Title

CORRELATION BETWEEN ARSENIC CONTAMINATION IN DRINKING WATER TO INCOME AND RACE DEMOGRAPHICS IN THE INLAND EMPIRE OF CALIFORNIA

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CORRELATION BETWEEN ARSENIC CONTAMINATION IN DRINKING WATER TO INCOME AND RACE DEMOGRAPHICS IN THE INLAND EMPIRE OF CALIFORNIA

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ABSTRACT

Arsenic is an element of the Earth's crust that can make its way into drinking water via industrial and agricultural activity as well as natural deposits. In its inorganic form it can be highly toxic and can lead to adverse impacts on human health, including neurological diseases, metabolic disorders and various cancers. The United States Environmental Protection Agency changed the drinking standard from 50ppb to 10ppb in 2001 to prevent the long-term effects that come with prolonged exposure to arsenic; however, standards lower than the ones established by the EPA can impact health. Although the Maximum Contaminant Level (MCL) is 10ppb, the Maximum Contaminant Level Goal (MCGL) is 0 which is the highest level of a contaminant in water at which there are no known or predicted harmful effects on human health. The environment plays a key role in several of the health problems impacting humans today from metabolic disorders to cancers. There is mounting evidence indicating that there is a connection between low median household income and socioeconomic status to exposure to poor environmental conditions. This project will explore whether there is a correlation between arsenic in drinking water to income and race demographics in the Inland Empire of California.

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INTRODUCTION

Arsenic

One of the main contents of concern in drinking water is Arsenic. Millions of people around the world are exposed to this semi-metal element through groundwater naturally or due to agricultural and industrial activity such as pesticides and irrigation drainage.[1,2] It ranked first on the Agency for Toxic Substances and Disease Registry's 2019 substance priority list, which is based on the potential damage it presents to human health.

Revision of Arsenic Standard

Due to epidemiological evidence, the United States Environmental Protection Agency (EPA) revised the arsenic standard for drinking water, MCL, from 50ppb to 10ppb and the MCGL to 0ppm in 2001 and was enacted in 2002. Public Water Systems were given until 2006 to adhere to these standards. [3]

The MCL is established at a level that is achievable and enforceable; however, it is set close to the MCGL in order to prevent long term effects of a substance. This indicates that drinking water across the United States is still capable of causing adverse effects to human health. California's equivalent to MCGL, Public Health Goal (PHG), is set to 0.004 µg/L (4ppt) by the Office of Environmental Health Hazard Assessment (OEHHA) of California Environmental Protection Agency according to epidemiological studies on the fatality of arsenic-induced lung and urinary bladder cancers researched in in Taiwan, Chile, and Argentina.[4]

Impacts on Human Health

The acute effects of arsenic on human health as listed by the World Health Organization, are vomiting, abdominal pain, and diarrhea. In severe cases, these symptoms are preceded by numbness and tingling in the extremities, muscle cramps, and fatality.[5]

Along with being a carcinogen the prolonged exposure to arsenic can cause cancer in the lungs, skin, and bladder, it also leads to neurological and metabolic disorders.[2,5–7] In Bangladesh, a study was conducted on children to better understand the neurological impact of arsenic exposure. The children were given doses at varying amounts and the study found that those with doses greater than 50 μg/L showed a decreased intellectual function compared to those whose exposure was less than 5.5 μg/L .[7]

Evidence also shows that exposure to inorganic arsenic can lead to inter- and transgenerational effects. In a study male mice were given low doses of arsenic in which the F0 males did not exhibit glucose intolerance, but their offspring did. Additionally, the F2 offspring exhibited growth retardation, and F3 displayed increase in weight.[8] Arsenic exposure in gestation and early infancy has been related to increases in mortality in youth due to numerous malignancies, lung disease, heart attacks, and kidney failure, all of which have negative effects on child health. [5,9]

Furthermore, in Chile a study concluded that Type 2 Diabetes was correlated to arsenic exposure, but most importantly, the occurrence of arsenic related Type 2 Diabetes was found to be related with low socioeconomic status.[2] Another study in Bangladesh that used socioeconomic factors such land ownership, education, household cooking, and food index to determine if there was a correlation between arsenic exposure to premalignant skin lesions. The study found that individuals from a low socioeconomic status were more likely to have arsenic induced skin lesions as compared to those who owned land specifically. [10] These studies demonstrate not only the harmful effects of arsenic exposure, but also how poor environmental conditions disproportionately affect people with low socioeconomic status.

