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Clean Water for All: Examining Safe Drinking Water Act Violations of Water Systems and Community Characteristics

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by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Drinking water systems in the United States confront several challenges such as aging infrastructure, polluted source water, and fragmented systems. The burdens, however, are not equally distributed across the nation. Disadvantaged communities such as communities of color are disproportionately affected by drinking water-related problems.

This study focuses on drinking water quality violations and slow enforcement actions of Safe Drinking Water Act (SDWA) during 2016 to 2018. The EPA's Safe Drinking Water Information System (SDWIS) was used to obtain violation records and characteristics of community water systems. The data set in this study contains 21,845 community water systems. Based on the political-economic perspective, it examines three main hypotheses: 1) whether SDWA violations are distributed randomly across geographic locations; 2) whether compositions of a community including race/ethnicity, poverty, and civic engagement are related to the exposure to contaminated drinking water; 3) and whether these factors are also associated with unequal enforcement of drinking water quality regulations.

The main findings are indicated: first, SDWA violations are concentrated in California's Central Valley, the Texas colonias and rural South; second, water systems serving communities with a larger proportion of Hispanic residents tend to have a higher frequency of SDWA violations; third, while the average length of water system's noncompliance appears longer in communities with higher proportion of Black and Hispanic residents, out-of-compliance water systems return to comply the standard quickly as communities have a higher capacity of civic engagement. The empirical findings in this study strengthens the environmental justice demand that US drinking water policies should be reformed at structural level for all, free from

discrimination, bias, or inequality. It also contributes to the importance of infrastructure reparations that particularly focuses on disadvantaged communities that were historically shaped by segregation.

CHAPTER ONE:

INTRODUCTION

Drinking Water Injustice and Green Criminology

Water is important to human life. Free flowing water, as a life-sustaining resource, has been controlled and managed in order to improve the efficiency of water service to people (Contorno, Sarango and Harlan, 2018). What we drink has been increasingly valued as a commodity. Restricted access to clean water can create lucrative profits for those who have and control water resources. The human utilization of natural systems has resulted in water problems throughout the world (Contorno, Sarango, and Harlan, 2018).

It is widely assumed that the United States has safe and affordable drinking water service available to all residents as well as one of the most advanced water supply systems in the world (Brisman, McClanaha, South and Waters, 2018). The United Nations estimates that all urban populations in the United States have access to safe water or sanitation. The benefits of those systems, however, have not been equally distributed across communities or populations (Contorno, Sarango, and Harlan, 2018; Cooley, 2012; Siegel, 2019). Clean water is commodified and only accessible to those who can afford it. While the United States has good water quality overall, small communities and low-income communities of color are exposed to water problems for drinking and household use (Vanderwarker, 2012).

One example is the drinking water crisis in Flint, Michigan. The Flint water crisis exposed as many as 98,000 residents to harmful containments, including elevated levels of lead, disinfection byproducts (DBPs), and harmful bacteria, which has severe detrimental impact on public health (Allaire, Wu, and Lall, 2017). The Flint Water Advisory Task Force published its finding that the water problem was caused by multiple factors such as mismanagement of water systems, insufficient community finances, regulatory failure of government institutions, and disregard for residents' complaints and concerns about their water quality (Davis et al., 2016). The conclusion was that "the Flint water crisis is a case of environmental injustice." The Michigan Civil Rights Commission's report also concluded that "deeply embedded institutional, systematic and historical racism" was indirectly responsible for the Flint water crisis. That is, the majority-Black community has suffered multiple disadvantages such as, 1) absence of a good tax base, 2) decades of disinvestment and 3) lack of political power, and became exposed to the environmental harm posed by contaminated drinking water.

As the Flint water crisis illustrated, the scope and nature of the water-related problems (e.g., inadequate water quality and institutional/regulatory failure of response) is complex, especially in poor and minority communities (Contorno, Sarango, and Harlan, 2018). According to the Urban Water Innovation Network's report (UWIN)[1], political-economic forces have resulted in the current condition of drinking water systems and management in the water industry. Based on interviews with 45 leaders of community organizations from national NGOs to state government officials, the report identified three main reasons of water inequalities and barriers to sustainability: 1) racial discrimination, 2) economics of free market logic, and 3) exclusive institutions and regulatory failure (Contorno, Sarango, and Harlan, 2018).

As far as the root cause of water inequality is specifically concerned, the current consequence of unequal distribution of basic water services and amenities, at first, resulted from

[1] UWIN is a coalition of academic institution and key partners across the U.S that collaborate on research, engagement, and educational programs to solve problems of urban water systems (Contorno, Sarango, and Harlan, 2018).

decades of racialized urban planning. Wealthy and white communities continue to take advantage of investments from both the public and private sector while poor and minority communities have historically suffered divestment. The unequal distribution of power and resources in geographic space produces unequal infrastructure development such as inferior water infrastructure. The legacy of racial segregation practices such as redlining and restrictive covenants also led minorities to live in concentration of adverse community conditions such as proximity to polluting facilities (Lynch, 2016). Residents living in disadvantaged communities are also exposed to pollution from industrial facilities that worsen local water quality.

In addition, the process of commodification and privatization of drinking water intensifies water injustice. Restricted quantities of fresh and clean water are marketable and lucrative to corporations and private developers. Good quality water is commodified and sold to those who can afford it (White, 2003). Higher cost of water services that is needed for water infrastructure repairment and efficient technologies replacement leads to water affordability issues. Those who cannot pay for water service are exposed to the threat of water shutoffs. The rising cost of drinking water disproportionately affect low-income communities (Mack and Wrase, 2017). The free market logic with lack of a safety net is another cause of unequal distribution of clean water.

Exclusive institutions and regulatory failure of water and environmental agencies also contribute to water injustice. The rigidity and bureaucratic culture of these agencies often fail to consider marginalized populations' complaints and concern. Whether it is intentional or not, poor communities, and communities of color have less of a voice when it comes to important decision-making process (Vanderwarker, 2012). Wealthier communities have more political power, and influence water policy and planning processes. In addition, contributing to water injustice, long-term noncompliance and weak enforcement of drinking water violation are more likely to occur in poor and minority communities (NRDC, 2019).

