The Effect of Poverty Levels and Minority Percentages on Lead Content in South Carolina Midlands School Drinking Water

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Increased drinking water contaminant concentrations have been frequently reported in communities with higher minority percentages as well as those with lower average incomes, causing numerous adverse effects. This study expands on current knowledge, examining lead concentrations in public school drinking water as it compares to each school's percentage of minority and poverty students, using a linear regression for each factor. Twenty-one schools participated in the study and provided three water fountain samples each, totaling 63 samples. The former regression regarding minority percentages yielded a p-value of 0.003 as well as a r-value of 0.602. The latter regression yielded a p-value of 0.010 and a r-value of 0.540. Both regressions showed significant correlations between socioeconomic factors and lead concentrations (p-value < 0.005 and r-value between 0.5 and 0.7). A linear regression was also conducted between minority and poverty percentages and yielded a p-value of 0.000 and a r-value of 0.964. While these socioeconomic factors are highly significantly correlated, the factors are not identical and yielded different p-values and r-values when compared to lead content. The regression argues that while minority and poverty percentages in student populations significantly correlate with lead concentrations in drinking water, minority percentages are more significantly correlated, and therefore a better predictor of lead, than poverty percentages. This suggests that there is a systemic problem in water access, where lower-income and predominantly minority populations endure lasting health effects that higher-income and minimally minority populations endure less.

Introduction

Under the Safe Drinking Water Act (SDWA)[1] enacted in 1974, the Environmental Protection Agency (EPA) was given the authority to establish minimum standards for drinking water to protect the health of the citizens of the United States (US) that are outlined in 40 C.F.R. 141 (National Primary Drinking Water Regulations)[2]. Despite this, American public schools are not required to test the quality of the drinking water provided to students from water fountains, even with the amendments made to the SDWA in 1996 (which further detailed the EPA's responsibilities) as well as the maximum contaminant levels (MCLs) the EPA sets on more than ninety contaminants. This includes regulation on lead concentrations in drinking water for which the MCL is 15 parts per billion (15µg/L). Since the SDWA denotes school drinking water regulation to state authorities, only fifteen states have policies regarding the testing of school drinking water for the presence of lead, as found in a study conducted by the Harvard School of Public Health[3]. In other states, like South Carolina, drinking water testing in public schools is completely voluntary and therefore risks the safety of students that regularly ingest the water provided. An article published by the National Education Association records a case in which a Pittsburgh school district decided to voluntarily test its drinking water and found that fourteen of its water fountains had elevated lead levels above twenty parts per billion, well above the MCL (15 parts per billion) as set by the EPA[4]. This trend is consistent with other case studies, including a report from the US Government Accountability Office[5] in which out of the 43% of schools that voluntarily tested for lead in drinking water, 37% had samples considered elevated (above the district's threshold for remedial action). The lack of testing in the other 57% of schools raises concerns over the unknown number of students that are exposed to lead and its effects daily.

Although the EPA requires drinking water to adhere to 40 C.F.R. 141 and MCL standards, it only tests the indicators it regulates at primary sources of drinking water, like water treatment facilities, before the water has passed through lead plumbing to be received by students within schools. The use of lead piping for installation or repair was banned with the 1986 amendment to the SDWA, but lead piping already in use was not to be replaced, meaning that a great deal of lead piping still remains in the US[6]. With the lack of regulation on the testing of drinking water in public schools, it is unknown how many schools are impacted by elevated lead levels, and therefore how many students are suffering from the negative side effects that come from the consumption of lead.

The presence of lead in drinking water has numerous adverse health effects including anemia, lowered IQ, premature births, decreased kidney function, increased blood pressure, behavioral problems, slowed growth, hearing problems, and in the most severe cases, seizures and possible death[7]. By making lead testing in schools optional, potentially harmful levels of lead in drinking water may be overlooked, and may consequently impact students' health and academic performance. Younger children and adolescents are the most vulnerable to higher lead concentrations, as their current growth and development makes it easier for them to absorb lead into their bloodstream, further exacerbating these harmful health impacts. While this testing would help protect students, it is often disregarded and neglected by government regulations.

