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Diversifying Clean Water: An Examination of Drinking Water Quality and Social Disparities in Michigan

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Abstract

Water is one of the most essential resources required to sustain life. However, it could be detrimental to the health of those without access to water that is properly treated. Although the Safe Drinking Water Act of 1974 set regulations to protect citizens from naturally occurring and man-made contaminants, some people are still without clean and safe water, which is speculated to be because of their race. This research examines the disproportionality of available clean water provided by government sources in Michigan and its correlation with race and household income. In the study, it has been found that one of the leading causes of water contamination is industrial activity, with the automobile industry being responsible for approximately 300 million tons of lead contamination in water, and that the manufacturing company's locations mostly centered in minority and low-income areas. Lower income cities, such as Hamtramck and Benton Harbor, have an average of 14.8 drinking water standard violations with the highest being 99 total violations, while higher income cities, like Novi and Bloomfield hills, have an average of 4 violations. Cities, like Flint and Detroit, which have a higher minority population, are 10 times more likely to have a water standard violation, and the minority population is proportionally related to the possibility of industrial manufacturing being located in those areas. These communities also face a higher risk of birth defects, developmental issues in children, and organ failure in adults, due to continuous exposure to water contaminants. Race as a direct causation could not be proven, but there are links to direct correlation through historical redlining and housing trends.

Keywords

Water Quality, Social Disparity, Michigan, Contaminants, Household Income, Income per Capita, Environmental Justice, Automobile Industry

1. Introduction

Exposure to environmental hazards in connection with socio-economic discrimination has been widely studied over the last decade. Several factors have now led to a branch of research known as environmental racism. Environmental racism is defined as "processes that resulted in minority and low-income communities facing disproportionate environmental harms and limited environmental benefits" (Taylor, 2010). Race and income of a general population are strong indicators of the likelihood of being exposed to environmental hazards.

One factor of this is the history of redlining in the United States, which was prevalent in the state of Michigan. After the end of slavery in the United States, many African-Americans migrated to the north and Midwest to take advantage of the rise in industrial work. In response, government regulation allowed for the explicit use of race and ethnicity to determine eligibility for government-backed mortgage loans. Those who were not Caucasian-American were pushed into more "undesirable" areas and it was made more likely that non-Caucasian-American applicants would be denied home loans (Wilkinson, 2017). The segregated neighborhoods with a largely minority population were held at the lowest value and were underinvested. This caused a blockage for minority families to relocate to more desirable areas due to the inability to obtain a loan or sell their current home.

This continued into modern day, with a 2016 study finding that African-American loan applicants in the state of Michigan were 1.8 times more likely to be denied a home loan than Caucasian-Americans (Smith, 2007). In the past decade, 21 Town & Country, a large real estate agency in Michigan, has faced several lawsuits with regard to racial steering by real estate agents. After an undercover investigation, it was found that whenever Caucasian-Americans or African-Americans requested to view homes in communities with the other race, both races were steered away into communities with the same race (Smith, 2007).

Another factor of disproportionate exposure to environmental hazards is the zoning of industrial activities. Throughout the United States, there is a disproportionate presence of toxic industries and waste sites in the vicinity of minority and low-income communities (Bolin et al., 2005). When zoning laws are put in place, wealthier income areas have more resources available, such as the ability to attend town hall meetings and funding local politicians, and reject environmental hazards in their areas, such as industrial activity. Due to the zoning laws favoring the wealthier sections of the population, industrial and waste facilities leading to the production of environmental hazards are more likely to be near working-class minority communities, and there are fewer funds available to improve infrastructure in these areas (Boer et al., 1997).

2. Water Contaminants and Regulations

One of the main exposers to environmental hazards is unsafe drinking water.

The Environmental Protection Agency (EPA) is responsible for regulating water safety and updating information on drinking water contaminants. EPA only regulates public drinking water systems that service at least 25 persons or more. Public drinking water systems are required under the Safe Drinking Water Act of 1974 to monitor the presence of certain individual contaminants at specific time intervals and locations to ensure compliance. Violations are reported to the Safe Drinking Water Information System Federal Reporting Services (SDWIS/FED), created in 1995. However, a 2002 EPA audit found that only 62% of violations are reported and states only required to report violations, but not contamination levels. This leaves citizens with only the knowledge of a possible violation (Environmental Protection Agency, 2016).

