FINDING SOLUTIONS TO DRINKING WATER INEQUALITIES IN THE US: A WHITE PAPER ON 65,000 CITIES

VARUNA™

FORWARD

Varuna's philosophy on Environmental Justice and collaboration with Loyola's Institute for Racial Justice

Varuna Tech Inc. develops cloud-based software solutions to provide visibility, insights, and awareness to elevated data-driven decision making at different levels of a water utility or a city managed water supply. Varuna targets small to medium water systems where resources are limited. Varuna solutions empower water operators and managers to stay ahead of operational and water risk challenges.

As the drinking water crisis in the US cities predominantly populated by minority, especially black and Hispanic communities increase, Varuna sees the need to provide expertise to evaluate and provide practical recommendations to these endemic inequalities. To achieve this goal, Varuna is partnering with a Chicago based university, the Loyola University's Institute for Racial Justice. This partnership aims at evaluating racial injustices in drinking water access at city scale across the US and provide guidance on how innovative technical solutions could be part of the ongoing examinations of how to address these inequalities at city level.

Loyola University's Institute for Racial Justice strives to provide transformational education, support change-making research, foster community collaboration and bring all these expertise together to fight for racial justice. Through partnership, the Institute for Racial Justice is creating innovative paths to a more equitable future.

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SECTION I: INTRODUCTION

The global commitment to achieve universal and equitable access to safe and affordable drinking water for all has been set for the year 2030. This commitment is part of the United Nation (UN) Sustainable Development Goal Six (6) which calls for "ensuring access to water and sanitation for all." The focus on safe clean drinking water is specifically monitored under the target of safe and affordable drinking water. As the US celebrates over 50 years of Clean Water Act and 48 years of Safe Drinking Water Act, its global standing towards this goal might look impressive to the global community but it does not to the US population which is still struggling with drinking water contamination. As of 2020, the US was at 97.33%, behind countries like Canada at 99.04%, Luxembourg at 99.45%, United Kingdom at 99.82%, and Singapore at 100%. Although the US has made progress towards safe drinking water for all, overcoming the 2.67% remaining to achieve 100% before 2030 will require more effort. This need is supported by findings that the Safe Drinking Water Act did not guarantee all Americans access to clean, drinkable water as it was set when enacted in 1974. The nationwide review of violations of the Safe Drinking Water Act from 2016 to 2019 demonstrated a strong relationship between sociodemographic characteristics such as race and drinking water violations. Findings of this review confirmed that the rate of drinking water violations increased with communities of color, low-income communities, areas with more non-native English speakers, areas with more people living under crowded housing conditions, and areas with more people with spare access to transportation.

The global problem of lack of access to safe drinking water can also be seen through the lenses of the current drinking water challenges present in American cities, and clean water hardship at household level. In September 2022, Robin Lloyd of Scientific American discussed a growing drinking water crisis threatening cities and towns. Robin highlighted recent drinking water quality deterioration recorded in different American cities. Examples of water quality deterioration in US cities in recent years include; Lead (Pb) in the City of Flint (MI), Arsenic (As) in tap water in public housing complexes in the City of New York, Escherichia Coli bacteria in drinking water supply in the West of the City of Baltimore, and multiple boil water advisories in the City of Jackson (MS). This observation emphasized that at city scale, communities are not experiencing the hardship of using deteriorated water quality at the same level, and that minority communities are the most likely to be impacted negatively.

[1] SDG Tracker. 2016. Water and Sanitation sdg-tracker.org. Accessed February 28, 2023.
[2] Kristi Pullen Fedinick, Steve Taylor,and Michele Roberts. (2019). Watered Down Justice Report, R:19-09-A, Natural Resources Defense Council, Coming Clean, and Environmental Justice Health Alliance. nrdc.org. Accessed March 01, 2023.
[3] Kiara Alfonseca (2022). Map: Where US cities are running out of clean water abcnews.go.com. Accessed March 04, 2023.
[4] Robin Lloyd (September 9, 2022). A growing drinking water crisis threatens American cities and towns. scientificamerican.com. Accessed March 01, 2023.
[5]Mueller, J.T., Gasteyer, S. The widespread and unjust drinking water and clean water crisis in the United States. Nat Commun 12, 3544 (2021). doi.org

Despite the inequality of water services by some communities at city level, everyday water systems in the US still work to provide safe and clean drinking water to all city residents. This is achieved through controlled and monitored operations of the water supply system and through different sampling stations, treatment plants, water transportation infrastructure, and distribution networks. The strategy of ensuring equality in water supply services across all communities residing in the city has to be further revised to remove disparities that are contributing to the use of unsafe drinking water in minority communities. The ongoing digital revolutions and the wave of financial support for infrastructure in the water industry is providing an opportunity to undo historically discriminatory practices that have left minority communities with contaminated drinking water.

SECTION 2: US WATER CHALLENGES

Historically, the US water challenges have evolved through multiple crises associated with concurrent growth of population and industry, urbanization, need for capital to fund water infrastructure development, regulation and policy oversight, and delayed adoption of innovative solutions to address water risk. Today, we are in the middle of the fourth water crisis in the US. All of the recorded water crises prior to the one we are witnessing today were related to water quantity, quality, finance, population growth, urbanization, and extended manufacturing growth to fuel the US economy.

> “ Building resilience to climate change and other stressors is critical for the long term sustainability of water and energy systems.

- The first water crisis emerged in the 1760s as a result of expanding population and industrialization of newly formed colonies. As more people moved into the colonies, they began to put a strain on the already limited freshwater sources. Water scarcity soon became an issue, with many areas experiencing severe shortages. Industrialization further compounded the problem by introducing pollutants and contaminants into the water supply, making it unsafe for drinking and bathing. By the 1811s, water contamination was becoming the apparent burden to waterways and water bodies due to the construction of factories and mills alongside rivers and streams which were being polluted by toxic chemical waste discharged from these facilities' operations. Furthermore, urbanization was leading to the increase in clean drinking water sources, draining existing water sources faster than they could be replenished and competing for existing pristine surface water with the increase of point (known sources) and nonpoint (unknown sources) sources of pollution. From the 1840s to the early 1900s came an increase in funding for water infrastructure development and the first attempts to regulate industrial water pollution. Huge projects like aqueducts and water reservoirs were commissioned for enlargement. The Croton aqueduct in New York City was completed during this period. It became the first water supply system and supported the population boom until 1958. The introduction of section 10 of the Rivers and Harbors Appropriations Act of 1899 by the US congress brought order to riverside constructions and reduced the expansion of commercial facilities, thus impacting pollution associated with discharge of toxic chemicals in waterways or water bodies.

[6] New York City Parks. nycgovparks.org. Accessed Mar 10, 2023.
[7] USEPA, Section 404 of the Clean Water Act, section 10 of the rivers and harbors appropriation act of 1899, epa.gov. Accessed Mar 10, 2023.

- The second water crisis extended from 1913 to 1963 and was exacerbated by the Great Depression and the first and second world wars. This wave of water crisis was associated with economic hardship, war actions that led to harbor pollution, industrial revolutions, and increasing energy demand leading to expansion of coal burning to satisfy growing demand during the war recovery period. Apart from the overall economic hardship, this period was also characterized by the droughts that emanated from reduced precipitation which led to increased water shortages for domestic use. The recorded industrial and population growth increased the discharge of toxic industrial and municipal solid and liquid waste into rivers, streams, lakes, and coastal waters. This water quality crisis led to the introduction of federal water regulations to mitigate and control water contamination.

- The third water crisis extended mainly from 1964 to 2014. This period centered around water quality deterioration and the need for federal regulation and funding to mitigate, control or prevent, and limit the impact of water contamination to human health and the environment. The expansion of manufacturing in the US Midwest after WWII, notably Michigan and Ohio, was the backbone of the US economy and also contributed to be sources of pollution that deteriorated water quality in the region. As a result of the increased chemical pollution in waterways and water bodies in the region, multiple fires were recorded on rivers in Michigan and Ohio in the late 1960s. The Rouge River was in flames in 1969, the Detroit, MI River burned for 7 hours during the month of October in 1969, and earlier in June, 1969, Cuyahoga River in Cleveland, Ohio also recorded a fire. Other river fires during the 1960s were recorded in Chicago, IL and in Buffalo, NY. The increase of water pollution and accompanying calls for action by activists led to the introduction of the Clean Water Act (CWA) by the US congress in 1972. Two years later, in 1974, the Safe Drinking Water Act (SDWA) was introduced to protect public health through the regulation of the nation's public drinking water supply systems. This era also saw more funding to expand drinking water infrastructure and paved the way for the enforcement of the CWA and SDWA to ensure public health protection. Since the introduction of these key federal water regulations, they have been updated multiple times to include contaminants as they materialize to ensure continuous control.