South Carolina has been known to fall behind when it comes to drinking water quality and its regulation. South Carolina is one out of 25 states in the US with no mandatory policy or encouraging programs for the testing of school drinking water. South Carolina is also said to be home to the "New Flint" (referring to the Flint Water Crisis in which residents were exposed to high lead concentrations), in the town of Denmark, South Carolina. In Denmark, HaloSan, a substance that was not approved by the EPA, was being used to treat the town's water and caused burning sensations, rashes, bleeding, and much more[8,9].

Recent studies have shown that variations in lead testing and concentrations have been found to differ based on many socioeconomic factors, mainly a community's primary ethnicity. For example, the American Water Works Association found that in lower-income communities with primarily African American and/or Hispanic residents, significantly more drinking water quality violations were reported. These results raised the question if higher poverty levels worsen the effects that minority communities face or if higher minority levels worsen the effects that low-income communities face[10].

Based on the evidence of elevated lead levels in schools and the lack of research as to how income impacts water quality and regulations, this study proposes the question: "To what extent do poverty levels and minority percentages impact lead concentrations in South Carolina public school drinking water?" It was hypothesized that South Carolina Midlands schools with higher percentages of students in poverty as well as those with higher percentages of minority students would have higher concentrations of lead in drinking water samples than those with lower poverty and minority percentages. The impact of poverty percentages was hypothesized to be greater than that of minority percentages since water provision is heavily based on funding and poverty percentages are more related to finances. To determine this, the goal of this research project was to determine if correlations existed between lead levels and the socioeconomic factors; poverty levels and minority percentages in public schools in a Midlands district in South Carolina, and if so, which was more heavily correlated. To quantify the study, drinking water samples were collected from Midlands schools and tested for lead content. Afterward, a linear regression was used to determine if there was a correlation between the lead content and the socioeconomic factors. The results were then compared to see which factor is more significant in terms of lead concentrations.

Literature Review

Recently, there has been a growing interest in drinking water quality on a global scale. This may be attributed to the United Nations' Sustainable Development Goals, which aim to provide access to potable water of a healthy quality under goals 3, 6, and 12, specifically under targets 3.9, 6.1, 6.b and 12.4[11]. In the US specifically, events surrounding drinking water quality, such as the Flint Water Crisis, have significantly increased focus on the topic.

As reported by the Natural Resources Defense Council[8], the city of Flint, Michigan (which is predominantly African American) switched its water supply to the Flint River in 2014 from the Detroit system, for financial benefit, resulting in an increase in the lead content of Flint's drinking water. These reports, accompanied by many protest efforts, increased the public's awareness of the issue of lead contamination, the economic reasoning behind some forms of water supply, and even the impact of ethnicity on water provision. Before the Flint Water Crisis even began, however, the EPA and the Center for Disease Control and Prevention (CDC) had warned the public about lead and the dangers of its presence in drinking water. After this incident, research into the presence of lead in the US' drinking water and water quality in general increased greatly.

A similar situation occurred in Denmark, South Carolina, another predominantly African American community that was affected by poor water quality practices. Residents were concerned about the rust-colored water they were receiving. After further examination, this was due to HaloSan, a chemical being used to treat high iron levels in Denmark's drinking water. This chemical had not been approved or completely reviewed by the EPA, therefore its usage in treating drinking water was in direct violation of the SDWA. The EPA did publish a risk assessment about HaloSan in which it described the many known health risks associated with its usage which include skin irritation, burning sensations, rashing, bleeding, etc. South Carolina's Department of Health and Environmental Control believed HaloSan was EPA approved, leading to its unfortunate usage which was harmful to the Denmark community. This event emphasizes the importance of in-depth water quality practices to ensure the safety of the public as well as the need for increased drinking water regulation in the state of South Carolina.[8]