2.1. Contaminants in Drinking Water

Drinking water regulations expect that water contains a minimum number of contaminants, and the levels of contamination are monitored rather than the presence. The regulated contaminants are featured on the Contaminant Candidate List (CCL). The EPA's definition of a contaminant is any physical, chemical, biological, or radiological substance or matter in water that isn't water molecules. Drinking water standards include a maximum contaminant level and treatment requirements for over 90 contaminants (Environmental Protection Agency, 2020). **Table 1** lists the most common drinking water contaminants and their possible sources.

Both chemical and physical attributes of water are important indicators of its quality. Chemical attributes can affect the smell, look, taste, and toxicity of water. Physical attributes, such as changes in temperature may indicate the presence

Table 1. Common drinking water contaminants with their relative limits and sources (Environmental Protection Agency, 2016).

Contaminants	Limits	Sources
Lead	0.15 mg/L	Lead containing plumbing and runoff from manufacturing industries
Copper	1.3 mg/L	Mining, farming, and manufacturing
Arsenic	0.010 mg/L	Natural deposits, agriculture, and industrial runoff
Nitrate	10 mg/L	Fertilizer runoff
Nitrite	0.1 mg/L	Fertilizer runoff
Radioactive Substances	0 - 15 pCi/L	Natural deposits, fertilizer, and mining
Fluoride	4.0 mg/L	Added to water
Mercury	2.0E−5 mg/L	Natural deposits
Chlorite	1.0 mg/L	Natural Deposits
Microorganisms	0% - 5%	Natural Deposits
Viruses	0	Natural Deposits

of certain effluents. Changes in color and turbidity of water affect its acceptability for drinking (Nyakundi et al., 2020; Sivaranjani et al., 2015).

Microbial contaminants, such as bacteria, protozoa, and viruses are especially dangerous for children, due to their underdeveloped immune systems. Children are especially sensitive to contaminants such as Giardia, Cryptosporidium, *E. coli*, noroviruses, and Legionella. Agricultural and industrial runoffs, such as nitrates, nitrites, arsenic, and lead, and nitrites and nitrates are often found in groundwater from fertilizer, livestock manure, and sewage, are significant sources of chemical contamination (Environmental Protection Agency, 2016). Elevated levels of these contaminants cause methemoglobinemia or Blue Baby Syndrome and are associated with thyroid dysfunction in children and pregnant women. Fluoride is often added to water during treatment to encourage healthy teeth, but an excessive amount has been associated with bone developmental problems (Environmental Protection Agency, 2019).

Lead poisoning in water has been sourced mostly to corrosion from lead pipes and other water distribution systems (Centers for Disease Control and Prevention, 2020). Another leading cause of exposure to lead in water is automotive industry activity. Lead is used in multiple parts of a car, with the majority being placed in the starter battery.

The automotive industry is responsible for the release of 300 million tons of lead through mining, smelting, manufacturing, recycling and disposing, with approximately 16 tons of lead per car (Gearhart et al., 2003). Children are the most susceptible to lead poisoning, and exposure in infants and children can be associated with IQ loss and neurodevelopmental issues (Centers for Disease Control and Prevention, 2014). Adults with lead exposure often have higher reports of suppressed humoral immunity, neurotoxic effects, such as peripheral neuropathy or nerve damage, and motor nerve dysfunction, along with other health issues (Centers for Disease Control and Prevention, 2014).

2.2. Effects of Contamination Exposure

The presence of contaminants in water can lead to many adverse health effects, along with negative economic impact on the communities involved. **Table 2** lists the most common side effects of exposure to drinking water contaminants. Infants, young children, pregnant women, the elderly, and those with compromised immune systems are at the highest risk.

Contaminated water is linked to the transmission of diseases such as Cholera, Dysentery, Hepatitis A, Typhoid Fever, Polio, gastrointestinal illnesses, reproductive issues, and neurological disorders (World Health Organization, 2019). Approximately 829,000 people die each year from diarrhea, as a result of exposure to unsafe drinking water (World Health Organization, 2019). Infants and pregnant mothers living in areas with contaminated drinking water have higher reports of lower birth weights by 14.55% and premature labor by 10.3% (Vodela et al., 1997). Studies also provide evidence for associations of trihalomethanes

Table 2. Common contaminants and the effects of exposure (Environmental Protection Agency, 2016).