[8]National Drought Mitigation Center, the University of Nebraska, the Dust Bowl drought.unl.edu. Accessed Mar 10, 2023.
[9]John H. Hartig, Mohiuddin Munawar, John D. Dingell, and Alfred M. Beeton (2010). Burning Rivers: Revival of Four Urban-Industrial Rivers That Caught on Fire.Multi-Science Publishing Company; 1st edition, ISBN-13 : 978-1907132162.

- The fourth water crisis started in 2015 and exposed issues like increased health risks due to deteriorating water infrastructure, the need for infrastructure funding, the need for alternative water sources, and integration of modern technology to improve daily water systems operations. While the state of California has been dealing with the most significant drought that began in 2012, Michigan and New Jersey were dealing with Lead (Pb) in drinking water in minority communities. It became apparent that the SDWA which was believed to ensure safe and clean water for all Americans had not worked for overburdened communities. The highest water hardship was found to be represented by a nationwide environmental injustice as it was associated with social dimensions of poverty, ingenuity, rurality, education and age. Furthermore, the findings of a nationwide drinking water violation analysis from 2016 to 2019 by the Environmental Justice Health Alliance for Chemical Policy Reform (EJHA) and an NGO based in Louisville, Kentucky called Coming Clean, Inc. were astonishing and supported our findings on the disparity in clean water access in overburdened communities. This review confirmed key sociodemographic characteristics such as the relationship between race and drinking water violations. Apart from these violations, major issues in the fourth water crisis primarily point to deteriorated water infrastructure across the US which impacts the quality of tap water. An estimate of 21 million people was exposed to tap water that violates federal guidelines due to high levels of pathogens (bacteria and viruses), nitrates, Arsenic (As), and harmful byproducts from disinfectants (e.g., Chlorine (Cl)). One of the solutions provided by the federal government to control the impact of deteriorating drinking water due to aged infrastructure is the US Infrastructure Investment and Jobs Act (H.R. 3684) that sets aside over $50 billion for upgrades, rehabilitation and repair for drinking water and wastewater infrastructure in the US.

[10] California Department of Water Resources, report generated by CalMatters . Major California droughts infographics infogram.com. Accessed Mar 15, 2023.
[11] Lauren Aratani (2019). The damage has been done: Newark water crisis echoes Flint. theguardian.com. Accessed Mar 15, 2023.
[12] Mueller, J.T., Gasteyer, S. The widespread and unjust drinking water and clean water crisis in the United States. Nat Commun 12, 3544 (2021). doi.org.
[13] Steve Taylor, Coming Clean and Michele Roberts, and EJHA (2020). Watered down justice report. nrdc.org. Accessed Mar 10, 2023.
[14] Allaire M, Wu H and Lall U 2018 National trends in drinking water quality violations Proc. Natl Acad. Sci. USA 115 2078–83.

Engaging stakeholders across sectors, including government agencies, utilities, businesses, and coordination in water and energy management.

(World Bank, 2016)

Recent drinking water emergencies across the US re-affirmed that drinking water crises are not shared evenly across affected communities. Overburdened communities are the most impacted by these drinking water challenges and will require more assistance than their counterparts. The recent crisis in the Cities of Flint (MI), Benton Harbor (MI), Cahokia Highlights (IL), and Jackson (MS) confirmed that the needs in poor and minority communities are far greater than often estimated. The question remains whether there are strategies that could help these overburdened communities solve drinking water challenges in their communities and make a long lasting sustainable and resilient impact. A recent case study in California by Glade and Ray (2022) investigated the contemporary processes by which distributive injustices persist in California's Central Valley and suggested that the existing steps required to mitigate drinking water violations propagated inequalities. There is a need to understand the implementation of initiatives at scale and at the city level, and develop tangible solutions to address the legacy of inequitable clean drinking water access in the US.

[15] Sara Glade and Isha Ray (2022). Safe drinking water for small low-income communities: the long road from violation to remediation. Environmental Research Letters, Vol. 17, 044008 DOI 10.1088/1748-9326/ac58aa.

SECTION 3: THE ENVIRONMENTAL JUSTICE LENS

Environmental Justice emerged during the third (3rd) US water crisis and continues to be the dominant safe drinking water challenge in overburdened communities through the currently ongoing fourth (4th) water crisis. The US Environmental Protection Agency (EPA) defines environmental justice (EJ) "as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies". Studies of Environmental Justice in the US have focused on three different issues related to drinking water in minority communities: (1) lack of access to safe drinking water in the low-income communities, (2) inequitable participation and unfair treatment in decision making for their water resources,, and (3) drinking water injustice supported by historical structural barriers to equitable access and planning policies in support of systemic discrimination in the US, . In addition, the major barriers to safe drinking water access at community level were identified to include mainly lack of technical, managerial and financial capacity. The fourth water crisis underway is generally affecting US communities due to the adverse impact of aging infrastructure on drinking water quality. Overburdened communities are paying the biggest price since they have historically been experiencing the use of polluted drinking water as suggested in environmental justice literature.

3.1. Current top five (5) drinking water challenges affecting minority communities in the US

To better understand the current burden faced by minority communities across different cities in the US, we examined the five (5) most dominant challenges they are facing. They include Lead (Pb) service lines, aged water system infrastructure, drinking water contamination, lack of capital and financial capabilities, and shift in purchasing power.

[16] The USEPA glossary of Environmental justice terms - epa.gov. Accessed Feb 20, 2023
[17]Mueller J T and Gasteyer S 2021 The widespread and unjust drinking water and clean water crisis in the United States Nat. Commun. 12 3544.
[18]Balazs C L and Ray I 2014 The drinking water disparities framework: on the origins and persistence of inequities in exposure Am. J. Public Health 104 603–11.
[19] Rutt R L and Bluwstein J 2017 Quests for justice and mechanisms of suppression in Flint, Michigan Environ. Justice 10 27–35.
[20] London J et al 2018 The Struggle for Water Justice in California's San Joaquin Valley: A Focus on Disadvantaged Unincorporated Communities (Resources Legacy Fund, Water Foundation) UC Davis Center for Regional Change, Commissioned byavailable at: regionalchange.ucdavis.edu. Accesed 13 January 2020.
[21] Meehan K et al 2020 Exposing the myths of household water insecurity in the global north: a critical review WIREs Water 7 e1486.
[22] State Water Resources Control Board 2015 Safe Drinking Water Plan for California: State Water Resources Control Board Report to the Legislature in Compliance with Health & Safety Code Section 116365 available at: senv.senate.ca.gov. Accessed March 12, 2023.

LEAD (PB) SERVICE LINES

According to the US Environmental Protection Agency (EPA), it is estimated that 6 to 10 million of Lead (Pb) service lines are still buried across multiple water distribution systems in the US. Different communities in the US are racing to remove Lead (Pb) service lines in order to prevent potential health risks, most especially among kids. Financial hardship within poor cities remains the biggest challenge to addressing this Lead (Pb) service line issue. These cities are often inhabited by minority communities so they are typically exposed to Lead (Pb) in drinking water.

AGED WATER SYSTEM INFRASTRUCTURE

Water system asset replacement and or rehabilitation both represent a financial burden to cities populated predominantly by minority communities which have less tax-based revenues to cover basic infrastructure needs. Recent analysis of the case of Jackson, Mississippi demonstrates that if the city would have continuously been financially supported to cover all required infrastructure repairs, replacement or rehabilitation, the current ongoing water crisis that left over 150,000 residents with deteriorated drinking water could have been averted. After what was witnessed in the City of Flint, Michigan, another city predominantly populated with minority communities could have been spared and saved from lack of access to clean drinking water. The lack of sufficient financial resources at city level does not only affect the drinking water needs, but it also often affects other sectors across the public works; public health, education, and communications, to name a few.