The adverse consequences of drinking water problems have contributed to a growing body of environmental justice (EJ) research. Based on the assumption of environmental justice that every community has an equal right to be free from environmental harms, EJ studies tend to demonstrate patterns of "differential victimization," - especially African American, Hispanic, and poor communities - that are related with exposure to risky commercial/industrial operations, air pollution, and chemical accidents (Cole and Foster, 2001; Lynch, Long, Stretesky. and Barrett, 2017; Taylor 2014; White, 2010). Research on EJ and drinking water contamination also demonstrates that low-income communities and minority communities are more affected by drinking water violations than other populations (Allaire, Wu, and Lall, 2017; McDonald and Jones, 2018; Switzer and Teodoro, 2017). These findings emphasize the local and national inequality of drinking water access and require an EJ effort to remove threats to water service and management. EJ issue around drinking water, thus, demands water policy reformations for all, free from discrimination, bias or inequality (Vanderwarker, 2012).

Even though past analyses have found the relationships between drinking water contamination and EJ indicators, these findings do not provide a complete picture of drinking water problems. For example, several studies have been limited in terms of spatial scope. These studies focus on single state (e.g., Arizona) or on sections of states (e.g., California's Central Valley).

In order to fill the gap in the literature, Alluire, Wu and Lall (2017) have conducted a national assessment on drinking water quality violations for several decades. This study indicated that there are hot spots (e.g., rural areas) of water contamination and vulnerability factors (e.g., small water systems) associated with the water system violations. The findings emphasized financial assistance and technological skills as the solutions to the problems in community water systems. One of the limitations of that study, however, is that it did not focus on the water related problems connected to a broader range of political-economic forces, even though problems in local water systems are recognized as a complex phenomenon under social, racial and EJ issues (Contorno, Sarango, and Harlan, 2018). Alluire, Wu and Lall's study was the first investigation of national assessment for drinking water injustice over three decades, but it did not focus on the origins of water inequities as well as the importance of addressing drinking related problems at a structural level.

Currently, Natural Resources Defense Council's (NRDC) report examined the correlation between sociodemographic factors and compliance with and enforcement of the safe drinking water act nationwide (Fedinick, Taylor, and Robert, 2019). Even though this study represented the first analysis on the association between EJ indicators (e.g., race, ethnicity, immigrants) and inadequate enforcement of the Safe Drinking Water Act (SDWA) at the national scale, and demonstrated the positive association using Pearson correlations analysis, the results did not isolate the association between enforcement actions and specific utility characteristics.

The issues reviewed above related to drinking water access as a social and environmental justice concern deserves more attention in green criminology for several reasons. First, even though green criminology has dealt with a broad range of environments (e.g., land, air) and environmental issues (e.g., mining, timber harvests) (Lynch et al., 2018; White, 2003), it has not drawn sufficient attention to drinking water related problems[2]. That is, green criminology

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[2] Currently, there is one book published in 2018, *"Water, Crime, and Security in the Twenty-first Century: Too Dirty, Too Little, Too Much",* which discusses water crime, harm and security with the criminological perspective (Brisman et al., 2018).

researchers have not given serious attention to drinking water regulation violations as green crime and injustice (Brisman et al., 2018). Second, investigation on environmental issues, within the green criminological perspective, demands an appreciation of how green harm is socially and historically constructed (Lynch et al., 2018; Lynch, 2016; White, 2003). Based on the framework, it requires understanding of how drinking water inequities are shaped by broader factors of social, political, and economic justice, which are left empirically unaddressed. Drinking water problems need to be discussed in diverse contexts. Third, drinking water contaminations as environmental harm also deserves attention because they often have more victims and produce more damage than street crimes (Lynch, Michalowski, and Groves, 2006). As seen from the Flint water crisis, drinking water contaminations may pose an acute health threat to public health such as low birth weight, cancer, or nervous system problems (Allaire et al, 2017). Considering these adverse outcomes, this study provides new insight into drinking water injustice by examining drinking water regulation violations and incompliance to the Safe Drinking Water Act (SDWA) linked with community characteristics at the county level across the nation.

The Present Study

Communities that are already socially and politically disempowered are exposed to drinking water related problems today. Clean water access restrictions and pollution violate human rights and social equality – that is, safe and clean drinking water must be accessible and affordable for all of residents, regardless of race, ethnicity, and class (White, 2008). Drinking water injustice deserves an attention to be theoretically and empirically discussed in green criminology.

This study assesses drinking water quality violations and the enforcement of the SDWA within the political-economic context. The EPA's Safe Drinking Water Information System (SDWIS) for 2016-2018 was used to obtain violation records and characteristics of community water systems. The SDWA was enacted in 1974 to authorize the EPA to regulate drinking water quality. The EPA sets national health standard to protect drinking water at the federal level. States are primarily responsible for regulating public water systems to meet adherence with the standards. When the water systems fail to ensure an EPA-set drinking water standard, drinking water violation can be reported. The EPA regularly collected data on drinking water violations and publicly provide the information through the SDWIS.