Contaminants	Common Effects
Lead	Birth defects, kidney disease, infant mortality
Copper	Liver or kidney damage, gastrointestinal illness
Arsenic	Skin damage with circulatory problems, risk of cancer
Nitrate	Infant illness or death, Blue Baby Syndrome
Nitrite	infant illness or death, Blue Baby Syndrome
Radioactive Substances	Increased risk of cancer
Fluoride	Bone disease
Mercury	Kidney damage
Chlorite	Anemia, nervous system damage
Microorganisms	Gastrointestinal illnesses
Viruses	Gastrointestinal illnesses

(THMs) with low birth weights, neutral tube defects (NTDs), and spontaneous abortions (Bove et al., 2002).

Contaminant exposure can impede the development of bones and can last for decades (Vodela et al., 1997). The effects of healing from exposure can be detrimental to households due to lacking access to affordable healthcare. Those who do not die lose available income during their recovery time. In 2004, 143,000 lives were lost to lead poisoning, and 8,977,000 years of life adjusted to disease and recovery were lost worldwide (Brown & Margolis, 2012).

3. Materials and Methods

3.1. Materials

Secondary data related to drinking water quality was obtained from the annual water safety report for the counties in Michigan. Additional information was collected by contacting water service offices to obtain information not readily available in the annual water safety report. Data including median annual household income was obtained from the United States Census Bureau (United States Census Bureau, 2020).

3.2. Methods

The water quality data was then prepared for descriptive statistical analysis. Tables were generated to record income per capita for the counties (provided by the Census Bureau) along with their drinking water sources (provided by the state and local water services departments) and correlated to the levels of contaminants.

The disparities among the average household income in different counties and their water quality are shown using multi-variable charts. **Table 3** features the

Table 3. Ten largest cities in Michigan and their relative income and population.

City	Median Gross Income	Population
Detroit	$29,481	670,031
Grand Rapids	$47,173	201,013
Warren	$47,419	133,943
Sterling Heights	$63,126	132,438
Ann Arbor	$63,956	119,980
Lansing	$40,325	118,210
Clinton Charter Township	$54,587	100,471
Flint	$27,717	95,538
Dearborn	$52,498	93,932
Canton	$89,991	93,704

specific cities being analyzed in this study.

Additional information regarding safe water violations was gathered from SDWIS/FED for the 20 highest income and 20 lowest income cities in Michigan. SDWIS/FED is reported and updated regularly during inspections. The violations include all data collected since the formation of the SDWIS/FED until 2020.

4. Results and Discussion

After compiling the information, the water quality data was prepared for descriptive statistical analysis. Histograms were used to illustrate the comparison of violations, population, and income in Michigan between the largest cities. Statistical analysis is also used to analyze the disparities based on lower income households versus higher income households using basic statistical measurements. The basic statistical analysis of the drinking water violations in comparison with general income is shown in **Table 4**. The data is derived from the 20 highest and 20 lowest income cities in Michigan water quality reports in the SWDIS/FED, which is listed in **Table 5**.

The average amount of violations accumulated by the highest income cities in Michigan is 4.7 with a standard deviation of 8.9 and a median of 5. The highest amount of violations is 42 with the lowest being 0. However, the average for the lowest income cities is 14.8 with a standard deviation of 26.6 and a median of 10. The highest amount of violations is 99 with the lowest being 0. This implies that communities with lower incomes are 3 times more likely to be exposed to drinking water contaminants. This likelihood increases when factoring in the racial background of majority of the community.

Data was collected to compare the racial background of the largest cities in Michigan, their gross household income, and the cities' drinking water violation counts, as shown in **Figure 1**. To ensure that the cause of these disparities is not due to the larger populations or access to more water sources, Figure 2 was created to compare the amount of facilities available in each city to the number of violations. No definitive correlation was found.