DRINKING WATER QUALITY AND EMERGING CONTAMINANTS

Deteriorated drinking water quality due to heavy metals associated with aging infrastructure is becoming a trend in cities populated predominantly with minority communities. Heavy metals (Lead (Pb), Cadmium (Cd), Copper (Cu), and Iron (Fe)) found in drinking water are mainly related to aging infrastructure, industrial contamination of source water (Mercury (Hg) and Chromium (Cr)), and are naturally occurring in the groundwater source (Arsenic (As) and Manganese (Mn)). Beyond these heavy metals, minority communities are also facing health risks associated with emerging contaminants. Today, the most dominant of all of them are known as forever chemicals or PFAS (The per-and polyfluoroalkyl substances). PFAS are a group of chemicals previously used in the manufacture of fluoropolymer coatings and products that resist heat, oil, stains, grease, and water. Today, they have leached into many groundwater aquifers and require heavy investment for removal treatment to ensure public safety. Cities like Ann Arbor, Michigan, have invested more than $1 million in PFAS removal treatment to ensure safe drinking water supply. However, such an investment is often not available for minority cities which are struggling to cover routine operations and maintenance at the treatment plant and throughout the drinking water distribution system.

LACK OF CAPITAL AND FINANCE CAPABILITIES

Lack of capital and financial resources reduces the ability of a city to support its communities. They simply cannot afford to cover ongoing operational costs resulting in the deterioration of basic infrastructure such as water, wastewater, and energy. The recent state government's heavy investment in refitting aging infrastructure, particularly water infrastructure, is a testament to the capital needed to appropriately solve existing water problems. Dry capital-intensive improvement plans that remain on paper due to lack of financial backing for implementation are often found in cities populated by predominantly minority communities. These cities are also struggling with lower credit scores and will likely have less access to loans to boost the finances needed to cover heavy capital projects for the city's operations. These cities might also not qualify for the State Revolving Funds that were established to support capital intensive infrastructure projects in the water and wastewater sector. Some of these minority populated cities like Benton Harbor, Flint (MI), and Jackson (MS) had to be put under state of emergency to access state and federal support for necessary capital injection in order to solve the most urgent drinking water infrastructure issues such as replacing Lead (Pb) service lines, upgrading treatment plants, and improving water storage capabilities.

POPULATION MOVEMENT

The US municipal public water supply systems rely mainly on the consumers' payments to cover maintenance and operations. Since the 1980s, some cities populated predominantly by minority communities such as Detroit, Flint (MI), and Jackson (MS) have experienced population mobility. This phenomenon led to the decrease of purchasing power and consequently increased drinking water bills rates which were meant to relatively keep up with the high price tag of maintenance, operations, and upgrading of the aging infrastructure. This population mobility also impacted the ability of the city to maintain access to loans or bonds that could have alleviated financial hardship. Till date, cities with a high percentage of minority communities across the US are dealing with lack of capital to cover or maintain essential water systems functionalities and infrastructure upgrade from water source to the taps of customers.

[23] USEPA (2022) Lead service line replacement program epa.gov. Accessed February 15, 2023.
[24] Class Action complaint for injunctive relief and money damages with jury trial demand, City of Jackson Mississippi, US District Court Southern District of Mississippi Northern Division lieffcabraser.com. Accessed Mar 10, 2023.
[25] Associated Press (2021). Key moments in Flint, Michigan's lead-tainted water crisis. apnews.com. Accessed Mar 14, 2023.
[26] Renwick DV, Heinrich A, Weisman R, Arvanaghi H, Rotert K. Potential Public Health Impacts of Deteriorating Distribution System Infrastructure. J Am Water Works Assoc. 2019 Feb 4;111(2):42-53. doi: 10.1002/awwa.1235. PMID: 32280135; PMCID: PMC7147732.
[27] Mueller, J.T., Gasteyer, S. The widespread and unjust drinking water and clean water crisis in the United States. Nat Commun 12, 3544 (2021). doi.org.
[28] Brett Theodos and Brady Meixell (2019). Preventing unequal investment in the US Cities usnews.com. Accessed February 25, 2023.
[29] Kim Kozlowski (2021). Detroit's 70-year population decline continues; Duggan says city was undercounted detroitnews.com. Accessed Feb 20, 2023.
[30] Paul Rozycki (2021). Commentary: Flint loses 20,000 residents. What does it mean for the city? eastvillagemagazine.org. Accessed Feb 20, 2023.
[31] Priya Krishnakumar and Christopher Hickey (2022). Tea leaves unread: Jackson's water crisis follows years of economic decline cnn.com. Accessed March 05, 2023.

SECTION 4: DRINKING WATER INEQUALITIES: A TALE OF 65,000 CITIES

4.1 Methodology

To understand drinking water violations in the US minority communities, we provide insight into minority and non-minority cities with the most drinking violations. This is achieved by aggregating data from the US Environmental Protection Agency (EPA), which documents drinking violations dating back to 1987, and the US Census of 2020 as reported by the US Census Bureau. The EPA's database used for this work has drinking water violation records of over 108,000 US cities. This US EPA database spans from 1987 to July 2022, and it includes all forms of reported violations. The EPA dataset is combined with the latest (i.e., 2020) census demographic information which includes racial compositions of cities, average household size, and median household income, among others, to explore the relationships between these named demographics and drinking water violations.

The analysis of the data is reported in three parts. The first part focuses on the full sample of over 108,000 cities in the EPA database with their corresponding median income, household size, and racial compositions and reports on total drinking water violations across US cities. In the second part, the sample is restricted to cities with 50 percent or more minority populations to better decipher and characterize the drinking water violations in predominantly minority communities. Finally, in the third part, relationships between drinking water violation and race, median income, and unemployment rate are examined using a regression analysis.

> “ Building resilience to climate change and other stressors is critical for the long term sustainability of water and energy critical types of the systems.

Specifically, we regressed the log of the number of drinking water violations on demographic characteristics, namely; percentage of minority population, log of median annual household income, unemployment rate, and percentage of people with college education or higher. These explanatory variables were selected based on data availability and in accordance with prior findings of Fedinick, Taylor, and Roberts (2019).