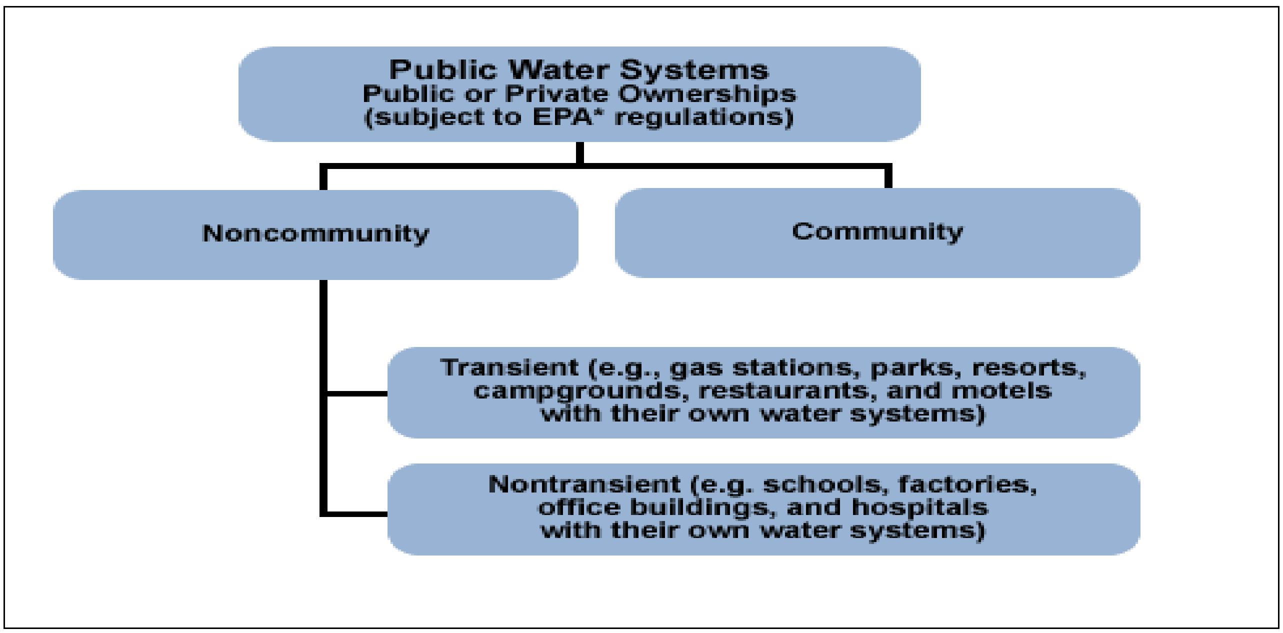

Figure 1. Public Water Systems in the United States.

Source: Centers for Disease Control and Prevention.[3]

[3] For public water systems, see https://www.cdc.gov/healthywater/drinking/public/index.html#one.

The number of public water system in the US is approximately 155,693. Of the public water system, 52,100 (33.5%) are community water systems and 103,583 (66.5%) are non-community systems, including transient systems and non-transient systems (EPA, 2008).

This study focuses on violations of the SDWA committed by a community water system in the community context. Community water systems, as a kind of public water systems, serve at least 15 service networks or 25 or more customers, and are subject to the regulatory standards of the SDWA. Reportedly, 96% of the US population are served by community water systems (VanDerslice, 2011). In this study, violations and characteristics of community water systems that serve over 500 people were collected from the SDWIS between 2016 and 2018, because very small systems (serving fewer than 500 people) are more likely to report violations of the SDWA inadequately (Allaire, Wu, and Lall, 2017; Rubin, 2013). The data set in this study contains 21,845 community water systems.

SDWA violations are primarily self-reported. Under the SDWA, community drinking water systems are required to submit basic information (e.g., ID number, county served, number of people served, and sources of water) and violation information (e.g., compliance with mandated treatment techniques or violations of any maximum containment levels) to primary agencies[4]. Primary agencies are required to collect the information on water systems, reporting them to EPA regularly. The information submitted by primary agencies to EPA includes enforcement results that water systems return to comply regulations, if they are out of compliance. Based on the self-reported information on water systems, EPA manages and evaluates state drinking water policies and regulations. The reported data are updated and checked for accuracy every quarter during a verification period. Quarterly and annual reports are

[4] See the detail information about the Safe Drinking Water Information System at EPA's website: https://echo.epa.gov/help/sdwa-faqs.

available at the Safe Drinking Water Information System (SDWIS) federal report search website[5].

This study used the self-reported SDWA violation data including 1) health-based drinking water violation, and 2) length of time out of compliance from 2016 to 2018, which was downloaded 2019 quarter 1 dataset of the SDWIS. Characteristics of community water systems are included: sizes (service customers), type of source water (groundwater or surface water), ownership type and service location.

SDWIS also provides county-level locations served by each community water system. Since the demographics information about customers of a community water system is not publicly available, counties served by each system can be matched with the geographic names in the U.S Census Bureau American Community Survey to find possible association between drinking water violations and community characteristics. That is, US Census demographic data for a county are linked to the violation data from community water systems serving the region.

This study examines how three dimensions of community characteristics - 1) racial/ethnic proportion, 2) poverty, 3) civic engagement - are hypothesized to be associated with drinking water system's violations and length of time out of compliance of the SDWA. By doing so, this current study makes three contributions to the previous studies as indicated below.

First, consistent with the previous literature (Contorno, Sarango, and Harlan, 2018; Schaider et al., 2019; Vanderwarker, 2012), it is expected that community water systems serving minorities communities are more likely to commit violations of the SDWA and to have longer length of time out of compliance than those serving white communities. That means that communities of color are more likely be exposed to the drinking water violation and slow

[5] See EPA, "Safe Drinking Water Information System Federal Reporting Services," https://www.epa.gov/ground-water-and-drinking-water/safe-drinking-water-information-system-sdwis-federal-reporting.

enforcement of the SDWA than white communities. Decades of racialized urban planning (e.g., land-use planning, housing) contributed to unequal distribution of water infrastructure (e.g., water piped systems) that exist across communities currently. In addition, minorities communities may have less political power and may be marginalized from budgetary decision-making processes, and therefore the minorities community's water systems may have fewer resources to keep new treatment technology in response to the drinking water contamination. Given the reason, the water systems serving communities of color will also face slower and insufficient compliance of SDWA than white communities.

Second, along with racial discrimination in zoning and urban construction, this study analyzes the logic of economics that are hypothesized to lead to drinking water injustice. That is, community water systems serving poor communities are more likely to commit drinking water violations than those for wealthy communities because water distribution systems are constructed at a local level, but access to water financing (e.g., in the form of loans and grants for infrastructure construction to maintain the system) is often hard to obtain for low-income community water systems characterized by absence of tax bases and lower relative household incomes (Copeland, 2010). In that system, wealthier communities are prioritized for infrastructure improvements, where there is an expected return on investment. Given the inequitable distribution of fund for water systems, lower income communities are associated with higher number of drinking water violations and longer length of time out of compliance of the SDWA.

Lastly, this study explores the hypothesis that civic engagement is independently associated with drinking water violations and slow enforcement of the SDWA. Environmental justice literature indicates that civically organized communities are more likely to have political mobilization to solve environmental issues (Hamilton, 1993; 1995). As such, communities reflecting more civic participation have more political influence over decision-making process of local water management agencies to fix its related problems.

The political power of community generally depends on compositions of residents' socioeconomic status because people of color and low-income communities have less resources such as knowledge, time, money to access local policy makers and managers (Core and Foster, 2001; Pastor, Sadd, and Hipp, 2001). Prior researchers tend to use demographic measures as proxies of civic political weakness including high proportion of minority and low income (Pastor et al, 2001). Thus, poor communities of color are more exposed to high proportion of environmental hazards than white and wealthy communities, because race and poverty are often highly correlated with the limited capacity of collective civic participation and least resistance (Bullard, 1996; Hamilton, 1993; Pastor, Sadd, and Hipp, 2001; Pellow, 2004).