The cities with a higher minority population, specifically African-American populations, seem to have higher rates of drinking water violations. One outlier

Table 4. Comparison of statistical measurements of drinking water violations in differentiating gross incomes of various cities.

Basic Statistical Measures - Higher Income				Basic Statistical Measures - Lower Income			
Location	Variability			Location	Variability		
Mean	4.6500	Std Deviation	8.91052	Mean	14.84211	Std Deviation	26.64429
Median	3.0000	Variance	79.39737	Median	6	Variance	709.91813
Mode	3.0000	Range	42.0000	Mode	3	Range	99
		Interquartile Range	2.0000			Interquartile Range	7

Table 5. The highest income cities and the lowest income cities in Michigan with relative amounts of drinking water violations. Violations are reported since the start of SWDIS/FED until 2020.

Highest Income	Violations	Lowest Income	Violations
Ann Arbor	42	Detroit	6
Grosse Pointe	3	Standish	4
Royal Oak	4	Big Rapids	1
Plymouth	2	Flint	9
Berkley	2	Gladwin	10
Hickory Corners (Barry Township)	4	Carson City	2
West Bloomfield	4	Royal Oak Township	0
Forest Hills (Grand Rapids)	1	Cheboygan	3
Beverly Hills	5	Caspian	16
Rochester Hills	3	Mills Township	3
Troy	2	Hamtramck	10
East Grand Rapids	1	Buena Vista Township	5
Northville	5	Yates Township	14
Birmingham	2	Mount Morris	4
Huntington Woods	3	Muskegon Heights	6
Grosse Pointe Farms	4	Evart	5
Novi	0	Webber Township	79
Traverse City	3	Rose City	12
Grosse Pointe Shores	3	Benton Harbor	99
Bloomfield Hills	0	Highland Park	8

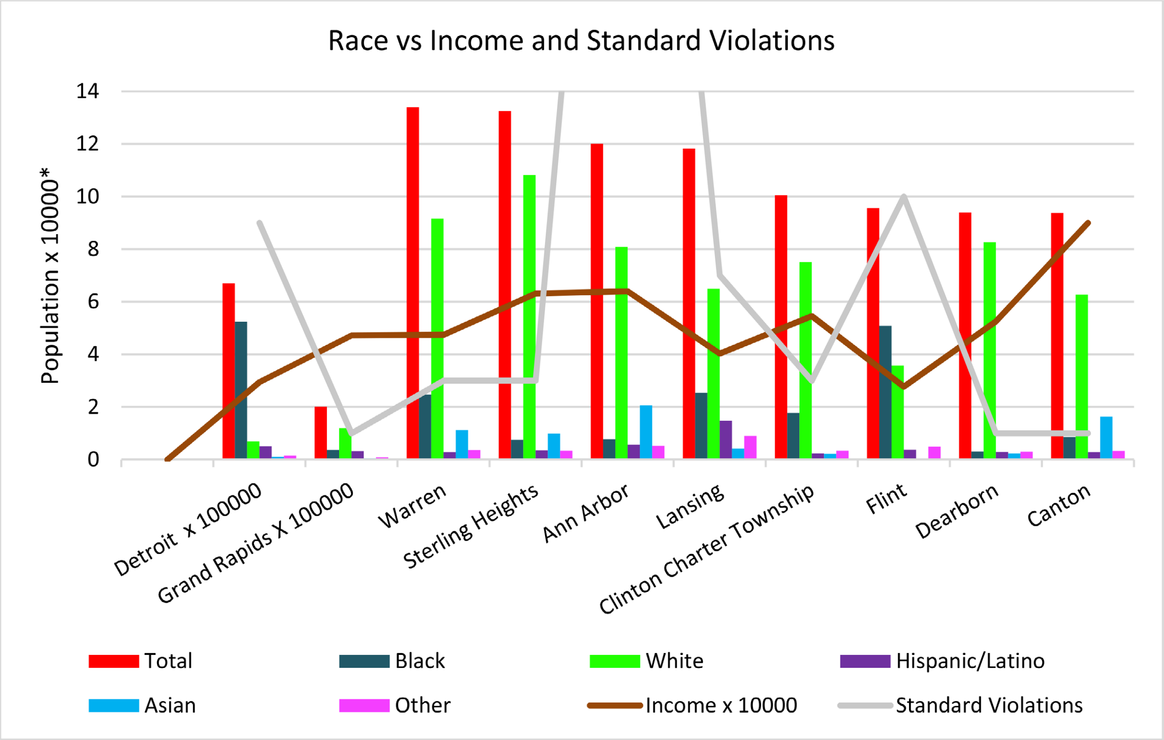

Figure 1. Comparison of community racial make-ups, gross income, and drinking water violations. Ann Arbor has 42 total violations, which exceeds the range shown.