Environment and Socioeconomic Status

There is a growing body of evidence that indicates that low socioeconomic status increases the likelihood of developing environmentally induced diseases because of subpar environmental conditions. A study conducted in the San Joaquin Valley in California was assessing whether community water systems operating between 2005-2007 complied to the revised arsenic standards set by the EPA. The research took into account the compliance burdens and disparities in exposure when the revised standards were implemented. They discovered that MCL standards were not complied in populations that were of low socioeconomic status, specifically those of people of color and lack of home ownership. This was due to a lack of resources and funding in the particular area to decrease contamination.[1]

High levels of arsenic were also discovered in Oregon's community water systems, with the study concluding that these systems primarily served Hispanic communities, low-income individuals, and those who spoke a language other than English at home.[11] Inequalities in community water systems exist and impact those of low SES with factors such as low income, being people of color, land ownership, etc throughout the United States.[1,11–13]

Why the Inland Empire?

The Inland Empire consists of the San Bernardino and Riverside counties and is one of the fastest growing regions in California. People flocked to the region to the prospect of citrus farming in the 1870s and 1880s and within 30 years the region became an agricultural center for citrus and other specialty crops. The labor force that gathered, sorted, and packed the fruit was drawn from successive waves of immigrants from the Eastern United States, Asia, or Mexico. Through the late 1930s, the prevailing type of production relations was a marriage of money capital and rural industrial agriculture producing for domestic and international markets. It financed a racially, ethnically, and gender-segregated labor market, segregated residential housing, and a distinct social-class system. The region then moved to become more industrialized in the 1940s and by the 1980s was predicted to become the third largest metropolitan in California. The reason being that deindustrialization that was taking place at the national and state level in the 1970s manifested later on in the Inland Empire, which led to a large influx of people moving to the region and rising property taxes in other areas of California forced people to relocate to the Inland Empire, where housing was cheaper.[14] The population boom led the area to great economic growth; however, the region was plagued with economic instability due to the foreclosures in 2008, high unemployment, and low paying jobs.[15] This left lasting effects on the region; however, the Inland Empire is slowly recovering.

The poverty rate of San Bernardino County has decreased from 14.9% in 2018 to 13.3% in 2019 and this decrease was seen throughout all age groups. Unfortunately, the poverty rate is still higher than the state's and nation's, but lower than Los Angeles County's. Compared to San Bernardino County, Riverside county's poverty rate is 11.3% which is lower than both California and the nation's. Income is an essential factor that needs to be taken into consideration when determining the impacts of environmental factors.[16] Additionally, Hispanic and immigrant households were mainly touched by poverty. [17] It is worth noting that the Inland Empire has a higher Latino population than the remainder of Southern California and 1 out of every 5 people in the Inland Empire is an immigrant.[18] It is important to consider socioeconomic status when assessing the impact of environments on the health of populations. The agricultural and industrial history of the Inland Empire makes it a strong candidate for high levels of arsenic in the water.

This paper will focus on cities in the Inland Empire and determine if there is a correlation between average arsenic levels in drinking water using water quality reports of 2019 to median household income and race demographics. I hypothesize that there will be a negative correlation between levels of average arsenic in water to median household income and a positive correlation between levels of average arsenic in water to people of color. This work will contribute to determining which cities and populations in the Inland Empire are heavily exposed to high levels of arsenic and add to the literature on whether socioeconomic status hinders adherence to laws.

METHODS

Data Collection

For this research, the average arsenic levels in drinking water, average household income, and race demographics of 2019 in all of the cities of the Inland Empire were collected to determine if there is a correlation between arsenic levels to median household income and race demographics.

The average arsenic contaminants in drinking water will be obtained via water quality reports/consumer confidence reports or public health report goals for each city depending on what each city has stated on their websites. It is important to note that some cities do not have the arsenic levels listed on their reports because it was not found. In this case, the arsenic levels will be denoted as 0. However, in some cases the arsenic levels are stated as “not detected” (ND) or are not included because they are not above DLR, Detection Limit for purposes of Reporting, which is 2 μg/L. Due to this, the cities’ arsenic levels will also be denoted as 0. Furthermore, several cities that receive water from multiple water districts will be omitted because this paper is compiling data based upon each individual city’s average arsenic concentrations.

