on E Union next year. Though there is water quality testing data for this building, Meany was not included in the analyses since there is no single student population that uses the building. Rather, the building has housed a number of alternative schools over the years. Due to lack of demographic data for all water quality testing years, Meany was not included in the analyses at all. The school is scheduled to reopen in a new building in Capitol Hill in 2017
- Cascadia Elementary and Licton Springs K-8 are both temporarily located at the Lincoln High School building.
 - Cascadia moved to the Lincoln High School building in 2011 due to growing enrollment. There is no water quality data on Cascadia Elementary before its move to Lincoln High School. Lincoln High School only has one testing year since 2011 when at least 50% of sources were tested (in the year 2013, 64% of Lincoln’s water sources were tested). Thus Cascadia Elementary was not included in this analysis.
 - Licton Springs K-8 (formerly known as Pinehurst K-8) moved to the Lincoln High School building in 2014. There is no water quality data available for Licton Springs/Pinehurst before its move to the Lincoln High School Building. Thus Licton Springs was not included in this analysis.
- Schmitz Park Elementary moved to a new building in the fall of 2016 and also received a name change with that move (now called Genessee Hill). Thus, Schmitz Park is referenced as Schmitz Park/Genessee Hill Elementary School. Water testing data was taken from the original Schmitz Park school building site up until the time of the move. Water testing data from 2016 on was taken from the new Genessee Hill school building.
- Louisa Boren K-8 opened in 2011, and while there is water quality testing data for previous years, those years were when the building was being used as an interim site by various schools and programs. Thus, since its inception as a school in 2011, Boren k-8 only has 2 years of water quality testing data. It was not used in this analysis.
- McDonald Elementary was built in 1914, and closed in 1981 due to low enrollment. It reopened in 2010 at a temporary site (Lincoln High School) while its original building underwent renovations. Students moved back to the newly renovated school in 2012. While water quality testing data exists for the McDonald Elementary School starting in

2004, there are only two years of water quality testing data that exist for when students were actually housed/present in the building once the school reopened. Furthermore, there is no socioeconomic data for the school before 2011 since the school did not reopen until the 2010-2011 school year. Given the insufficient data, McDonald Elementary was not used in this analysis.

- There is no water quality information on The Center School. It will not be included in this analysis.
- Nathan Hale High School has fewer than three years of water quality testing data where 50% or more of sources were tested. Therefore, it was not included in this analysis.
- There is no water quality information on the Interagency Academy. It was not included in this analysis.
- There is no water quality information on Middle College. It was not included in this analysis.
- There is only water quality data from 2015 for NOVA High School. It was not included in this analysis due to insufficient data.
- Chief Sealth High School temporarily moved into the Boren building in 2008 and then into its own, new building in 2010. Thus water quality data for Chief Sealth High School in 2008 was taken from Boren, and subsequent years from the Sealth building.
- There is no water quality testing data at all for the Seattle World School. It was not included in this analysis.