A study published by the American Water Works Association was particularly inspired by the Flint Water Crisis and examined how the socioeconomic status of a community affected the ability of utilities to supply safe drinking water to its residents, noting that Flint, Michigan is a predominantly African American community. Researchers found strong evidence that there is "a systemic issue in utilities serving low-income communities of color across the United States" due to the increase in reports of drinking water violations in these areas[10]. The study notes that both African American and Hispanic populations had more water quality violations but more so in Hispanic communities. This study examined the issue with drinking water quality in regards to the performance in supplying rather than the quality of the drinking water itself. Switzer and Teodoro also raised the important question of if high minority levels exacerbated the effects found in low-income communities or if lower-income exacerbated the effects found in minority communities. While it noted this trend, it did not analyze the extent of it. Either socioeconomic factor could easily act as a lurking variable for the other since the two are so closely related. In fact, a linear regression between the two factors has a p-value of 0.000, meaning the two are virtually identical. For example, if minority levels were the driving force behind differences in drinking water quality, it would only make income-based factors appear to be related to water quality. Determining which factor is the true driving force would ultimately determine which should be used to predict high-risk communities for excess lead content in drinking water, and therefore where testing should be encouraged the most.

A study published in the journal of *Preventive Medicine Reports*, explored drinking water destinations, inspecting how demographic factors like school type (elementary, middle, and high school), location, and age impacted the implementation of various school drinking water quality practices, such as the ability for students to bring a water bottle as well as water quality education[12]. It concluded that most schools allowed students to bring water bottles, although very few schools emphasized the importance of drinking water quality. In high schools, students were more likely to be given these privileges, unlike elementary and even middle school students. While this study adequately compares socioeconomic factors as they compare to water quality practices in schools and related factors, as a good example for this study, it does not focus on drinking water quality itself, which is a more direct and summative representation of SDWA and C.F.R. 141 regulation and implementation.

In addition to this, a study published in the journal of *Environmental Health* examined the drinking water quality across the United States in terms of nitrate levels based on a variety of socioeconomic factors including race, poverty level, and percent of cropland. The study did not find a great number of areas with unlawfully high levels of nitrate (as based on MCL standards), but it did find nitrate levels that it considered high enough to cause negative health effects. This trend was seen further in low-income communities as well as those where higher percentages of Hispanics reside[13]. The study shows the importance of socioeconomic factors on water quality, but not lead specifically which is a more common and harmful contaminant.

Research studies regarding drinking water quality have taken even more unique approaches like one published in *Nature Medicine*[14] which used socioeconomic factors to calculate lead exposure risks through drinking water which was then compared to cognitive test scores and brain imaging. This found that more at-risk populations had lower cognitive scores which was also evident in brain imaging. This heavily supports the concept that lead exposure is more common than most assume and concurred with data reported by the Institute for Health Metrics and Evaluation and the University of Washington[15]. This report argued that "lead exposure accounted for 63.2% of the global burden of idiopathic developmental intellectual disability [intellectual disability for which the cause is unknown], 10.3% of the global burden of hypertensive heart disease [caused by high blood pressure], 5.6% of the global burden of the ischaemic heart disease [decreased blood flow] and 6.2% of the global burden of stroke" as quoted by the World Health Organization in 2019[16].

While studies can take this approach, those that focus on drinking water regulations, quality, and practices are much more common. However, there is a gap in studies that directly test for lead concentrations as compared to socioeconomic factors, especially in schools that are home to the most vulnerable populations; children and adolescents, who more easily absorb lead into their bloodstream. Many of these research studies examine any possible correlation between socioeconomic factors and drinking water quality, education, and practices on a national level while research on a smaller level is still needed. Furthermore, current studies only examine economic or social factors and therefore do not determine which has a greater influence on water quality. This research project aimed to address this gap by examining the presence of lead in school drinking water as compared to important socioeconomic factors: poverty levels and minority percentages in student populations, in an area that is known to be at risk for unhealthy drinking water quality, South Carolina, specifically in its Midlands region due to its lack of water testing regulation and implementation as well as the Denmark water crisis as aforementioned.