The average household income and race demographics were obtained via the United States Census Bureau website. The demographics includes the following races: White, Black or African American, American Indian & Alaska Native, Asian, Native Hawaiian & Other Pacific Islander, Two or More races, Hispanic or Latino, and White alone not Hispanic or Latino.[19] Furthermore, cities that were not listed in the United States Census Bureau website will also not be taken into consideration in the paper to prevent misinformation and skewing of the data analysis and results. All of this data was collected on Microsoft Excel. The software, Jamovi, was utilized to run the Pearson Correlation and Multiple Regression. However, Microsoft Excel was utilized to acquire the Analysis of Variance because Jamovi did not provide that information.

RESULTS

Correlation Analysis

Figure 1: Correlation Matrix

Correlation Matrix

		Average levels of Arsenic
Average levels of Arsenic	Pearson's r	—
	p-value	—
White	Pearson's r	0.016
	p-value	0.935
Black or African American	Pearson's r	0.326
	p-value	0.084
America Indian & Alaska Native	Pearson's r	–0.336
	p-value	0.075
Asian	Pearson's r	0.116
	p-value	0.548
Native Hawaiian & Other Pacific Islander	Pearson's r	0.531 **
	p-value	0.003
Two or more races	Pearson's r	0.142
	p-value	0.463
Hispanic or Latino	Pearson's r	–0.101
	p-value	0.602
White alone not Hispanic or Latino	Pearson's r	–0.039
	p-value	0.840
Median Household Income	Pearson's r	–0.279
	p-value	0.142

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Between each independent variable and the dependent, correlation analysis statistics were computed. The Pearson's Coefficient (r-value) was -was 0.016 between White and levels of average arsenic in drinking water; the p-value was 0.935. The Pearson's Coefficient was 0.326 between Black or African American and levels of average arsenic in drinking water; the p-value was 0.084. The Pearson Pearson's Coefficient was 0.336 between American Indian and Alaska Native and average levels of arsenic in drinking water; the p-value was 0.075. The Pearson's Coefficient was 0.116 between Asian and levels of average arsenic in drinking water; the p-value was 0.548. The Pearson's Coefficient was 0.531 between Native Hawaiian and Other Pacific Islander; the p-value was 0.003. The Pearson's Coefficient was 0.142 between Two or more races and levels of average arsenic in drinking water; the p-value was 0.463. The Pearson's Coefficient was -0.101 between Hispanic or Latino and average levels of arsenic in drinking water.; the p-value was 0.602. The Pearson's Coefficient was -0.039 between White alone not Hispanic or Latino and average levels of arsenic in drinking water; the p-value was 0.840. The Pearson's Coefficient was -0.279 between the median household income and average levels of arsenic in drinking water; the p-value was 0.142.

Multiple Regression Analysis

Figure 2: Multiple Regression Analysis

Model Fit Measures

Model	R	R^2	Adjusted R^2
1	0.767	0.589	0.394

Model Coefficients - Average levels of Arsenic

Predictor	Estimate	SE	t	p
Intercept	13.10	15.41	0.850	0.406
Median Household Income	–1.91e–5	9.37e–6	–2.034	0.056
White	1.72	2.29	0.751	0.462
Black or African American	–7.86	15.94	–0.493	0.628
America Indian & Alaska Native	–63.29	26.47	–2.391	0.027
Asian	–9.38	15.65	–0.600	0.556
Native Hawaiian & Other Pacific Islander	40.42	42.51	0.951	0.354
Two or more races	–3.53	11.41	–0.310	0.760
Hispanic or Latino	–12.64	15.03	–0.841	0.411
White alone not Hispanic or Latino	–13.41	15.69	–0.855	0.403

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	9	10.405	1.156	3.023	0.020
Residual	19	7.267	0.382		
Total	28	17.672			

The multiple regression analysis was performed to determine how the independent variables impact the levels of arsenic collectively since a correlation analysis provides impact of each independent variable individually. The correlation coefficient (multiple R) was 0.767, coefficient of determination (R^2) was 0.589, and the adjusted correlation coefficient was 0.394. According to ANOVA the p-value is 0.020. Furthermore, the regression SS is 10.405 and the total SS is 17.672. The residual SS is 7.627.