While residential compositions are largely associated with political capacity, one cannot assume demographic factors alone determines organizational capacity and political weakness of a community (Zahran, Hastings, and Brody, 2008). Even poor and minority communities can mobilize their members into collective action aimed at resolving environmental issues. Mobilizing resource in communities relies on civic vitality, which is partially independent of community demographic indicators (Zahran, Hastings and Brody, 2008:184).

Given this background, a community with greater level of collective civic engagement is more likely to have effective reactions to the quality of governance and the sense of responsibility of water utilities and local governments. Residents' political activity may foster environmental pressure on water systems to meet the regulations and provide healthier drinking water to local people. In other words, communities with the least amount of collective civic engagement are also more likely to fail in adequate enforcement for the regulations. Prior research has rarely considered the possibility that geographies of civic engagement have an important implication for community drinking water quality. It is expected that regulatory failure of drinking water system is associated with civic engagement of communities, even when racial composition and/or economic status are considered.

Overview of Chapters

This current study is organized as follows. Chapter two introduces the current challenges of drinking water in the United States. Specifically, it includes several considerable problems drinking water systems across the nation has faced, such as 1) aging water-related infrastructure, 2) unregulated contaminants in drinking water, 3) fragmented water system, and 4) bureaucratic culture of water manager and government agencies.

Chapter three provides the knowledge of drinking water injustice. Based on the political-economic framework and environmental justice perspective based on the green criminological scholarship, the problems related to drinking water are explored with three dimensions: 1) racialized urban planning, 2) profit-oriented policies and regulations, and 3) exclusiveness of decision-making process in the water governance and importance of civic engagement.

After the review of previous literature, chapter four provides the research hypotheses, methods, and measures. This chapter also provides information of the data collection procedure, sample of this study, and limitations of this study.

Chapter five describes the analyses, the results, and their implications. In this section, the analytic procedures for the data, descriptive information and results of hypotheses are provided.

The final chapter discusses the findings from this study relative to previous studies. It also provides implications for policy and suggests for future study.

CHAPTER TWO:

DRINKING WATER IN THE UNITED STATES

Trends in National Water Use

Water is generally available in both stocks and flows. Stocks of water contain groundwater, lakes, soil moisture, small volumes in rivers. Flows of water contain rainfall, streamflow, and evaporation and are estimated in water amounts per unit time (Gleick, 2012). According to the 2017 US Geological Survey (USGS), water is used in the United States for eight purposes in general: public supply, self-supplied domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric power. Most of water, which accounts 90% of the national total, are used by irrigated agriculture, thermoelectric power, and public supply (USGS, 2017).

Water use in the United States greatly increased since the 1950s due to growing populations and expanding economic and industrial activities. Since then, increasing demands for water put more pressures on the nation's water systems to secure diversion and manipulation of surface water resources and withdrawals of groundwater resources. The rising water demand resulted in a massive investment in water related infrastructure such as dams, irrigation systems, municipal water purification and wastewater collection and treatment systems (Gleick, 2012). This trend, however, changed in the 1980s. Water use in the nation roughly doubled between 1950 and 1980 but then began to decrease, despite increasing population and economic growth.

Average water uses in 1980 peaked at about 370 billion gallons per day. Current use in 2015 is approximately 280 billion gallons per day.

There are several factors that have contributed to the decline in water use over 25 years, including efficiency improvements in water use, federal regulations on wastewater discharge (e.g., the Clean Water Act), and the transition from a water-intensive manufacturing economy to a less water-intensive service economy (Gleick, 2012: p.11; USGS, 2017).

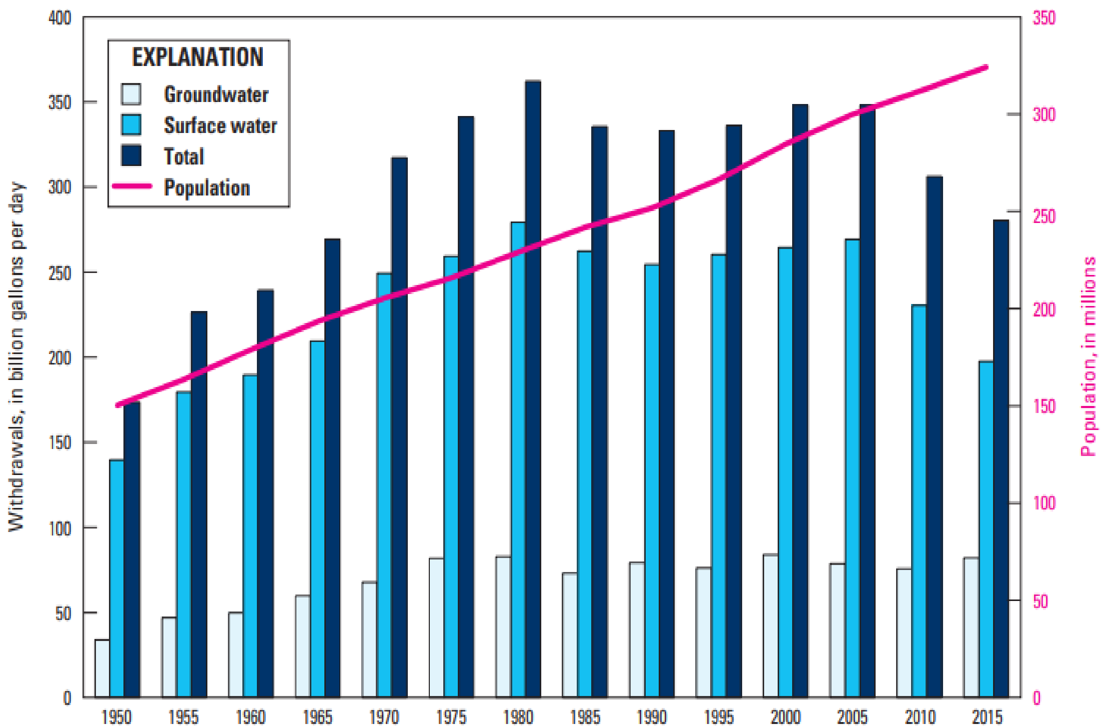

Figure 2. Trends in Population and Freshwater Withdrawals by Source, 1950-2105.
Source: Pacific Institute analysis, from USGS, 2017.