Methods

The design of this project, as developed from the similar studies examined in the literature review, included obtaining water fountain samples from various subjects (public schools in Midland South Carolina), and testing those samples. The average lead concentrations were then compared with the schools' respective socioeconomic data which was compiled from data publicly provided by the South Carolina Education Department. The poverty level data from the 2020 South Carolina School Report Card[17], which is publicly available under the Every Student Succeeds Act, was used as well as the minority percentage of the student population as calculated from the 180 Day Active School Headcount by Gender, Ethnicity, and Pupils in Poverty for the 2019-2020 school year data[18]. Using a correlation research method similar to that of the studies mentioned above in the literature review, collected lead concentration data, poverty percentage (PP) and minority percentage (MP) data, and a linear regression, these factors were statistically analyzed to determine if a correlation exists and which is stronger.

This study has clear explanatory and response variables as follows; the PP and MP data for the student population at each school served as the explanatory variables while the lead concentrations, in µg/L, served as the response variable. All other variables were controlled as much as possible including the procedure in which water fountain samples were taken, the containers in which samples were collected, and the methods for testing said samples. The environment in which samples were tested also stayed constant for all of the tests. All data collected was presented and analyzed in a quantitative form so it can be statistically analyzed to determine if a correlation exists.

The South Carolina Midlands region consists of twelve counties in which there are 22 public school districts. For this study, only one of the said districts was used to control the experiment as much as possible by reducing disparities in outside contaminants that are not being considered in testing. The school district selected will remain anonymous for its protection, but it is important to note that it is a higher income district in general with an average household income of $93,789 compared to the average household Midlands district income of $66,714[19]. The district has 21 elementary, middle, and high schools, excluding schools that are in construction or specialty schools in which students from home schools go to take specialty classes.

Each school was called prior to visitation to ask for approval of participation. Three drinking water fountain samples were then taken from various locations around each school's campus. Samples were collected in plastic bottles (borrowed from a school science lab) that could hold at least 150mL. The containers were thoroughly washed before sampling to minimize the risk of contamination and inaccurate readings. Samples were taken in locations far from each other to ensure the averages would be as accurate as possible. It was also ensured that the fountains had been running for at least ten minutes prior to testing to reduce particulate matter, which could affect the testing results. After testing, the concentrations of lead in each sample were then averaged to determine an estimate of the school's general lead content. With 21 participating schools and three samples from each school, 63 samples were collected and tested in total. These 21 averages (n=21) were used during the statistical analysis.

To determine the lead concentrations in the samples, all 63 samples were tested with a water quality test strip (shown in **Appendix A**) that has a range of zero to fifty parts per billion (ppb) or micrograms per liter (µg/L) for lead concentrations. These tests were dipped into the sample for two seconds and after a minute would show a color indicating the lead concentration which was compared with the key given in **Appendix B** (the testing process is shown in **Appendix C**). The specific instrument used in this study, Med Lab Diagnostics 16 in 1 Reagent Test Strips for Water Testing, has a specific range that concurs with the EPA's MCL of 0.015 mg/L or 15 µg/L, which many test strips fail to do. Each strip tests for lead, fluoride, iron, copper, mercury, total chlorine, nitrite, nitrate, pH, hardness, aluminum, and sulfate, some of which have negative health effects when present in drinking water. If any tests seemed abnormal (drastically different from the other samples or had levels over the MCLs), they were retested using the test strips to ensure results. Any hazardous levels were immediately reported to participating schools.

The PP data for each school was recorded using the South Carolina School Report Card[17] data. To access the data used, a number of factors needed to be selected in the database. After selecting "View Report Card", the current year, type of school (high, middle, elementary), chosen district, and respective school had to be selected. Under the "School Environment" category, "Financial Data" was selected. This section shows financial data from teacher salary to expenditures for different resources, many of which are the same for schools in the same district. For this study, "Percent of students in poverty" was used to depict the financial conditions of the student population specifically. Income statistics were only available on the district level and therefore could not be used as the economic factor in this study. The poverty percentage is defined by many factors including the student being "homeless or migrant for the current school year, Medicaid enrollment at any time in a three year period, Supplemental Nutrition Assistance Program enrollment at any time in a three year period, Temporary Assistance for Needy Families enrollment at any time in a three year period, and foster care involvement at any time in a three year period"[17].