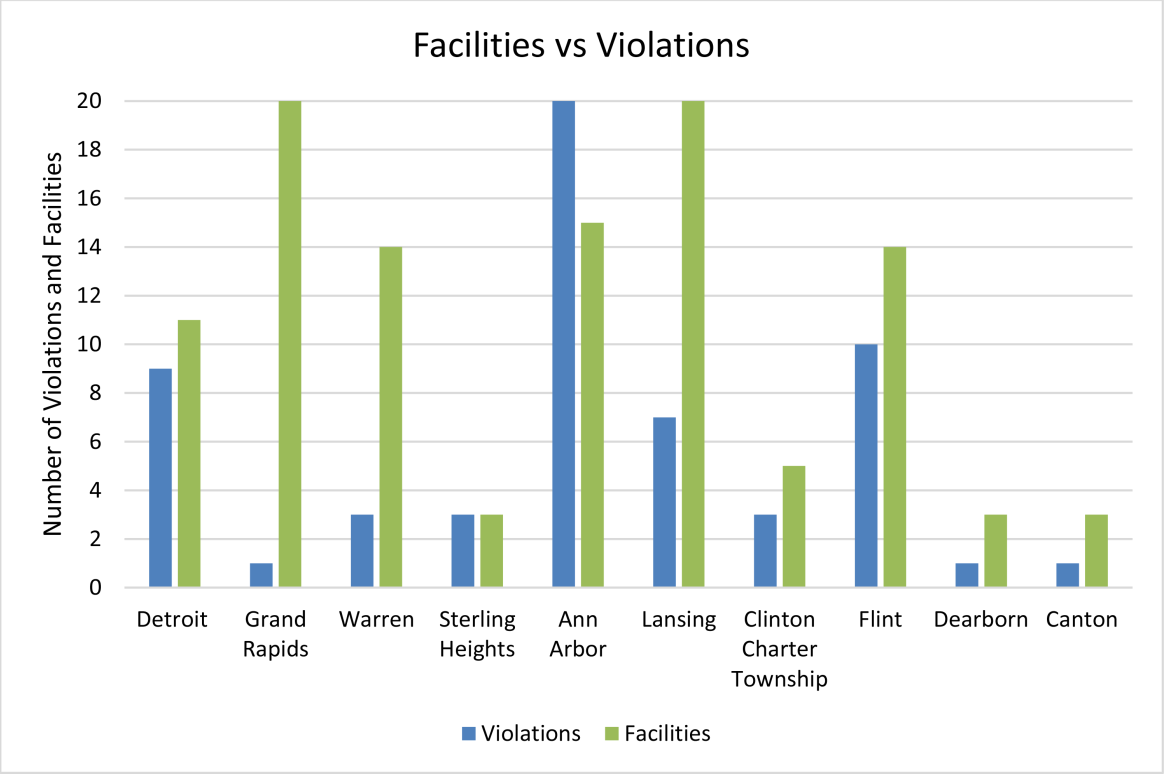

Figure 2. Comparison between the number of facilities and the number of violations in each relative major city. Grand Rapids' and Lansing's facilities amount exceeds the range shown, with 21 and 160 facilities, respectively. Ann Arbor's violations exceed the range with 42 total violations.

is Ann Arbor with 42 violations, due to a treatment issue for one summer in 1994, which has since been resolved. These majority African-American cities, despite their size, also tend to have lower incomes, such as Detroit and Flint.

Detroit has the largest population in the entire state of Michigan, and also has the largest African-American population along with being the 21st lowest income city in the state, even while being host to many of the United States' largest automotive companies (World Population Review, 2022).