Given the trends in freshwater availability in the United States, the nation has not suffered from absolute scarcity of water resources. Despite the plentiful water resources, the United States has confronted several problems associated with the inequitable distribution of water resources across different regions, unhealthy drinking water quality, and disputes over drinking water management and policies (Contorno, Sarango, and Harlan, 2018; Gleick, 2012).

Water Pollution in the United States

There are sources of water – for example, rivers, streams, lakes, springs, and ground water - that offer water to public drinking water supplies and private wells. Since drinking water utilities must meet the requirements of the Safe Drinking Water Acts, protecting sources of water from contamination helps save treatment costs and may avoid or defer the need for complex treatment. Source water protection can also bring benefits to protecting water quality for wildlife and recreational use, and maintaining the availability and volume of water supplies (EPA, 2020) [6].

Even though there are many source water protection programs, a variety of activities (e.g., disposal of agricultural, urban, and industrial effluents into water bodies) can contaminate drinking water or diminish freshwater resources, which may cause chronic health effects and harm the ecosystem (EPA, 2004; White, 2003).

Water pollution is generally characterized as originating from *point-source pollution* and *nonpoint-source pollution*. Point-source pollution is caused by direct discharges into waterways through plant pipes, sewers, or other discernible outlets. Nonpoint-source pollution comes from land runoff, atmospheric deposition, drainage, or hydrogenic modification. That is, common types of nonpoint-source pollution include runoff of excess fertilizer and pesticides from agricultural

[6] There are examples of source water protection - riparian zone restoration to reduce runoff pollution; stream bank stabilization to reduce sedimentation; land protection/easements; developing emergency response plans; Educating industry, business, and citizens on pollution prevention and source water protection (EPA website: https://www.epa.gov/sourcewaterprotection/basic-information-about-source-water-protection, 2020)

land or residential areas, oil and toxic chemicals from urban runoff and energy production, and sediment from eroding streambanks (EPA, 2020).

Point Source of Water Pollution

Wastewater discharges from facilities may contain contaminants at levels that affect the quality of water. In order to prevent point-source of water pollution (i.e., direct discharge of contaminant into waterways from an identifiable or specific source), the Clean Water Act (CWA)[7] created the National Pollutant Discharge Elimination System (NPDES) in 1972. The NPDES requires facilities (e.g., wastewater treatment plants or factories) that discharge wastewater into waterways to obtain a permit and to comply with the restrictions and monitoring requirements regarding the amounts and types of contaminants that can be released (Allen, 2012).

Despite the regulation that was originally designed to help achieve a zero discharge goal[8], large quantities of pollutants, however, are discharged from the facilities into water bodies. For example, EPA (2004) reported that over 850 billion gallons of untreated sewage from domestic, industrial and commercial pollution, and sewage overflow are emitted into waterways annually. A recent study indicated that around 200 billion pounds of contaminants from state owned/concentrated publicly owned treatment work (POTWs) were also discharged into water bodies in 2014 (Lynch, Stretesky, and Long, 2017). POTWs receive various sources of mercury from hospitals and laboratories, and release considerable quantities of mercury pollution into harbor (Cerreno, Panero, and Boehme. 2002).

[7] The Clean Water Act (CWA) that was the amendment to the Federal Water Pollution Control Act of 1948 is the law protecting surface water quality in the United States. This act is to achieve the purpose of "restoring and maintaining the chemical, physical and biological integrity of the Nation's waters." (Allen, 2012: 112).
[8] The CWA indicates that "it is the national policy that a major research and demonstration effort be made to develop technology necessary to eliminate the discharge of pollutants into the navigable waters, wasters of the contiguous zone, and oceans." (33 U.S.C. §1251(a)).

Weak enforcement of CWA regulations and outdated limitation guideline for wastewater treatment facilities contribute to the failure to address the water quality problems (Allen, 2012). According to a report, more than half (around 57%) of 7,000 major permitted facilities across the nation did not keep their permit limits in 2005. Additionally, since minor facilities are inspected far less often than the major facilities, the violations of NPDES permit will be higher than that of major facilities (Andreen and Jones, 2008). Considering the EPA allows different permit standards across states, states have substantial variabilities in EPA-imposed water discharge limit (Sigman, 2002)[9]. Under the condition, it is possible that states make a trade-off between economic growth and environmental protection. Some states have lesser environmental regulations on the water discharge permit limit to attract industry for economic development and interests (Lynch, Stretesky, and Long, 2017).

Based on the analysis of green crime and justice within a political economic perspective, the massive quantities of direct discharge of pollutants into waterways are regarded as a green-state crime that leads to ecological disorganization (Schnaiberg, 1980). As mentioned before, green criminologists have proposed the definitions of green crime that expand beyond the legality to encompass activities that lead to ecological, nonhuman species or human health harms (Lynch, 1990; Lynch et al., 2017; Beirne and South, 2007; White, 2009; Brisman and South, 2013). The discharge into waterways from facilities (e.g., POTW emissions) are conceptualized as green crimes because the emissions are legally acceptable yet toxin pollutants that promotes the disruption of waterway ecosystems.

[9] Sigman (2002) states that there are variabilities for NPDES permits across states for five types of contaminations such as cadmium, copper, lead, mercury, and zinc. For cadmium, the weakest strict state limit was four times lower than the strongest strict limit; for copper, 38 times lower, for lead 312 times lower; for mercury, 750 times lower; and for zinc, 60 times lower.

Nonpoint Source of Water Pollution

Today nonpoint source pollution is the leading cause of water pollution problems. Nonpoint sources come from various activities so that the effects of these contaminants on waters may not be always fully evaluated (EPA, 2020). The primary origins of nonpoint source pollution are unclassified (i.e., unidentifiable) specific sources. For example, while we know that nonpoint source pollution comes from rain or snowfall, we cannot necessarily identify the source of the pollution in the rain or snowfall. Other nonpoint sources include agricultural runoff, roadway and sewer system runoff, pollution drift and deposition, and even hydrological modification (e.g., shifts in water tables).