A bivariate analysis was then conducted using this data which was statistically compared with the averages of lead concentrations above using a linear regression t-test to determine if a correlation existed between the factors.

MP data was accumulated using the 180 Day School Headcount by Gender, Ethnicity, and Pupils in Poverty for the 2019-2020 school year data[18]. This database breaks down student populations by sex, age, and ethnicity. Using this data, the ratio of non-white students to the total student population in each school converted to percent form served as the minority percentage data for each school. Another linear regression was then conducted using this data.

A null hypothesis was also created to be accepted or rejected by the outcome of the linear regression which stated that the selected socioeconomic factors have no impact on lead concentrations in South Carolina schools. By following the **procedure** outlined above, average school lead concentrations can be statistically compared to socioeconomic factors to determine if a correlation exists between the factors and therefore if the null hypothesis is accepted or rejected.

Results

After each school was sampled and all 63 samples were tested, the results were compiled into a spreadsheet which outlined the school name (which will be presented as a number for these purposes), the respective PP, respective MP, each sample's lead concentrations (samples are referred to as A, B, and C), the averages for these concentrations (abbreviated as Aver [Pb]), any other important information regarding water quality, and the averages for these values as seen in **Table 1**. All lead concentrations are presented in µg/L. "A", "B", and "C" refer to Samples A, B, and C from each school.

Table 1. Lead Concentrations and socioeconomic data

School #	PP	MP	A [Pb]	B [Pb]	C [Pb]	Aver [Pb]	Other
1	37.4	34.5	0	0	0	0	N/A
2	38.2	20.1	0	0	0	0	N/A
3	20.4	16.6	0	0	0	0	N/A
4	26.3	17.1	0	0	0	0	N/A
5	22.6	18.2	0	0	0	0	N/A
6	56.3	60.5	2	2	2	2	N/A
7	70.5	66.8	1	0	1	0.67	N/A
8	38.3	52.3	0	2	0	0.67	N/A
9	41.8	47.8	1	1	1	1	N/A
10	68.8	66.1	1	0	1	0.67	N/A
11	76	75.6	0	2	1	1	N/A
13	69.6	72	4	3	2	3	N/A
14	66.1	67.1	2	2	2	2	N/A
15	18.6	16.4	0	1	0	0.33	High F
16	74	72	1	1	1	1	N/A
17	70	63.8	1	1	1	1	N/A
18	42.4	36.6	1	1	0	0.67	N/A
19	34.4	34.7	2	2	3	2.33	N/A
20	87.3	86.7	3	3	4	3.33	N/A
21	26.6	26.4	0	0	0	0	N/A
Average	43.3	39.1	0.67	0.75	0.67	0.69	N/A

The poverty percentages ranged from 18.6% to 74% with an average of 43.3%. The minority percentages varied more but remained generally similar, ranging from 16.6% to 86.7% with an average of 39.1%. Average lead concentrations ranged from 0µg/L to 3.33µg/L with an average of 0.69µg/L. 21 out of the 36 tests indicated no presence of lead whereas nine tests contained 1µg/L, three tests contained 2µg/L, two tests contained 3µg/L, and one test contained 4µg/L. No samples exceeded the EPA MCLs for any indicator. However, aluminum and fluoride levels varied between samples. Aluminum concentrations ranged from 0 to 15 parts per million. Aluminum only affects the taste of water and has no known health effects at such low levels. Aluminum is only included in the Secondary Drinking Water Regulations (which focus on aesthetic water factors i.e. odor, taste), so it was excluded from the study. Fluoride was slightly elevated in one sample from School 15 but not enough to cause any health effects or other concerns. While no sample had any levels that exceeded the MCLs, it is important to note that the EPA recommends no lead content in drinking water due to its severity[7].