The automotive industry is one of the leading industries in the state of Michigan (**Figure 3(a)**), being one of the main sources of income for most households in the state. However, it is also one of the leading sources of lead pollution in drinking water systems (Gearhart et al., 2003). Pollution from this industry comes from runoff from cars and hazardous waste dumping into water sources. This most negatively impacts African-American communities because automotive plants are disproportionally located in these areas, as shown in **Figure 3(b)**, while the impact is much less in the Caucasian-American community (**Figure 3(c)**).

One major city in Michigan with a majority African-American population that has most negatively been impacted by automotive activity and water contamination is Flint. The city of Flint was negatively impacted by unsafe drinking water allegedly from 2014 to 2020. In order to lower utility costs, the city's local government decided to end its contract using the Detroit River as a water source. Initially, the city intended to use Lake Huron as a resource; however, due to

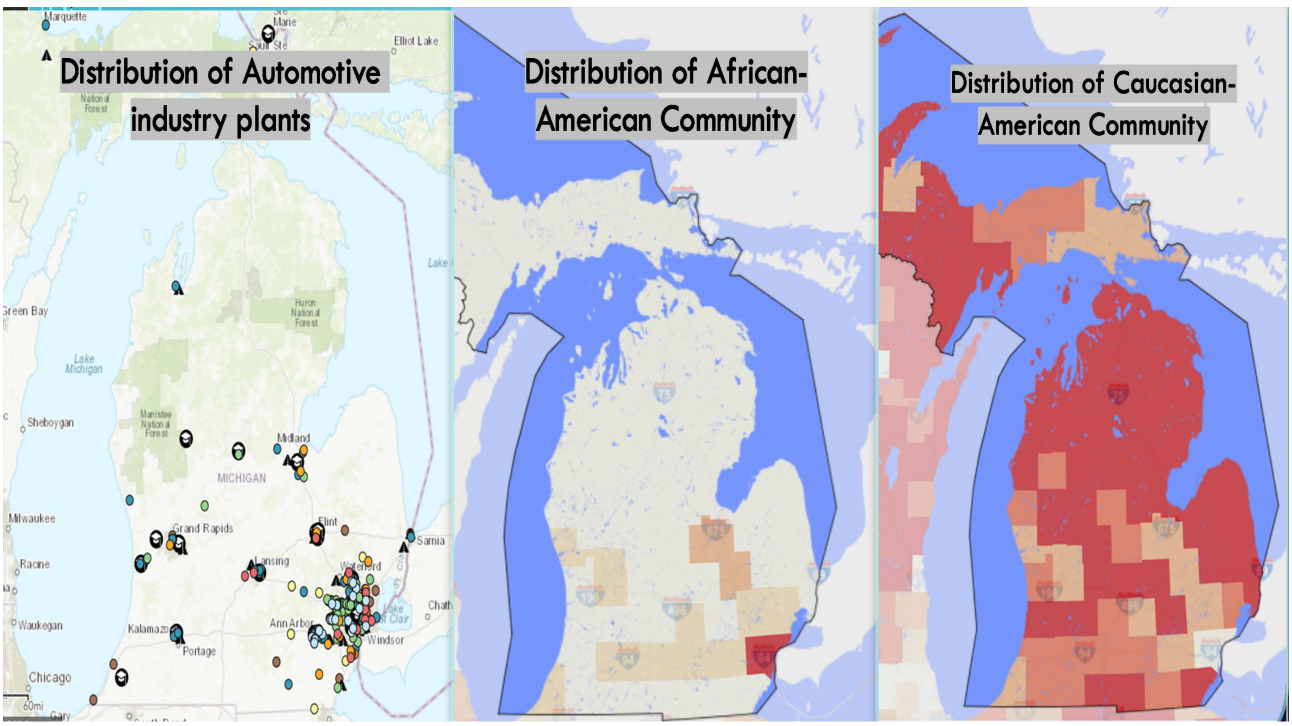

Figure 3. Comparative maps of the distribution of automotive plants and racial backgrounds of those locations (MICHauto, 2020; United States Census Bureau, 2021). (a) Distribution of Automotive Industry Plants; (b) Distribution of African-American Community; and (c) Distribution of Caucasian-American Community.