Petroleum storage in underground tanks poses one of greatest threats to ground water quality. According to the EPA (2003), approximately one-third of all such storage facilities in the United States leak. One example is large-scale ecological additions caused by oil refiners and other chemical plants located in the stretch of the Mississippi River (Southern Louisiana) between New Orleans and Baton Rouge – that is called, "Cancer Alley" because of its concentration of petrochemical plants. One fourth of US petrochemical supply comes from Cancer Alley. This area is a designated enterprise zone that attracts the large number of oil refineries and petrochemical facilities with tax incentives and lax regulatory regime on business and economic development (Lynch et al., 2017). However, the high concentration of the chemical and oil refiners located in Cancer Alley poses not only threats to human health (e.g., cancer risk) but also contributes to the massive amount of wetland loss. Wetlands play a crucial role in revitalizing ecosystems, controlling water flow, and providing storm buffers (Darvis, 2010) [10].

[10] Wetlands work like a sponge, socking up and storing extra runoff water after a storm and then releasing it slowly into an aquifer or nearby stream or lake. Without wetlands to temporarily store storm waters, flooding would be more prevalent. Retrieved from https://www2.southeastern.edu/orgs/oilspill/wetlands.html.

According to the news article, *Propublica*[11], even though a large concentration of petrochemical plants has significant adverse effects on the residents and the ecosystem of Southern Louisiana, seven large new petrochemical plants have been approved for areas in the stretch of the Mississippi River since 2015. The number of industrial plants in Louisiana that reported their toxic discharge increased from 255 to 320 (25% increase) during the last three decades (1998 to 2017). The article indicates that: alternative sites are not attractive to the plants in terms of economic sense because Cancer Alley provides 'built-in advantages for manufacturers such as easy access to ship lane, plenty of cheap land for facilities and a lax regulation on them'. Thus, the economic advantages of them disregard the environmental impact like wetland loss.

Another case of ecological additions into a river water is related with abandoned mining operations. On Aug. 2010, the EPA accidentally discharged more than three million gallons of wastewater into the Animas River during investigation on leaks from an abandoned mine in Colorado. The spill of poisoned waste polluted over 100 miles of the river and damaged communities in Colorado, New Mexico, Utah and the Navajo Nation that relied on water from the river. To note, beyond this local disaster, there are around 500,000 abandoned mines scattered across the nation. According to the EPA, the drainage from these abandoned mines has affected 40% of the headwaters of Western watersheds. (Brisman et al., 2017; Editorial 2015). One of reason for the problem comes from the General Mining Law of 1872 that permits mining corporations to obtain federal land for $2.50 -$5.00 an acre, with no royalty, lax environmental regulations on the mining operation, and no cleanup afterward (Earthworks, 2019). The purpose of the law was to promote Western expansion. Currently, the Hardrock Mining and Reclamation Act of 2015 amends this 19th century law by imposing a federal minerals royalty, establishing fund

[11] See, https://www.propublica.org/article/welcome-to-cancer-alley-where-toxic-air-is-about-to-get-worse (published on Oct. 30. 2019)

for the cleanup of abandoned mines and requiring a review of areas that may be inappropriate for mining (Earthworks, 2019).

There are various types of contamination on water, and its source varies widely across geographic areas (Vanderwarker, 2012). As green criminologists within the political economic approach indicated, the capitalist system's continuous search for increases in production explains why environmental harm such as water pollution occurs. Massive ecological additions that result from dominant local industries (e.g., petrochemical companies in the stretch of the Mississippi River and western expansion of mining industry) threaten the ecosystem such as local water and cause human health complications. However, the burdens of contamination risk or proximity to contaminated sources are not equally distributed across different racial, ethnic, and class. Those who are socioeconomically disadvantaged and/or ethnic minorities are unequally exposed to contaminated water victims, and become green or environmental victims of these pollutants.

Challenges in Drinking Water Management

Water systems in the United States are well-developed that provide good-quality, reliable water supply and wastewater services to most of the American population. However, there are still serious and increasing challenges confronting the water resource systems across the nation, which, if left unaddressed, can pose threats to public health as well as economic vitality (Cooley, 2012: 168; EPA, 2016). For example, drinking water systems across the U.S. are under pressure from 1) aging infrastructure, 2) unregulated contaminants in the nation's tap water (e.g., perfluorianted compounds), 3) fragmented water industry and 4) lack of transparency and bureaucratic culture of institutions that undermine the sense of water security (Contorno, Sarango, and Harlan, 2018; Cooley, 2012; Siegel, 2019).

Aging Water Infrastructure

Drinking water infrastructure across the nation was largely built during three great construction booms: the 1890s, the 1920s, and the years after World War II. In each of these three periods, the water pipes were made of different materials and applied by different manufacturing skills to be connected into the water mains (Sigel, 2019). While the underground pipes at different times have different life expectancies, thousands of miles of the pipes from each of these three ears will come to the end of their expected life span, and all at about the same time (AWWA, 2001). To better understand this issue, the American Water Works Association (AWWA) conducted studies of 20 large and median drinking water utilities and found that the oldest pipes that were buried in the 1890s last for 120 years; the pipes from the 1920s, for 100 years; and the post-World War II pipes for around 75 years (AWWA, 2001: p.6).

Frequent repairs and modern technology can make their life expectancy longer but not forever. As the AWWA stated (2001), 'the dawn of the replacement era' has arrived. Recently, there are more than 240,000 water mains disruptions in annual in the United States. These water main breaks lose more than two trillion gallons of drinking water per year – it costs as much as $10.2 billion for the lost water. The rate of water main breaks is increasing, which means that more of water pipes need to be replaced (ASCE, 2017).

The replacement cost for the aged drinking water pipes could be more than $1 trillion over the next 25 years (AWWA, 2001; Siegel, 2019). By 2030, the average water fees could rise as much as three times to pay for the new infrastructure. On average, the replacement cost value of water mains including water treatment plants and pumps is about $10,000 per household. Water affordability is already a serious issue for some communities with limited local financial ability. In Detroit, for example, as water rates had been increasing annually for several reasons (i.e., insufficient local tax base, replacement cost of aged water infrastructure, and rising energy costs), water service was shut off to over 45,000 customers who could not afford rising water bills (Vanderwarker, 2012). The higher cost of water services is also an emerging concern in other cities such as Boston, due to more investment in replacement of the aged pipes and old-style systems (Contorno, Sarango, and Harlan, 2018).