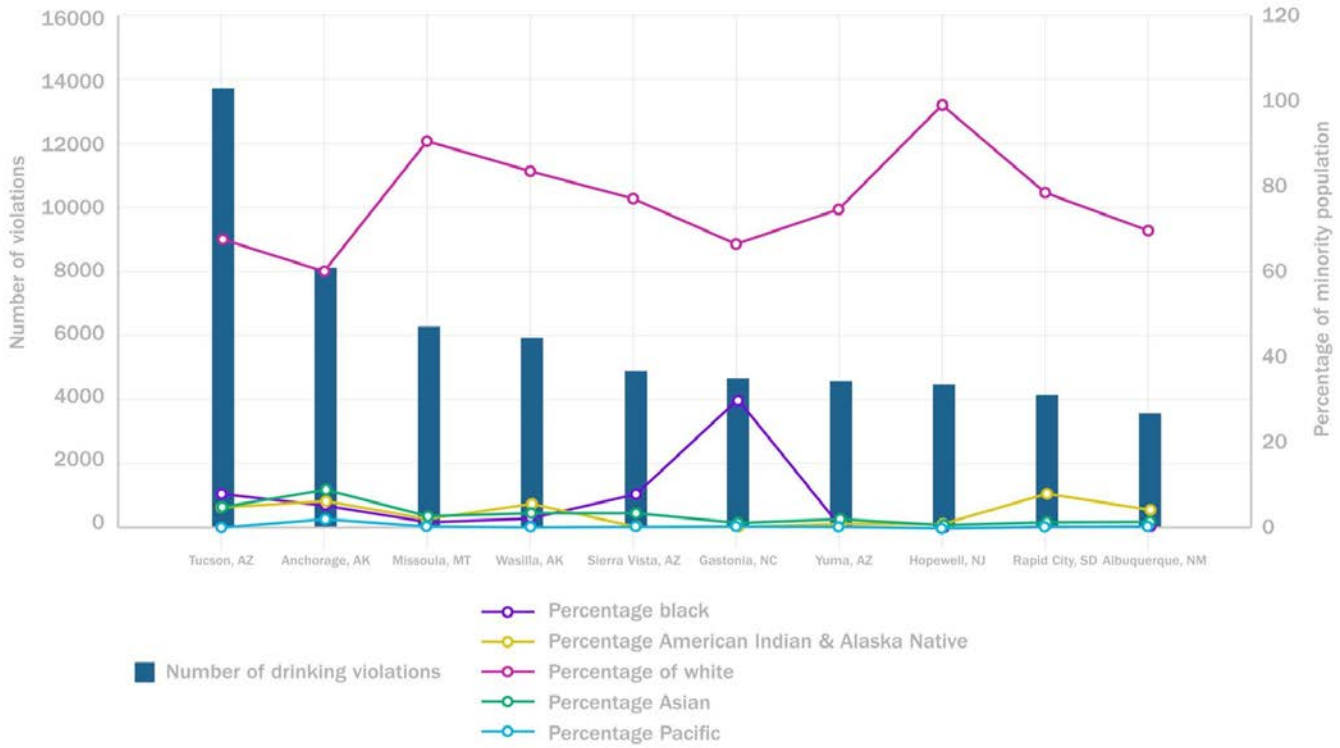
4.2 Results

4.2.1 DRINKING WATER VIOLATIONS IN US CITIES IS A SHARED ISSUE ACROSS RACES.

Out of the 108,372 cities identified in the EPA database, 13,616 reported one or more drinking water violations. Of these 13,616 cities, we report on the top ten (10) cities with the most cumulative drinking water violations. Figure 1. shows the top ten (10) cities with the most drinking water violations across the US, with their respective percentages of racial compositions. Among these top ten (10) cities, three (3) cities are located in Arizona (Tucson, Sierra Vista, and Yuma), and two (2) cities (Anchorage and Wassila) located in Alaska. Tucson (AZ), top the list with cumulative drinking water violations of various forms of over 13,937 (from 1987 to July 2022), followed by Anchorage (AK) with 8,037 reported cases of drinking water violations. It is important to note that in all these cities over 60 percent of the population identifies as white. Although these cities are predominantly white in race per population, Gastonia, (NC) with a population of 29.2 % black in race per population came in sixth with a total of 4,604 cases of drinking water violations between 1987 and July 2022. In fact, out of the top five (5) cities on the list, Arizona and Alaska produced two cities each. While it is widely documented that elevated levels of drinking water violations are recorded in predominantly minority-occupied communities, it is important to note that a significant share of predominantly non-minority occupied communities are also experiencing poor access to drinking water as evidenced by their violation’s records.

[32] Kristi P. Fedinick, Steve Taylor, and Michele Roberts (2019). Watered down Justice Report. Natural Resources Defense Council, Coming Clean Inc., and e Environmental Justice Health Alliance for Chemical Policy Reform nrdc.org. Accessed March 3, 2023.
[33]Kristi P. Fedinick, Steve Taylor, and Michele Roberts (2019). Watered down Justice Report. Natural Resources Defense Council, Coming Clean Inc., and e Environmental Justice Health Alliance for Chemical Policy Reform nrdc.org. Accessed March 3, 2023.

Figure 1: Top 10 cities across the United States with the most drinking water violations

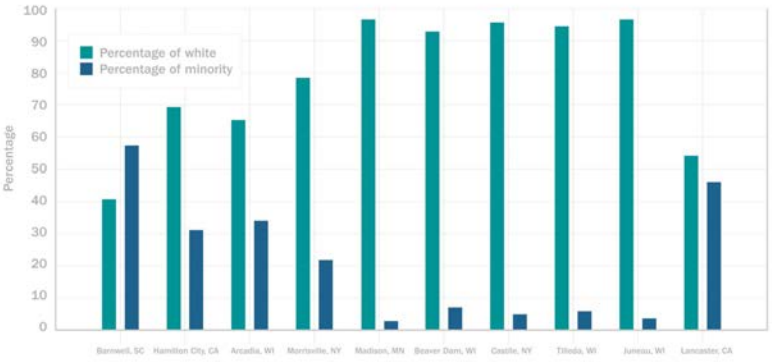


Source of data: Author's compilation from the US EPA drinking water violations database and 2020 US Census data from Census Bureau. The analysis reported here excludes cities located in Puerto Rico and Onan, Virginia because the 2020 US Census data from the US Census Bureau does not have data on racial compositions for these cities.

Furthermore, we examined the relationship between drinking water violations and race through another lens. We focused on cities in the EPA database with no drinking violations and explored their racial compositions. Of the 108,372 unique cities in the EPA database, 94,756 reported no form of drinking water violations. We randomly selected 10 cities with no drinking water violations and examined their racial compositions. The findings are summarized in Figure 2. Overall, the analysis suggests that while predominantly white occupied communities are less likely to record any form of drinking water violation, a significant number of predominantly minority-occupied communities are also less likely to record drinking water violations. Out of the 10 randomly selected cities with no drinking water violation over the last 34 years, five (5) have 91% or higher of their residents who identify as white. It is, however, important to note that the city of Barnwell (SC) which recorded no drinking water violation in the past 34 years, and which also made the earlier mentioned list has over 54% of its residents who identify as minority. Another city with a significant proportion of minority population (i.e., 45%) which also made it to the list is Lancaster (CA).

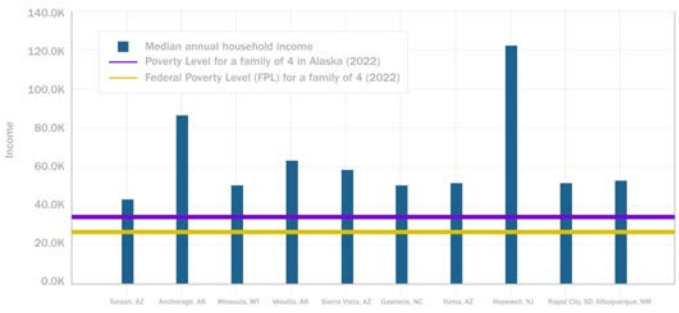
Source of data: Author's compilation from the US EPA drinking water violations database and 2020 US Census data from Census Bureau.

Figure 2: Racial compositions of 10 randomly selected cities in the EPA sample with no drinking water violations



Aside from race, drinking water violations are argued to be related to income. We explore this by examining the median annual household incomes of the top 10 cities and how they compare with the Federal Poverty Level. Figure 3. shows the median annual income of the top ten (10) cities with the most drinking water violations. The median income is also compared with the two horizontal lines representing the Federal Poverty Level of a family of four (4). The latter was used because the average household size in the cities under consideration is 3.2 members. The median household income is represented by the bar graphs, while the dotted lines represent the Federal Poverty Level for the 48 Contiguous States (in red) and Alaska (in black). Median income in the two cities from Alaska on the list is compared with the dotted black line, while all eight remaining cities are compared to the Poverty Level for the 48 Contiguous States. Although none of the cities that reported high levels of drinking water violations is below the Federal Poverty Level, the median annual household incomes are relatively close to the Federal Poverty Level (Tucson - $45.2K, Missoula - $50.9K, Gastonia - $50.3K, and Yuma - $52.2K). It is also important to note that a high-income city such as Hopewell (NJ) is among the top ten (10) cities with the most drinking water violations. Although a relatively high-income city such as Hopewell (NJ) is among the top 10 cities with the most drinking water violations, overall, the finding is somewhat consistent with findings by America's Health Rankings' 2023 analysis of Safe Drinking Water Information System that notes that drinking water violations are higher in low-income communities compared with higher-income communities. This suggests that efforts at addressing drinking water violations may be a priority in low-income communities and cities.

Figure 3: Median annual household income for the top 10 cities across United States with most drinking water violations

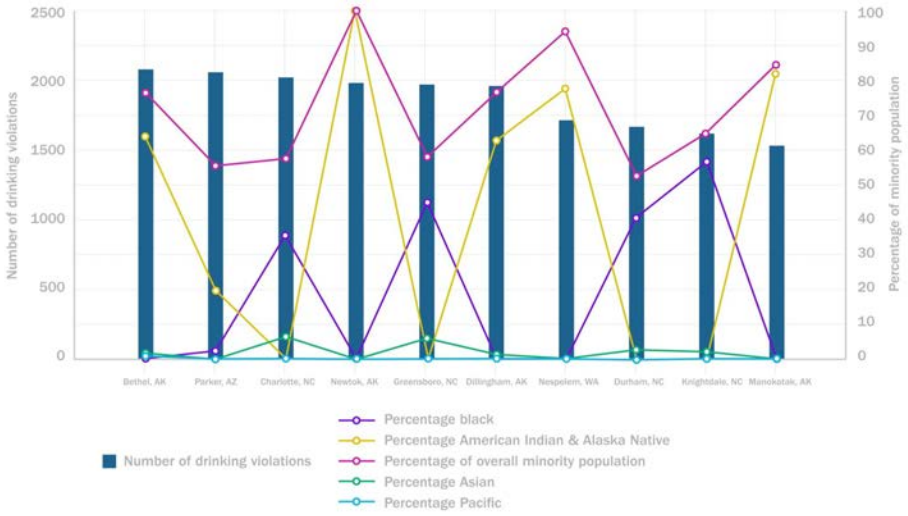


Source of data: Median annual household income data was obtained from the 2020 US Census. Federal Poverty Level data was obtained from the US Department of Health and Human Services.