the length of time it would require creating new regional water authority and pipeline, they switched to the Flint River. This became an issue, due to Flint River being used notoriously to dump industrial waste from General Motors and various criminal activities. The large amount of pollution in the water was exceedingly corrosive, to the point it began impacting the General Motors plant itself, causing them to be granted permission to return to using the Detroit River as a water source. However, this permission was not granted to the citizens of Flint. The corrosive effects of the water led to the leaching of lead and other harmful chemicals from the pipes. It is not definitive whether the city had anti-corrosive measures in place (Pulido, 2016). Based on the data presented in **Figure 4**, exposure to lead and other contaminants adversely affected the health of the citizens of Flint. Exposure to lead can result in an increase in birth defects, such as low birth weights and premature births. It can also cause long term effects on infants and children, such as neurological and physical impairments (Centers for Disease Control and Prevention, 2020).

Since the beginning of the Flint Water Crisis, there has been an increase in birth defects in infants, especially in low birth weights. A possible cause of this is mass exposure to lead and other water contaminants. When comparing all factors, the likelihood of an infant born with birth defects is consistent with the previously stated information, as shown in **Figure 5**. The cities that have a larger African-American community were found to have a lower income and higher rates of drinking water violations. They also tended to have higher rates of infants born with birth defects. This information implies that African-American

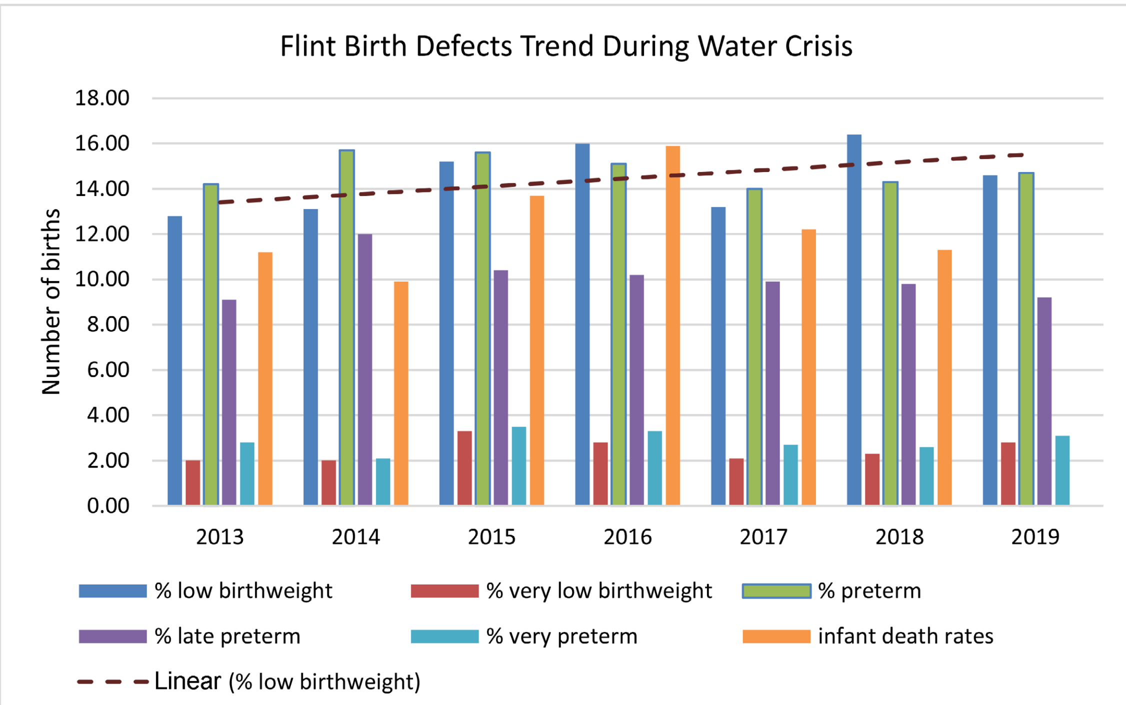

Figure 4. The progression in negative birth defects since the beginning of the Flint Water Crisis until the end (MDHHS, 2022).