However, the cost for replacement of the aged water infrastructure could be possibly higher for the customers served by smaller water systems and those in communities with a declining population such as poor and rural areas, due to the disadvantage of its small scale, which produces a financial burden on fewer customers (AWWA, 2001). The water problems caused by the aged water infrastructure disproportionately affects sparsely populated, low-income communities across the United States, because water infrastructure is local and thus vulnerable to demographic change (AWWA, 2001; Contorno, Sarango, and Harlan, 2018). As the population grows, financial investment on the water infrastructure is expanded, but as the population declines, the financial sources of water pipe repair and replacement also shrink, resulting in financial burdens on the remaining residents (AWWA, 2001).

For example, in 2019 *the New Public* had a report on rural America's drinking water crisis (Jones and Atkin 2018). The report presented one story from Martin County, Kentucky where more than a thousand families in the community suffered from contaminated drinking water with excessive volume of disinfectant chemicals. The main causes of this problem came from aged and deteriorating water supplies with limited financial capacity. According to the report, millions of rural Americans living from Appalachian in Kentucky to the Texas borderlands are exposed to unclean and often illegitimate levels of chemicals in drinking water from aging water pipes. Big cities' water issues like Flint, Michigan, attracted the most attention on the water issues, because the failing water systems affect great numbers of residents at once. However, in reality, rural and small communities suffer from most of health-based violations of drinking water regulations across the nation due to aged water-treatment facilities that cannot adequately filter out the chemicals such as nitrates and trihalomethanes. That is, many of rural America's drinking water problems can be attributed to aged, broken, untrustworthy water infrastructure such as leaky pipes, clunky filtration systems, and back-up sewers. Regarding rural America's drinking water crisis, *the New Public* (Jones and Atkin, 2018)[12] said,

> "*As the economic gap separating rural America from its urban and suburban counterparts continues to grow, this basic inequality is set to become more entrenched- and possibly more dangerous, as sickness seeps into rural America*".

Fixing a broken water main and replacing the aged water pipes are expensive and inconvenient. However, if the replacement of the aged infrastructure is deferred, it will bring more cost for emergency repairs and more inconvenience and the potential for poor drinking water quality (Siegel, 2019). To note, rural and low-income communities are disproportionately vulnerable to the water-related problems that can result from aged water infrastructure.

Drinking Water Quality

Safe and healthy drinking water is considered as a basic human right. Over the past century, the United States has improved the overall quality of drinking water as well as reduced the types and amounts of contaminants released into water resources such as rivers and lakes.

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[12] See the *New Republic,* "Rural American's Drinking-Water Crisis" retrieved from https://newrepublic.com/article/147011/rural-americas-drinking-water-crisis.

General access to the safety of drinking water has been achieved through massive investment in water related infrastructure, municipal water purification, and wastewater systems. The federal government has also contributed to safe drinking water through implementing water quality laws (e.g., the Clean Water Act, the Safety Drinking Water Act) that legally enforce water-related agencies to identify contaminants in water and to protect Americans from the toxic substances.

Through these efforts, Americans receive good quality of drinking water. However, not all Americans gain access to or afford healthy drinking. Increased detection of synthetic chemicals in treated drinking water - such as insecticides, pharmaceuticals, fragrance mixtures, and flame retardants - exacerbates uncertainty and concern about drinking water quality (Stackelberg et al., 2004).

According to GAO, 700 chemicals are annually added into the environment and over 800,000 chemicals are now registered for use in the United States (GAO, 2009). It is possible that some of these chemicals get into drinking water during treatment and distribution process (Ternes et al., 2002; Allen, 2012). Community water systems typically include 1) a treatment facility that stores and uses chemicals to eliminate biological contaminants and 2) a distribution system that consists of water towers, piping grids, pumps, and other components provides treated water to customers. Diverse mixes of synthetic chemicals are often detected in drinking water through leaks during the treatment and distribution processes. Synthetic chemicals in drinking water are also identified because conventional approaches (i.e., coagulation, sedimentation, purifications, and chemical sterilization) of water treatment are often ineffective at eliminating the chemicals (Ternes et al., 2002; Allen, 2012).

To protect Americans from the health hazards in drinking water, EPA has established National Primary Drinking Water Regulations for over 90 chemical compounds under the Safe

Drinking Water Act (EPA, 2009: 15). However, there are many unregulated contaminants identified in drinking water. According to the report by The Environmental Working Group (EWG, 2019a), for example, collected data from about 50,000 community drinking water utilities across 50 states by annual tests found more than 160 unregulated contaminants in drinking water across the United States. The study found that some amounts of contaminants found in drinking water affect human health – particularly harm to the brain and nervous system, fertility problems and/or hormone functioning disruption, and changes in the growth and development of the fetus (EWG, 2019a).

The EWG's report (2019a) also stated that legal limits for the level of contaminants in drinking water are often higher than health standards recommended by scientific researchers. That is, while many of contaminants detected by community water utilities' test are found at levels that may be legally acceptable under the Safe Drinking Water Act, scientific studies have found these are well beyond levels to affect human health (Hayes et al., 2002; Langlois et al., 2010; Raham, Yanful, and Jasim, 2009).

Furthermore, there is often more than one chemical identified in contaminated drinking water (Allen, 2012). According to studies, mixtures of chemicals can pose health risks that a single chemical does not (Jaeger, Carlson, and Porter, 1999; Kortenkamp, 2007). For example, the mixture of pesticides and nitrates is likely to cause biological change in human health, while individual nitrates would rarely lead to such adverse outcomes (Jaeger, Carlson, and Porter, 1999).

Although unregulated contaminants, inadequacy of the safe standards, and mixture of chemicals may cause adverse health effects, the EPA takes slow steps toward the primary goal under the Safe Drinking Water Act - 1) identification of contaminants in drinking water supplies at concentrations that possibly threaten human health; and 2) determination regarding appropriate actions to protect Americans from health risks incurred by contaminated drinking water (Allen, 2012; Sigel, 2019; EWG, 2019a). Since the 1996 Amendments to the Safe Drinking Water Act, the EPA is required to issue a new list of no more than 30 unregulated contaminants to be monitored by public water systems every five years – known as the Unregulated Contaminant Monitoring Rule (EPA, 2016). There are three separate processes for the EPA to decide whether a new contaminant is regulated under the law: first, the chemical compound has proven to cause adverse health effects; second, the contaminant is frequently found at levels in drinking water; and third, the EPA must prove that there is a "meaningful opportunity" to reduce the public health risk through regulation.