The Model of coefficient shows the p-value for median household income was 0.056 and the coefficient was -1.91e-5. The p-values for White population was 0.462 and the coefficient was 1.72. The p-value for Black or African American population was 0.628 and the coefficient was -7.86. The p-value for the American Indian and Alaska Native population was 0.027 and the coefficient was -63.29. The p-value for Asian population was 0.556 and the coefficient was -9.38. The p-value for Natice Hawaiin and Other Pacific Islander population was 0.354 and the coefficient was 40.42. The p-value for Two or more races was 0.760 and the coefficient was -3.53. The p-value for Hispanic or Latino population was 0.411 and the coefficient was -12.64. The p-value for White not Hispnaic or Latino was 0.403 and the coefficient was -13.41.

DISCUSSION

Correlation Analysis Discussion

The correlation matrix showed a small positive correlation for the following race demographics: Black and African American, Asian, and Two or more races to levels of average arsenic in drinking water. This indicates that as the population of Black and African American, Asian, and Two or more races increases, the levels of average arsenic in drinking water weakly increase as well. There was a large positive correlation for Native Hawaiian and Other Pacific Islanders to levels of average arsenic in drinking water, indicating that an increase in Native Hawaiian and Other Pacific Islanders correlates to an increase in average levels of arsenic in drinking water. There was a small negative correlation for the following race demographics: American Indian and Alaska Native and Hispanic or Latino to levels of average arsenic in drinking water. This indicates that increase in these race demographics correlates with a decrease in levels of average arsenic in drinking water. There was also a small negative correlation for Median Household Income to levels of average arsenic in drinking water, indicating that an increase in median house income correlates to a weak decrease in levels of average arsenic in drinking water. Furthermore, there is no correlation between White and White alone not Hispanic or Latino to levels of average arsenic in drinking water.

The results are similar to the results from other studies exemplifying that an increase of people of color is associated with higher levels of arsenic in drinking water and low income is correlated with higher levels of arsenic.[1,2,6,7,10,12] This is exemplified through the small positive correlation for Black and African American, Asian, and Two or more races to levels of average arsenic in drinking water and the small negative correlation between Median Household Income to levels or average arsenic in drinking water. There was small negative correlation for American

Indian and Alaska Native and Hispanic or Latino which was surprising because the study conducted in Oregon found Hispanic or Latino populations were served water with higher levels of arsenic.[11] Moreover, the Inland Empire has a very high population of Latino immigrants compared to the rest of Southern California, so this made this result was unexpected. Furthermore, most Hispanic and immigrant households experience poverty[17] so a negative correlation was expected.

The p-values of the independent values were all above 0.05 and only the value for Native Hawaiian and Other Pacific Islander was below 0.05; therefore, this was the only value that was significant. This implies that the above-mentioned results are not statistically significant, implying that there is no substantial, if any, association between the dependent and independent variables, except for the correlation between Native Hawaiian and Other Pacific Islanders and levels of average arsenic in drinking water.

Multiple Regression Analysis Discussion

The Regression statistics showed a R^2 value of 0.589 which is a high value meaning that the independent variables can explain about 58.9% of the variance in levels of arsenic in drinking water. The Correlation coefficient is 0.767; however, since there are multiple independent variables, the adjusted R^2 is the value of importance. In this case the model can predict 39.4% of arsenic levels based on race demographics and median household income.

The Analysis of Variation (ANOVA) set shows that the model is significant because the p-value is 0.020 which is less than 0.05. Moreover, the regression SS is 10.405 and the total SS is 17.672, which explains about 59% of the variability in the data.

Based upon the Model Coefficients, the only relationship that is significant is American Indian and Alaska Native to levels of arsenic in drinking water (taking in account the other independent variables) because the p-value is below 0.05. Furthermore, the coefficient value is -63.29 which is a very large value which also exemplifies the strength of the relationship. However, the remaining independent variables had p-values greater than 0.05, exemplifying that there is not enough evidence to conclude that there is a significant relationship between the dependent and independent variables.

The results for the multiple regression analysis varied from the correlation analysis because in the correlation analysis the Native Hawaiin and Other Pacific Islander had a positive significant relationship with levels of average arsenic in drinking water. However, in the multiple regression analysis the relationship that is significant is that between the American Indian and Alaska Native race demographics and levels of average arsenic in drinking water. This can be explained because correlation analysis takes each independent variable and dependent variable relationship individually; whereas, multiple regression analysis takes into account how all of the independent variables impact the dependent variables.