Data Analysis

To measure the correlation between the PP, MP, and lead concentrations, a linear regression was used. There are clear explanatory variables, PP and MP per school, and a response variable, lead concentrations, in this study which will allow for the data to be analyzed using this method. Using these values, an ordered pair was created for each school for which the x-value would represent the socioeconomic factor as a percentage and the y-value would represent the average lead concentrations of the three samples taken from the school in micrograms per liter. Using these points, a fitted line was constructed using the Minitab 18 software[20]. The p-value, r-value, and slope of the best fit line were all considered when analyzing the results. The p-value describes the probability that results occurred by random and can be compared with a significance level (alpha) to determine if the results are statistically significant. For this study, a 0.05 significance level was used, meaning that any p-value less than 0.05 would be considered statistically significant. The r-value (ranges from -1 to +1) describes the strength and direction of an association in which a greater absolute value of the r-value would describe a stronger association. A positive r-value corresponds to a direct association (increases in explanatory variable causes increases in response variable and vice versa) and negative r-value corresponds to an inverse association (increases in explanatory variable causes decrease in response variable and vice versa). The slope does not provide statistical meaning in terms of describing a correlation, but it can be used to show the rate at which increases/decreases in one factor can cause increases/decreases in another.

The data in **Table 1** was statistically analyzed using a linear regression to determine if a correlation exists between the poverty percentages and the lead concentrations. The regression had a p-value of 0.010 which suggests that the results were not random and are statistically significant using the 0.05 significance level. The regression also had a Pearson correlation coefficient (r-value) of 0.540 which indicated a positive association with a moderate level strength because it is between 0.50 and 0.75 (considered the moderate range). This means that when PP increases, lead content ([Pb]) also increases and vice versa (a direct relationship). A fitted line plot was created using the ordered pairs and a line of best fit that had an equation of $[Pb] = -0.2405 + 0.02683PP$. The slope (0.02683) of this line indicates that for each one percent increase/decrease in PP, lead content increases by 0.02683µg/L. The fitted line plot is shown in **Figure 1**.

The same method was used to analyze the MP versus lead content. Another linear regression test was performed and yielded a p-value of 0.003 and therefore the results were not random and are statistically significant using the 0.05 significance level. It also yielded a Pearson correlation coefficient of 0.602 which indicated a moderate positive association (between 0.5 and 0.75). The fitted line plot of the factors yielded the equation $[Pb]=-0.2434+0.02786MP$. The slope (0.02786) indicates that for every one percent increase/decrease in MP, the lead content increases/decreases by 0.02786µg/L. The fitted line plot is shown in **Figure 2**.

Discussion

The results of the data analysis were very similar to those discussed in previous studies. The linear regressions supported that both socioeconomic factors were significantly, moderately, positively correlated with lead content as determined by examining p-values, r-values, and best fit line slope. However, MPs indicated a stronger correlation with lead content than that of PP and lead content with a higher r-value (MP 0.602, PP 0.540) and a lower p-value (MP 0.003, PP 0.10). The slope of the fitted line plot for MP (0.02786) was also greater than that of PP (0.02683), indicating that lead content changes at a higher rate as MP changes than when PP changes.