4.2.2: DRINKING WATER VIOLATIONS ARE MORE LIKELY TO OCCUR IN LOW-INCOME COMMUNITIES.

Among the top ten (10) cities across the US with the most drinking water violations, only Gastonia (NC) with 30% black population (Figure 1) made the list. These results helped us postulate the question of whether one minority city in ten (10) with high drinking water violation was the true representation of minority communities across the US. To answer this, we focused on a subset of EPA and US Census data to understand drinking water violations in cities that are occupied predominantly by minority populations. We restricted the data analysis to cities populated by 50% or more minority populations. Figure 4. documents the top ten (10) minority-occupied cities with the highest number of drinking violations. Overlaid lines represent the percentage of the minority population and specific minority racial groups. Overall, eight (8) cities among ten (10) with high drinking water violations and predominantly populated by minority were found in the States of North Carolina (NC) and Alaska (AK) (NC: Charlotte, Greensboro, Durham, Knightdale, and AK: Bethel, Newtok, Dillingham, and Manokotak). Furthermore, the predominant minority group identified in these eight cities are Black, and American Indian and Alaska natives. This suggests that Black, and American Indian and Alaska natives continue to be the predominant minority groups that continue to witness elevated levels of drinking water violations.

Figure 4: Top 10 predominantly minority-occupied cities with most drinking water violations

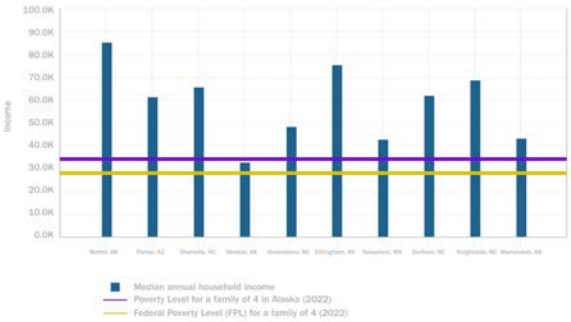


Source of data: Author's compilation from the US EPA drinking water violations database and 2020 US Census data from Census Bureau

To understand how household income of the top ten (10) minority occupied cities with the most drinking water violations compares with the Federal poverty level, we made a note of their median household income.

Figure 5. examines how the median incomes of these predominantly minority populated cities compare with the Federal poverty level for a family of four (4). The median household income of these cities is represented by the bars, while the dotted lines represent the Federal poverty level for the 48 Contiguous States (in red) and Alaska (in black). The median income in all four (4) cities from Alaska on the list is compared to the poverty level of Alaska, while the remaining cities are compared with the poverty level of the 48 Contiguous States. While only one of these cities has its median annual household income below the respective poverty level, the median annual household income of three other cities (i.e. Manokotak (AK) ($42.1K), Nespelem (WA) ($41.3K), and Greensboro (NC) ($49.5K)) are slightly above the poverty level. These findings suggest that drinking water violations are more likely to occur in low-income communities. Previous studies by Glade and Ray (2022) and Muller and Gasteyer (2021) and Kristi et al. (2019) demonstrate similar findings.

Figure 5: Median annual household income of top 10 predominantly minority occupied cities with the most drinking water violations



Source of data: Median annual household income data was obtained from the 2020 US Census. Federal Poverty Level data was obtained from the US Department of Health and Human Services.

[34] America's Health Rankings analysis of U.S. Environmental Protection Agency, Enforcement and Compliance History Online, Safe Drinking Water Information System, United Health Foundation, AmericasHealthRankings.org. Accessed 2023.
[35] Sara Glade and Isha Ray (2022). Safe drinking water for small low-income communities: the long road from violation to remediation. Environmental Research Letters, Vol. 17, 044008 DOI 10.1088/1748-9326/ac58aa.
[36] Mueller J T and Gasteyer S 2021 The widespread and unjust drinking water and clean water crisis in the United States Nat. Commun. 12 3544.
[37] Kristi P. Fedinick, Steve Taylor, and Michele Roberts (2019). Watered down Justice Report. Natural Resources Defense Council, Coming Clean Inc., and e Environmental Justice Health Alliance for Chemical Policy Reform nrdc.org. Accessed March 3, 2023.

4.2.3: DRINKING WATER VIOLATIONS INCREASE WITH AN INCREASE IN UNEMPLOYMENT RATE AND THE NUMBER OF MINORITY INDIVIDUALS

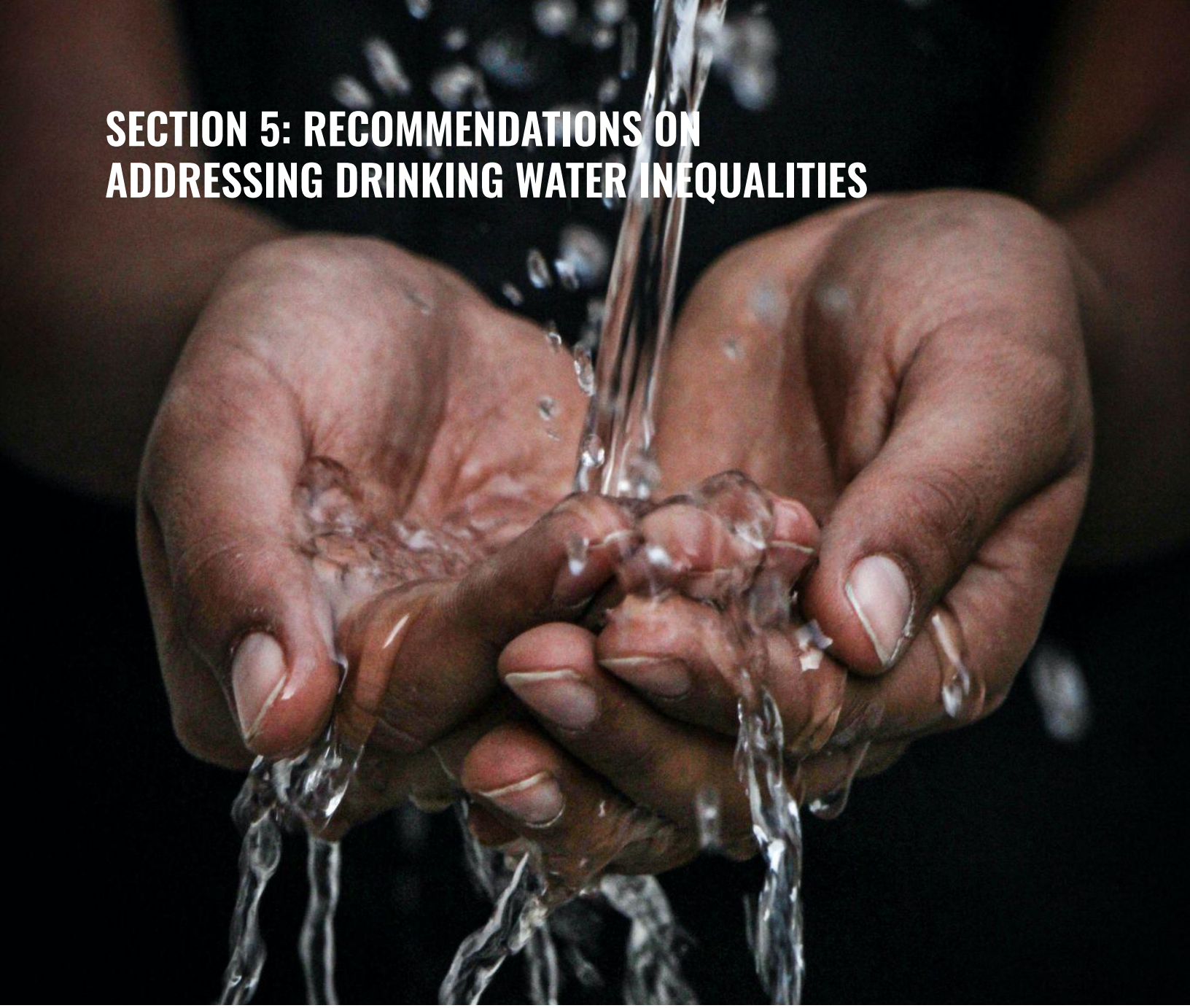
The results below presented in Table 1. are from an Ordinary Least Squares (OLS) regression analysis and provide in-depth understanding of the relationship between drinking water violations and the demographic variables earlier previewed. The results reported in column (1) used the log of the number of drinking water violations as the dependent variable while the results in column (2) used the number of facility violations as the dependent variable. First, we focus on the results in column (1) and discuss the relationship between median household income, minority population, unemployment rate, and the percentage of those with college education or higher. We find that although not significant, there is a negative relationship between the number of drinking water violations and household annual income. Thus, as annual household income increases the number of drinking water violations reduces, ceteris paribus. The finding is consistent with Fedinick, Taylor, and Roberts (2019) who note that drinking water violations increase with the number of low-income people. Most importantly, we find that the number of drinking water violations increases with the percentage of the minority population. The results suggest that a 1% increase in the percentage of minority population is associated with 0.6% increase in the number of drinking water violations, all else held constant. The results further show that an increase in drinking water violations is associated with an increased unemployment rate. Thus a 1% increase in the unemployment rate is associated with an increase of 2% in drinking water violations. Surprisingly, we find a positive relationship between the percentage of the population with college education or higher and drinking water violations.