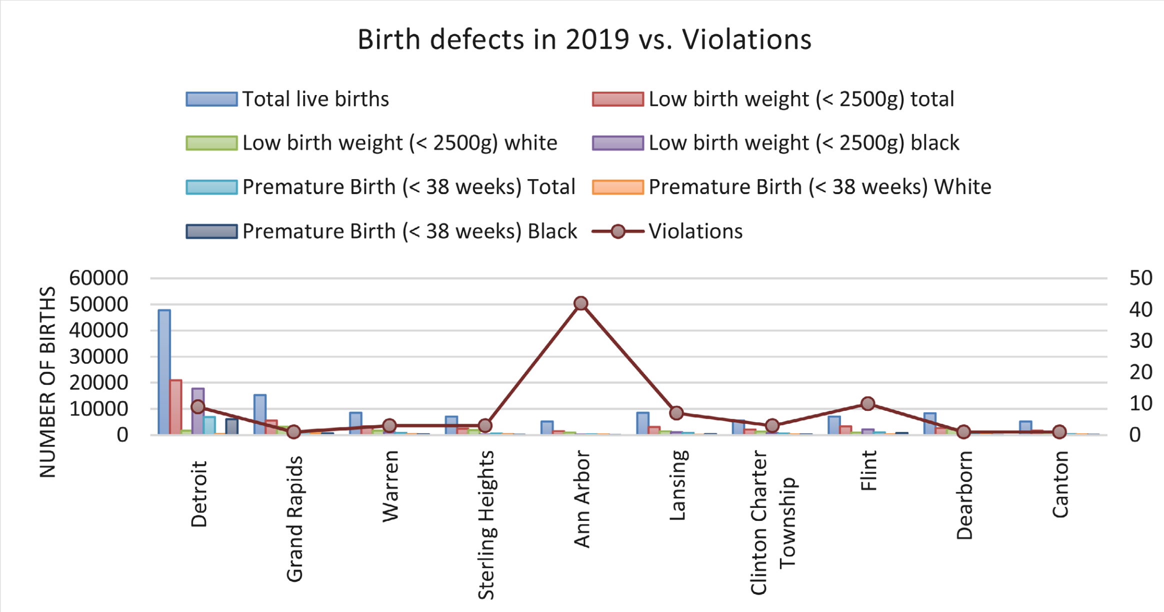

Figure 5. Comparison of total birth defects in 2019 to general violations in each city (MDHHS Reports & Statistics, n.d.).

and lower income communities are at higher risk of being exposed to contaminated water, and thus, have higher risk in terms of health and safety.

One possible solution to repair water quality in these areas is to improve drinking water infrastructure. Between 2004 and 2013, average annual investments in drinking water infrastructure were $447 million. This compares to an estimated investment need of between $731 million and $1.01 billion on an average annual basis until 2030 (Public Sector Consultants, Inc., 2016). This means that Michigan is severely underinvesting in their drinking water infrastructure. It leaves many citizens in a vulnerable state if they are not financially secure enough to fight for an improved state of living.

If the drinking water systems increased funding, this could provide employment, increase quality control, and lower the rates of drinking water violations. This would, in turn, decrease contaminant exposure and adverse health effects, which will then increase the number of able-bodied adults who can provide an income. Improving the water system would greatly benefit Michigan as whole, economically and socially.

5. Conclusion

Well-maintained water quality is essential to ensuring the health and quality of life for all humans. Several cities in the state of Michigan were examined in order to determine the correlation between socioeconomic disparities and drinking water quality. It was determined that areas with a larger minority population and a lower gross income are at higher risk of being exposed to water contaminants and adverse health effects. No specific cause of the disparities was determined, but it can be inferred that the root cause is possibly systematic in nature, due to the citizens' inability to have access to politicians and town hall meetings. The disparities as it related to the topic can be resolved through an increase in drinking water infrastructure and attention to areas that are negatively impacted.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Abbreviations

EPA	Environmental Protection Agency
SDWIS/FED	Safe Drinking Water Information System/Federal Reporting Services
CDC	Centers for Disease Control and Prevention
CCL	Contaminant Candidate List
WHO	World Health Organization
THM	Trihalomethanes
NTD	Neural Tube Defects