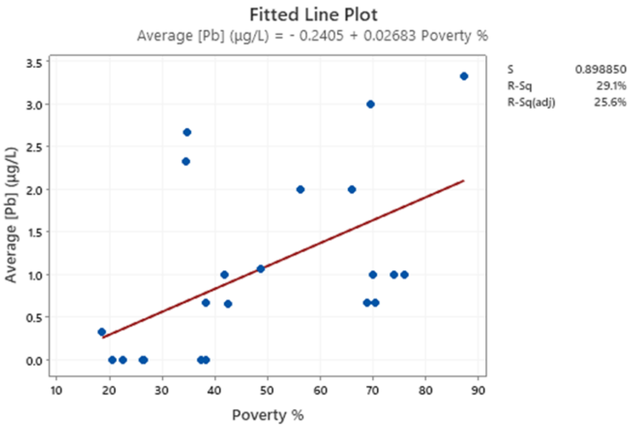

Figure 1

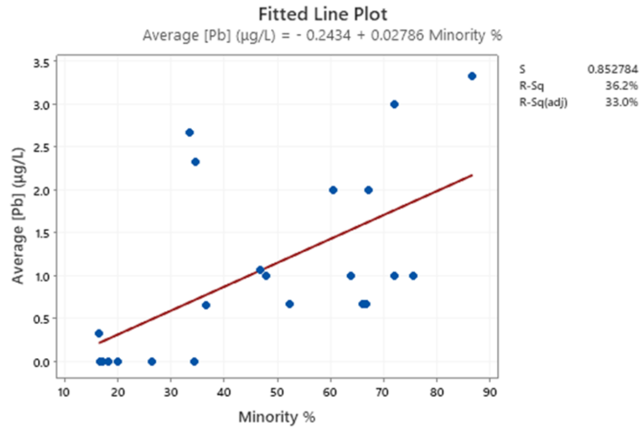

Figure 2

This information supports the hypothesis that regressions regarding MP and PP versus lead content would be significantly positively correlated, but it does not support the hypothesis that PP would have a stronger correlation than MP. The null hypothesis (there is no correlation between socioeconomic factors and lead content) of the study was rejected due to the significant correlation seen between factors.

The implications of this study urge for the protection of students via increased regulation regarding the testing of drinking water in schools. While no samples contained lead concentrations that exceeded the EPA MCL, 59% had lead present, which still carries numerous risks. The EPA even acknowledges this by setting 0µg/L as the maximum contaminant level goal (MCLG), which represents the threshold for no health risks, meaning that any lead content over 0µg/L is harmful. The MCLG is not enforced but it does show concern toward even low lead content[2,7]. With this in mind, public schools that refuse to test the water provided are risking student safety on a daily basis. Furthermore, the evidence that suggests that socioeconomic factors impact school water quality cannot be overlooked. Regardless of why this effect is seen, it is unjust that children and adolescents that are subject to differing socioeconomic statuses are inconsistently subjected to lead exposure and the risks associated with it. Testing should be either encouraged or enforced to remedy this issue for the safety of students, regardless of their socioeconomic status.

The Federal Government has begun taking action against socioeconomic discrimination in drinking water provision with the recent American Rescue Plan that formed as a relief program in response to the COVID-19 outbreak. The plan "contains $500 million in assistance for clean and drinking water customers" with an emphasis on low-income customers[21]. This legislation is a positive advancement as it recognizes the impact of income on water quality, but it still lacks regulation for schools and assistance for predominantly minority communities.

Conclusion and Future Directions

This information has provided a **n**ew understanding in the discussion of socioeconomic factors and the concentration of lead in drinking water. While it was previously indicated that socioeconomic factors, especially regarding minorities, were correlated with water quality, no research had been conducted as to its effects on lead concentrations specifically, even considering the severe health effects associated with its presence. Furthermore, the research previously conducted regarded water quality at the homes of residents as well as violations reported at these locations, therefore excluding schools that house the most susceptible populations to the effects of lead: children and adolescents. In this regard, this study addresses a gap in research by not only providing evidence of strong correlations between MP and PP versus lead content but also with MP having a more prominent correlation than PP.

The study did also encounter many limitations which impacted both the methods and conclusions. Due to financial restraints, inexpensive lead test strips were used instead of more accurate and specific equipment like a lead sensor. If this were not the case, the methods would have been modified to obtain more specific sample testing results. This reduced the overall accuracy and specificity of the study. Furthermore, time restraints combined with scheduling conflicts (collecting samples during school hours) restricted the number of schools that could be sampled. This was particularly limiting due to COVID-19 restrictions for which schools strived to limit visitors to a minimum. Another limitation arose from only testing one district in the area which was significantly a higher income district. This restriction on sample size reduced the accuracy of the results as more trials would have provided more data to further support or oppose the results. The results are also limited to the area of study, the South Carolina Midlands, but can still be used to indicate a need for future research. The conclusion of this study is therefore limited in that the results are limited in accuracy and the small sample size cannot confirm or deny the presence of correlations between the chosen factors, but it can support them.