When a specific form of drinking water violation (i.e., number of facility violations) is examined, a similar and consistent result is revealed (i.e., results in column 2). Thus, the analysis indicates that the number of facility violations increases with the percentage of the minority population. The results suggest that a 1% increase in the percentage of the minority population is associated with a 0.1% increase in the number of facility violations, all else held constant. This suggests that infrastructure or asset violations are more likely to occur in predominantly minority occupied cities.

Table 1: Regression Results of the Relationship Number of Drinking Water and Facility Violations and Race and Income

Variables	Log (Number of drinking water violations)	Log (Number of facility violations)
Log of median annual household income	-0.0654 (0.0507)	0.00323 (0.0322)
Percentage of minority population	0.00600*** (0.000745)	0.00100** (0.000474)
Unemployment rate	0.0209*** (0.00296)	0.00182 (0.00188)
Percentage of people with a college degree or higher	0.0139*** (0.00126)	0.0172*** (0.000802)
Constant	3.647*** (0.538)	2.387*** (0.342)
Observations	11,847	12,114
R-squared	0.027	0.064

NB: Standard errors in parentheses. * denotes p-value of null hypothesis less than 0.1; ** less than 0.05; *** less than 0.01. The results reported are from OLS estimation



SECTION 5: RECOMMENDATIONS ON ADDRESSING DRINKING WATER INEQUALITIES

Addressing inequalities in the US drinking water access is not an easy task. Some of the popular solutions has been the takeover of the financial and city operations management by an oversight team under the supervision of the state government. These approaches have often led to disastrous solutions that do not benefit the minority communities living in these cities. The city of Flint (MI) and Jackson, (MS) are examples of how controlled state financial support comes short of providing long lasting solutions which ultimately lead to public health risks. The progress made in the City of Flint (MI) after their water crisis might orient future planning to where prevention and response to crises are measured and adjusted to benefit local minority communities with upgrades to infrastructure, support, and public health protection.

How to address the drinking water access inequalities in minority communities

The retrospective analysis of drinking water violations over the last 34 years and related 2020 US Census at city level confirmed that drinking water challenges are likely to occur in overburdened communities. These findings demonstrated that drinking water challenges in minority communities have been overlooked for the last 34 years. The forward thinking efforts should be focused on problem solving and determine the best approach to start tackling these drinking water challenges. In the subsections that follow, we focus on approaches to examine the problem by identifying and positing implementation solutions, and then we determine where technology can add the most value by reinforcing the outcome of deployed solutions.

Newly revamped environmental justice strategy at federal level

The decade of the 1980s culminated with the publication of the first studies by the General Accounting Office and United Church of Christ (which is headquartered in Ohio) proposing that minority and low-income communities were disproportionately exposed to elevated levels of environmental hazards1. Since that report, the concept of Environmental Justice has been expanded by increasing the number of hazards examined. Deeper analysis of factors contributing to the observed human exposures, and reversed causation where minority communities' influx is recorded in areas with elevated levels of environmental hazards have been carried out. Although superfund sites and industrial facilities took precedence in the past, drinking water pollution in minority communities is becoming the dominant environmental justice concern of our time. Flint (MI), Newark(NJ), and Jackson (MI) are arguably the most recent shocking events where lack of access to clean drinking water was the center of the violation of environmental justice and civil rights.

To address these inequalities and make issues of environmental justice the forefront of the current priorities of the federal government, the Office of the US Attorney General, US Department of Justice (DOJ) developed a Comprehensive Environmental Justice Enforcement Strategy. This strategy was introduced in May 2022, forty-eight (48) years after the Safe Drinking Water Act was enacted and three (3) decades after first environmental justice research demonstrated the connection between the impact of environmental hazards, human health, and minority communities. This new strategy was given four (4) core principles developed around prioritizing environmental justice affecting overburdened and underserved communities. The EPA implemented the DOJ strategy by establishing a new Office of Environmental Justice and External Civil Rights (OEJECR), which provides leadership on environmental justice and external civil rights priorities.

This new strategy reassures overburdened, marginalized, and underserved communities that their environmental related problems will not be overlooked and emphasizes the commitment at federal government level which should be translated into action at state and local levels. Although this strategy is still new, the private sector is developing technologies to support water utilities and the municipalities in charge of the drinking water system serving minority communities. These solutions include tools that encompass environmental justice aspects because overburdened and underserved communities are the most dominant composition of the customer base in the served areas.

Step by step approach to addressing drinking water challenges of minority communities

Water systems serving cities populated predominantly by minority communities need to adopt new and innovative approaches to tackle drinking water challenges that lead to the supply of polluted water in served areas. The design of a water system must guide where the focus should be oriented. Focusing on three (3) major components of a water system (source water, treatment, and distribution), utilities and municipalities should target solutions at the most vulnerable and affected component of the water system and at the most deteriorated junction. If aged assets and deterioration are the major issues related to drinking water quality pollution, raising capital and setting priorities for asset replacement and rehabilitation should be prioritized.

Looking back on the history of drinking water contamination and water system deterioration in the US since the enactment of the safe Drinking Water Act, many solutions have been developed and experimented with in different communities. These experiences, which are listed below, guided the development of a step-by-step approach that tackles the top five challenges highlighted as dominant in minority communities. Best practices, scientific discoveries, and documented lessons learned throughout cities that have experienced drinking water challenges were also considered in the development of this baseline approach.

> Engaging stakeholders across sectors, including government agencies, utilities, businesses, and coordination in water and energy management.
>
> (World Bank, 2016)

STEP 1: IDENTIFYING THE MOST CHALLENGING DRINKING WATER PROBLEMS AND SETTING PRIORITIES FOR SOLUTIONS IMPLEMENTATION

- Municipalities managing water systems in minority communities should team up with community representatives and grassroots organizations to run a diagnostic of the entire water system from source to tap.
- Contributions of water system staff across the entire system should focus on assets, budgeting, and capital needs. While community representatives and grassroots organizations must formulate the chronology of community complaints about drinking water quality.
- The knowledge from all these sessions at technical and community levels should be assembled and re-organized to formulate a list of the most challenging drinking water problems for their community.
- The list of the most challenging problems should be arranged in chronological order from the highest priority to the lowest priority.
- The participating teams should also make a list of where technology assets and solutions will be integrated to support the problem-solving process and add value to the solution deployed.
- Enumerate the outcome of the step:
    - a list of the most challenging drinking water problems,
    - a list of these challenges prioritized and classified based on the components of the water system,
    - and a list of needed technologies and their locations on a water system.
- Water utilities and municipalities managing water systems are advised to go through this exercise regularly to stay ahead of the most urgent problems of the water system and include them in planning before they become legacy challenges.