Overall, the data shows that the null hypothesis is rejected because the model as a whole is significant. It can be concluded that there is a relationship between race demographics and median household income to the levels of average arsenic in drinking water.

Limitations

First, the data collected did not include all of the cities in the Inland Empire. There are 59 cities in the Inland Empire; however, only 29 cities were analyzed. This was due to the fact that one water utility company might provide water to multiple cities. This made it difficult to determine the levels of arsenic in drinking water because the levels of arsenic were collected individually for each city. This made it difficult to distinguish what water system was catered to which individual city. On further contact with the water utility companies, the representative also stated that it could not be distinguishable. Another reason cities were omitted was because one city received water from multiple water utility companies. The average could not be determined since the water sources were grouped together. Furthermore, Needles, Wrightwood, and Yermo were excluded because the cities were not listed in the United States Census Bureau website. This may have skewed the results because 30 cities were excluded which may have contributed to the overall results. Furthermore, the multiple regression analysis had less than 30 observations and more than 30 observations are ideally used for data analysis. However, due to difficulty in collecting data for each individual city, several observations were omitted.

Another limitation was that several cities do not list arsenic values or report them as "None Detected" because the contaminant level discovered is lower than the DLR limit. This also resulted in discrepancies in the data because cities with arsenic concentrations were listed as 0. Furthermore, nine cities such as Joshua Tree, Hesperia, Corona, etc. had levels less than 2 μg/L, but since levels were reported they cities were listed.

To overcome these limitations, the values for each community water system from each city can be requested. Also cities can also be grouped together based upon counties rather than focusing on each individual city. This will help obtain over 30 observations and also obtain data that is more representative of the region.

Implications

This study shows that there is a relationship between race demographics and median household income to levels of average arsenic in the Inland Empire. Most of the arsenic levels in the Inland Empire are attributed to erosion of natural deposits; runoff from orchards; glass and electronics production wastes.[20,21] The Inland Empire began based upon agricultural ventures which can explain the levels of arsenic contamination in some cities; however, there is arsenic is also naturally occurring. Therefore there is a relationship present between the independent and dependent variables.

Although the relationship is not firmly established on whether low income households and higher populations of people of color lead to higher levels of arsenic in drinking water, a relationship exists between these variables. This shows that one's income and race can have correlation to environmental conditions. For instance areas with low income may have higher levels of arsenic due to the lack of funding to clean and filter Community water systems properly or other water reservoirs.[1] Furthermore, this also suggests that the environment can contribute to negative human health impacts on certain communities because arsenic contaminant levels are dependent on race demographics and levels of average arsenic in drinking water.

CONCLUSION

To conclude, a correlation and multiple regression analysis was performed on race demographics and median household income to levels of average arsenic in drinking water from water quality reports of 2019. The findings showed a correlation between race demographics and median household income to levels of average arsenic in drinking water in the Inland Empire. However, the only significant values were those of a strong positive correlation between Native Hawaiian and Other Pacific Islanders and levels of average arsenic in drinking water in the correlation analysis. In the multiple regression analysis, the overall model was significant, but the only significant relationship was a strong negative relationship between American Indian and Alaska Native race demographics and levels of average arsenic in drinking water. This exemplifies that there is a relationship between race demographics and median household income and levels of average arsenic in drinking water; however, it was not fully determined how each independent variable impacts the dependent variable due to the limitations of the research. Furthermore, this may be due to the incomplete data collection because of the availability of resources. Therefore, it was not established if socioeconomic status can make it difficult to adhere to compliance standards.

For future research to determine if there is a relationship between socioeconomic status and arsenic contamination levels, there should be a comparison between different counties that have larger gaps in income. This can be done between San Bernardino County or Riverside County to Orange county etc. Furthermore, other variables can be taken into consideration such as home ownership, poverty levels, education attainment, etc. This would add to the growing literature of correlation between environmental impacts to variables related to socioeconomic status. This research can also be done on a macro scale in which contaminant levels are accounted for nationally to increase sampling and see the impact on a larger scale.

Although this project was unable to establish a correlation between low socioeconomic status and arsenic contamination in water, it was able to determine that there is a relationship between race demographics and median household income to levels of average arsenic in drinking water. This can add to research being conducted on the correlation between the environmental effects and variables such as income and race demographics.

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