The limitations of this study suggest numerous adjustments that can be made for future research studies. For future applications, the sample size could be expanded to include more schools and even more districts to further analyze the extent of this effect. More trials would provide more data which would improve the accuracy of the analysis for this trend. Furthermore, other socioeconomic factors could be analyzed including sex ratios, specific racial breakdowns (which have been seen to differ in previous studies), average income, and academic achievement (ie. Grade Point Average, standardized test scores, etc.). Age of the school could also be considered as lead piping was banned in 1986 so more recent construction would contain less lead piping and therefore less potential for increased lead content.

Overall, while the study was limited in both its methods and conclusions, the statistical evidence was able to reject the null hypothesis that there was no relationship between the socioeconomic factors and lead content. This rejection further supports the findings of previous studies and continues to advocate for further research that can be applied on a larger scale, with both a larger area and more socioeconomic factors. This research continues to support the idea that increased regulation is necessary to protect at-risk populations and contributes to a gap in research by extending socioeconomic water quality focused research to South Carolina Midlands schools and lead content.

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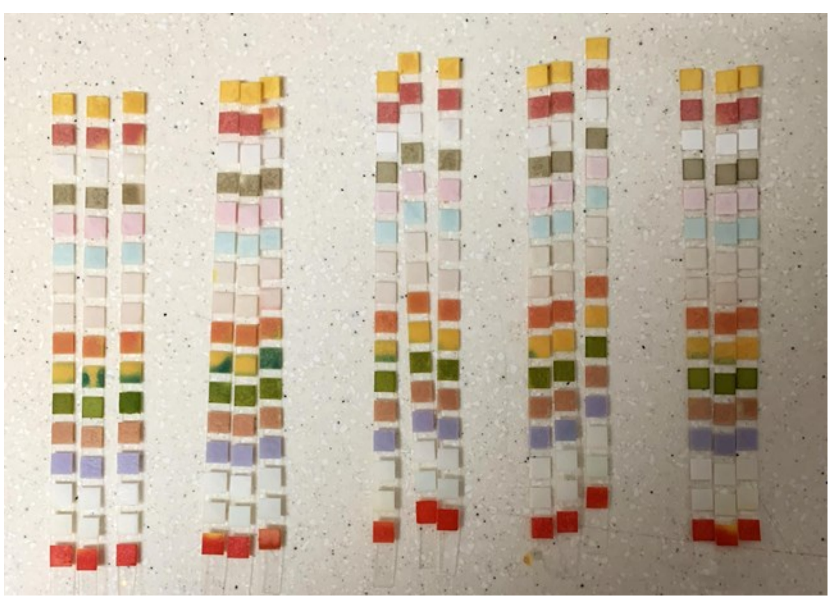
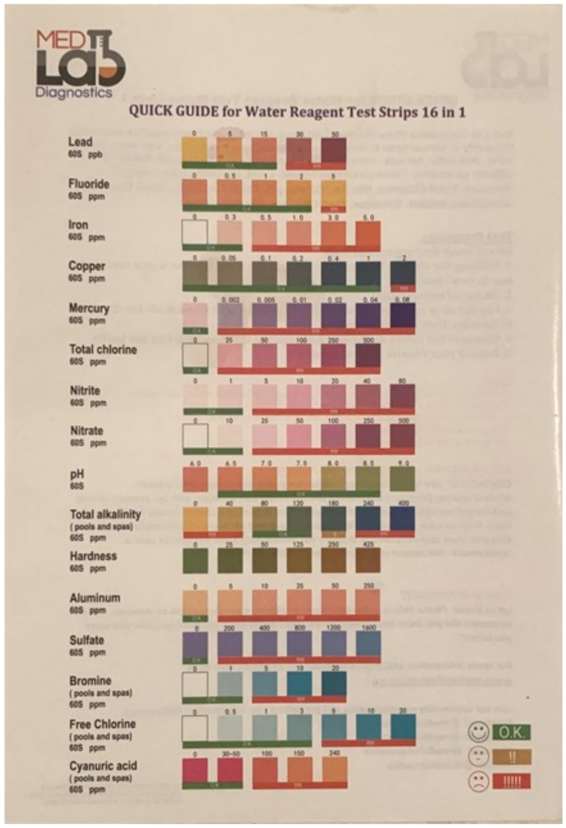
Appendix A



Appendix B



Appendix C