STEP 2: REVIEW PRIORITIES AND MATCH THEM TO AVAILABLE RESOURCES

- Leaders of utilities and municipalities managing water systems in minority communities will review the list developed under step one (1) and match available resources to identified and prioritized problems.
- Perform a review of the list of needed technology assets and identify resources available to support implementation of those matching prioritized problems.
- Enumerate the outcome of the step:
    - a table identifying priorities, available resources, and estimated timeline the problem might take to get resolved,
    - a list of priorities that were not matched to resources should be tabulated and potential sources of needed resources should be identified and listed to guide future follow up,
    - and a table of identified technology assets to match the need of prioritized problems, available resources, pilot needs and deployment timeline.

STEP 3: EVALUATION OF BUDGET NEEDS AND POTENTIAL SOURCES OF FUNDING

- This step will focus on the development of the budget needed to tackle identified problems now and in the future.
- The budget available to start working on problems that match available resources should be set aside.
- The budget needed for future work should be targeted and potential funding sources identified. Then, each of the least prioritized problems should be matched to a specific budget and its future potential funding source.
- A team should also be identified to pursue potential sources of funding. They will identify what is needed to gain access to these funds and draft applications for funding as required.
- Enumerate the outcome of this step:
    - The budget to cover the cost of problems that can be solved immediately and those that require a pilot scheme.
    - The budget of problems that requires access to other potential sources of funding.
    - List of funding applications drafted for identified potential sources of funding (private, federal, and state grants, or low interest loans).
    - Identify budget availability to integrate digital solutions where they are needed and detail potential sources for additional funding (e.g., Supervisory Control and Data Acquisition (SCADA) for automation of pump stations operations).

STEP 4: DEVELOP AND EXECUTE PILOT SCHEMES TO ADOPT DIGITAL INNOVATIVE SOLUTIONS

- Solutions matching prioritized problems will be the first to pilot.
- Piloting should only be considered for hardware or software innovative solutions being incorporated into solutions of prioritized problems.
- Classic assets problems such as replacing water main or fixing a water main break or rehabilitating a pump station should be addressed without any piloting process. Cost effectiveness should be the guiding principle in addressing these asset-related problems.
- The budget to cover the cost of solution and matching technology assets piloting should be taken into consideration while evaluating resources needed.
- Best practices and cost-effective solutions used should be documented to inform any other listed problems that would benefit from a similar approach.
- Enumerate the outcome of this step:
    - List of problems addressed that were related to water system assets.
    - List of successively piloted solutions and specific problems targeted by each piloted solution.
    - List of best practices and cost-effectiveness for solutions implemented.

STEP 5: SHORT-TERM AND LONG-TERM IMPLEMENTATION PLAN

- The list of piloted solutions should be used to determine their classification under short-term or long-term planning.
- The short-term piloted solutions should be identified based on the need and funds or capital available to fund the entire project.
- The long-term pilot solutions should be given an extended period in order to consider all application aspects when deployed.
- Develop a plan of short- and long-term solutions implementation that requires integral digital innovative solutions to achieve desirable value to customers.
- Enumerate the outcome of this step:
    - List of piloted solutions for short-term and long-term implementation plans.
    - List piloted solutions that require integration with adopted technology assets.

STEP 6: HOW TO COLLABORATE WITH THE CUSTOMERS

- Water utilities and municipalities that manage water systems and deliver drinking water to customers should establish a community or customer working group and provide a space where the complaints of customers are evaluated. It may be considered under ‘solutions being evaluated’.
- The working group should include managers of water utilities and municipalities, representatives of federal, state, county and city leadership on drinking water, mosques, synagogues, local grassroots and churches, schools, hospital leaders, community organization boards, and any other groups created as a response to the drinking water crisis the community is experiencing.
- The working group should be coordinated by water utilities and municipalities that manage the water system. They should develop goals and guiding principles, review them with all members, and offer a space to receive any contribution or suggest amendments.
- The working group should meet regularly to share progress, challenges, or implementations blockers in all aspects of prioritized solutions being implemented to address drinking water challenges identified in step 1.
- The working group should promote transparency and develop other channels for community members to ask questions, learn about solutions being implemented, and gain feedback on what is needed from them to ensure progress on improving the water system.
- The working group should prioritize making environmental justice part and parcel of any safe and clean drinking water solution and share insights with the group and customers.

Approaches used to address drinking water challenges in minority communities in the US

Lessons learned from recent drinking water crisis in cities populated predominantly by minority communities (e.g. Cities like Newark (NJ), Benton Harbor (MI), and Jackson (MS) showed that the federal and state government took the lead in problem identification, development of solutions and provision of regulatory oversight in addition to funding to tackle the root causes of the problem. For example, the state government in the State of Michigan provided needed funding to remove all Lead (Pb) service lines from homes of customers receiving drinking water from Benton Harbor municipal water system. At the same time, the US EPA provided technical assistance to run a study to answer community questions related to potential exposure to Lead (Pb) particles. The crisis in the City of Jackson (MS) led the US EPA to assume many roles such as management, regulatory leadership, and funding solicitation support.

These intervention approaches in the cities of Benton Harbor (MI), Newark (NJ), and Jackson (MS) were reactive, short-term, and followed emergency management protocol. The management of the water system and city leadership are often seen as part of the root problem. To address these drinking water crises, long-term planning should also start being the forefront of discussions preferable at the beginning of the crisis. After the short-term solutions, the questions that remain include: 'What is next?', 'Who is going to take the lead after the federal and state government is no longer involved?', 'Or is temporary professional management funded under emergency protocols no longer available?' All these questions can be addressed by including the water system managers and operators in every step of the way since they are going to take a lead after all emergency protocols have ended.

- To better use the lessons learned in addressing current and future water system challenges in minority communities, the following key points should be part of planning;
- Determine short and long term technical and professional teams to manage the water system and maintain operations at an expected level of service of providing clean drinking water.
- Identify and put in place mechanisms to provide training and certification upgrades for local water system operators.
- Identify and pursue commitment for a long-term source of funding to continue supporting timely assets repair, maintenance, and or rehabilitation.
- Establish a technical working group at the level of the municipal or local water system with participation of state and local government and use it as space for continuing education for local teams running operations beyond the period of emergency.
- Negotiate grant funding for all technical work needed to fulfill the requirement of accessing funding provided by the state revolving fund or other similar capital resources.
- Identify approaches to develop a long lasting relationship with served minority communities to promote trust in the safety of supplied drinking water.

Varuna's solutions and the technology assets strategy to address drinking water access inequalities

Modern technologies applied to improve water system operations are becoming increasingly important in the US. This is supported by the need of water utilities to move from a reactive to a preventive approach. There is a need to use technology to improve decision making and manage operations. Informed decision making is done through predictive tools and stakeholders can learn from previous water system events that were recorded or experienced or from regular events that are seasonal and reoccur at a similar time of the day or year.

As cities serving minority communities organize to solve drinking water problems, technology assets and solutions upgrades or introductions from scratch should be part of the conversation and planning. For example, SCADA upgrades. Its use as a source of data backed decision-making and as a predictive software tool should be part of the discussion of solutions addressing the drinking water challenges identified across a water system from source to tap. Water systems management and stakeholders are recommended to use an approach demonstrated and summarized in the table below to evaluate technologies needed to digitize a water system.

Summary table giving example of how to evaluate digital technologies needs at different levels of a water system

Water system	Problems summaries	technology assets & solution considerations	Example of Varuna solutions
Source water in-take	• Poor performance and waste of energy at the pump station • Lack of real-time water quality monitoring of source water conveyed to the treatment plant. • Lack of alerts about deteriorating water quality to inform chemical dosing.	• SCADA system connection to monitor and manage pump operation. • Software solutions using data and predictive analytics to identify optimum pump operations promoting energy saving. • Install real-time pressure, flow, water quality monitoring sensors.	• Software: Varuna wire-to-water dashboard for pump operations. • Software: Varuna system dashboard runs analytics and provides alerts where needed. • Software and Hardware: Varuna receiver connections to sensors and provide real-time visualization on Varuna system dashboard
Treatment plan	• Lack of automation for chemical dosing. • Lack of real-time pressure, flow, and water quality monitoring. • Lack of alerts about the state of finished water quality, drop or surge in pressure or change in water flow	• Use of a SCADA system to automate chemical dose and visualize pressure and flow data. • Use of software solutions to run analytics and generate alerts about change in pressure, water flow and water quality. • Install real-time pressure, flow, water quality monitoring sensors	• Software: Varuna system dashboard to visualize, run analytics and provide alerts where needed. • Hardware and software: Varun receiver connections to sensors and provide real-time visualization on Varuna system dashboard

Summary table giving example of how to evaluate digital technologies needs at different levels of a water system

Water system	Problems summaries	technology assets & solution considerations	Example of Varuna solutions
Water distribution system	• Lack of real-time monitoring for flow, pressure and water quality across the distribution system. • Lack of real-time monitoring for pump operations at booster stations • Lack of mapping capabilities for assets & real-time monitoring locations	• Use of SCADA system to monitor pump operations and automate operations where possible. • Use of software solutions for data and predictive analytics to stay ahead of problems. • Install real-time pressure, flow, water quality monitoring sensors at selected locations.	• Software: Varuna system dashboard to visualize, run analytics and provide alerts where needed. • Hardware and software: Varun receiver connections to sensors and provide real-time visualization on Varuna system dashboard. • Software: Varuna wire-to-water dashboard for pump operations.
The entire water system	• Determine the monthly risk priorities to solve current problems and contribute to future resilience of the water system	• Software solution to help manage risk and resilience for the water system	• Software solution: Varuna Resilience Dashboard. Monthly updates of risk priority, use of environmental justice and AI tools to improve capital investment in the water system.

To digitize a water system and incorporate the resulting data into day-to-day operations and decision making requires more than a single system or sensor or software for success. The three (3) steps below may be used to determine areas for the effective integration of a technology solution at different points of a water system:

STEP ONE: DETERMINE TECHNOLOGY SOLUTION NEEDS AND PRIORITIES

- The determination of technology solutions needed for a water system follows the identification of drinking water challenges.
- All technology assets review and selection have to support the solution road map developed to address prioritized drinking water challenges.
- Summarize selected digital solutions and their corresponding prioritized drinking water challenges which they will help to address.
- List selected technologies that need piloting before implementation and those that are ready-to-go without testing.

STEP TWO: PLAN TECHNOLOGY SOLUTION PILOTING

- Technology solution piloting and testing should be scheduled before full implementation.
- Piloting should be scheduled by taking into consideration the availability of the operators who will assume the use of the technology solution and its management after trial for the pilot as a teaching moment.
- Piloting period should be informed by the problem to be addressed and the knowledge of the team and the experience to apply the technology.
- Summarize lessons learned from the pilot to inform full scale implementation.

STEP THREE: FULL SCALE IMPLEMENTATION OF PILOTED TECHNOLOGY SOLUTION

- Ensure that the implementation of the solution to the drinking water problem matched to a piloted technology solution has been completed.
    - For example, a water system working to improve operations at the treatment plant will first implement all needed repairs, rehabilitation, and new hardware. Once this is completed, the treatment plant will then move to the installation of technology assets piloted or selected to be installed at the treatment plant to improve operations. This technology solution can include an upgraded SCADA system, installation of sensors for real-time monitoring for water quality, pressure and flow, and adoption of software to improve data use in decision making.
- Evaluate and address any identified blockers that could affect the implementation of the technology.
    - For example: ensure that all staff that will be involved in the implementation of the new technology have received the required training during the pilot stage. If any of the staff leave before full-scale implementation, refresher training will be needed to bring all involved staff back to the same level.

A successful digitization of a water system serving minority populations where challenges related to drinking water quality deterioration were previously identified requires a unique approach. We presented different key steps for drinking water challenges; identification and solution implementation, and identified key stages where digital solutions (technology) can be selected, piloted, and added in the solutions package to elevate daily operations. This approach combines two (2) different aspects of water system improvement to allow managers of water systems that serve minority communities to ensure the expected level of service of always providing clean drinking water. This is supported by the technology that was coupled with the improvement process where identified solutions will ensure advanced water systems that leverage preventive measures and data driven decision making in daily operations. This process should be backed with capital injected at the right time to avoid falling into the old and poor operating practice where drinking water becomes a human health risk.

SECTION 6: CONCLUSIONS AND RECOMMENDATIONS

The tale of 65,000 cities' demographics and historical drinking water violations provided insights on inequalities and the challenges that multiple cities are experiencing across the US. It offered recommendations on the improvement of water systems' operations and management for an effective and efficient life cycle.

- Overall, drinking water violations can be identified in any community regardless of race. However, population demographic and drinking water violations analysis confirmed the need to prioritize the water quality challenges of minority communities since they are likely to be the most affected with adverse health risks that are associated with the use of deteriorated drinking water quality.
- The socio-economic construct of poverty such as; low-income, unemployment, and low education rate should also be addressed as external factors with the potential to increase the problem of drinking water violations in minority communities.
- The overburdened communities to be prioritized for drinking water quality improvements programs are Black, American Indian and Alaska natives. Cities predominantly populated with these communities should establish a program solely dedicated to ensuring that there is equality and clean drinking water accessible to all populations living in the city.

The findings of this paper support a drastic need to review the current water system from the perspective of the community. If a water system is designed to provide clean drinking water to all communities in the served area, then compliance regulation should not stop just a couple of feet from the residential homes or buildings that are being supplied. We had often had issues of the peculiarity of home interior plumbing and its effect on water quality and residential tap water. Progress in science has provided solutions for residential pipe flushing coupled with sampling to alleviate this unique challenge, and it now allows the comparability of water quality of residential pipes in homes to that of the drinking water distribution system. The future improvements to water systems should consider an alternative analysis and combine community needs, conventional system design, and new development in treatment technologies to make room for improving the drinking water systems that can match the expectations of customers.

The technological applications across water systems has mainly focused on ensuring successful control of water flow, pressure, and treatment. The Supervisory Control and Data Acquisition (SCADA) system has been the most attractive digital tool used for real-time monitoring of treatment plants, water pressure control, flow control, and pump stations operations. Despite the progress and improvements made on SCADA systems, there is still a greater need to digitize the entire water system from source to tap. The current practice has prioritized the digitization of some components of a water system, while leaving behind other parts like the water distribution system. Today, water systems are still in the planning stage to determine a better approach and introduce grander innovative technology to allow for the digitisation of the entire water system. It will surely improve operations' decision-making and ensure better processes. Water systems serving minority communities often do twice the work to implement digital innovative technologies. The current water systems principals must first improve current conditions that have been deteriorated by decades of poor maintenance and operations due to lack of needed capital. Furthermore, most of these water systems have to demonstrate that they can operate independently while following regulatory requirements. While financially capable water utilities often test for the next solution to address their challenges, minority communities are far removed from this process. Often, they have to wait for the next emergency to raise capital to address pre-existing conditions before thinking of long-lasting innovative digital solutions.

These diverse advancements and the accompanying strategies across the water system confirm that the application of innovative solutions are due at different scales and at relative pace depending on the water system and the served communities. It points to the need to update and upgrade SCADA design, testing (piloting), application, and deployment. Water systems serving minority communities will need technical support, more resources, and capital to define the future of their technology solutions in order to receive insightful information to prevent the next Flint (MI) or the next Jackson (MS) water crises.

Key definitions

MINORITY COMMUNITIES

Evaluating the solutions for drinking water challenges in minority communities goes with understanding how "minority communities" are identified by federal institutions in charge of overseeing their access to safe and clean drinking water and protecting them from environmental hazards. As you go through this paper, minority communities and environmental justice terms will maintain the context provided by the US EPA and US Census Bureau's definitions.

The US EPA uses the minority community's definition of the US Census Bureau and defines these communities as "population of people who are not single-race white and not Hispanic. Populations of individuals who are members of the following population groups: American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic".

ENVIRONMENTAL JUSTICE

The US EPA defines environmental justice "as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies."

OVERBURDENED COMMUNITIES

The US EPA defines overburdened communities as "minority, low-income, tribal, or indigenous populations or geographic locations in the United States that potentially experience disproportionate environmental harms and risks. This disproportionality can be because of greater vulnerability to environmental hazards, lack of opportunity for public participation, or other factors. Increased vulnerability may be attributable to an accumulation of negative or lack of positive environmental, health, economic, or social conditions within these populations or places. The term describes situations where multiple factors, including both environmental and socio-economic stressors, may act cumulatively to affect health and the environment and contribute to persistent environmental health disparities."

Other definitions of environmental Justice terminologies by the US EPA can be accessed here.