Obviously, the multi-step process for the EPA requires many years to complete. Specifically, "the EPA evaluate the feasibility of removing the containment, the affordability of containment removal technologies for small water systems, and the costs and benefits of the regulation when proposing and promulgating a drinking water standard (EPA, 2016: 15)". To date, however, the EPA has not added any new contaminants to the regulated list for drinking water through the process, even though there are large number of new chemicals introduced every year (EPA, 2016).

One reason why the result of this process are slow stems from the lack of clarity in the 1996 Amendments to the Safe Drinking Water Act. Under such legal condition, decision about regulating new chemicals for the safety of drinking water is subjective. Specifically, the decision of whether to regulate a hazard component is based how the potential for it must cause public health risks, how frequently the contaminant must be present in drinking water, and how many medical problems (e.g., birth defects, hormonal disruptions) must present to be "meaningful"

(Allen, 2012; Siegel, 2019). Due to the ambiguity of the law, the determination to regulate or not-and at what level-depends on political pressure (Siegel, 2019). In the case of perchlorate, for example, the EPA announced that it does not need to regulate perchlorate under the Bush Administration in 2008. When the Obama Administration came into office in 2009, on February 11, 2011, the EPA announced that perchlorate posed a threat to the public health as many as 16 million Americans, and that it should be regulated under the contaminant requirement of the Safe Drinking Water Act. However, the regulation of perchlorate was not completed during the Obama Administration because of different views by the U.S. military, NASA, and the Department of Energy that are the largest users for perchlorate for several decades (Siegel, 2019). Under the Trump Administration, in October 2019, the U.S. District Court extended the EPA's deadline for final perchlorate regulation from December, 2019 until June, 2020 (Association of State Drinking Water Admonitors[13], 2019).

The other reason for the delay comes from non-health-based factors, a cost-benefit analysis, in the case of drinking water standards (Allen, 2012). When deciding whether to regulate a contaminant, a standard level or safe level of contamination in drinking water must be determined. This process requires a cost-benefit analysis to decide whether the benefits exceed the costs: it considers whether the cost of water treatment technologies that can remove the contaminant from the water is worth protecting human health (Allen, 2012; See EPA, 2016). The setting of safe drinking water standards often depends on economic comprises in order to keep treatment costs down (EWG, 2019a). For the water utilities as well as municipalities, when the legally allowed amount of a contaminant in drinking water is set to be lower, the reduction standard requires advanced treatment technologies, which impose additional economic burden on

[13]See, https://www.asdwa.org/2019/10/04/court-extends-epas-deadline-for-final-perchlorate-regulation/

their budget. With the financial stakes linked to the decision, the EPA delay or deny additional regulation or does not set a strict standard for the safe contaminant threshold (Allen, 2012; Siegel, 2019; EWG, 2019a).

However, the cost-benefit analysis of the drinking water regulation cannot comprehensively evaluate all the things. Specifically, as Akerman stated (2007: 5), while it can precisely estimate the cost of water contamination reduction, it is much more difficult to quantify the benefits of the treatment - especially, non-monetary value such as the length and quality of human life. The EPA's estimate can be a substantial underestimate of the value that most populations would emphasize on preventing illness or disease caused by being continuously exposed to toxin in the water (Akerman, 2007).

In addition, as the EWG report mentioned (2019a), under the cost-benefit analysis, the EPA has not effectively fulfilled the purpose of the Safe Drinking Water Act, which states that drinking water regulation should consider:

> "*the effects of the contaminant on the general population and on groups within the general population such as infants, children, pregnant women, the elderly, individuals with a history of serious illness, or other subpopulations that are identified as likely to be at greater risk of adverse health effects due to exposure to contaminant in drinking water than the general population*"[14].

Based on the law, water treatment regulation is required to consider the vulnerable populations, because they are more likely to suffer from illness and disease by lower levels of contaminants in drinking water than the general population (Allen, 2012). A recent EWG's study (2019b) also indicates that amounts of chemicals that were previously regulated to be

[14] Title 42. U.S. Code § 300g-1(b)(3)(C)(i)(V). National Drinking Water Regulations.

acceptable for drinking water (i.e., the legally acceptable amounts of nitrate[15], 10 ppm), can enhance the risk of cancer and may damage fetus growth and development (e.g., cause low birth weight, premature birth and neural tube defects). EWG suggests that the current legal limit of the nitrate level is too high to protect against cancer and harms to postmenopausal women. Based on their meta-analysis, the nitrate amount that is not associated with cancers and pregnancy problems would be 0.14 ppm – 70 times lower than the EPA's current legal limit (EWG, 2019b:5). Given the result of study indicating the inadequacy of the legally acceptable level of the chemical, in 2017, the EPA's Integrated Risk Information System program, IRIS, began to review the effect of nitrate in drinking water on human health. However, the assessment for nitrate was suspended because it was not identified as a priority for fiscal year 2019 (IRIS Program Outlook, 2019).

Fragmented Water System

Fragmented system of the U.S. water industry is another challenge. There are over 51,000 community water systems in the U.S serving about 300 million American residents (EPA, 2015). The U.S. has 3,141 counties, average sixteen drinking water utilities work per county. Around 92% of the U.S community water systems serve fewer than 10,000 customers. In case of California, there are around 7,500 water utilities; in Los Angeles County alone, there are about 200 water utilities (Orange County Water District, 2014: 9). As is true for the abundance of the

[15] Nitrate is a chemical in commercial fertilizers and manure that can run off of farm fields into sources of drinking water. Nitrate, primarily from agricultural runoff, contaminates the public water supplies of thousands of communities nationwide, with the problem most severe in farm country. The EPA's legal limit for nitrate in drinking water is 10 ppm. It was set in 1962 to protect against so-called blue baby syndrome (EWG, 2019:4).

U.S. water systems, many of California's water systems provide drinking water to very small numbers of customers (Siegel, 2019).

When comparing the water systems with other countries – for example, the U.K has fewer than 30 – the U.S water systems are also relatively fragmented. The bigger areas and relatively low population density of the U.S. possibly explain the many water systems. However, as a study indicated (Levin et al., 2002), "the U.S. water industry has remained quite decentralized even while local public services such as schools and police have consolidated substantially (p.44)." When even comparing other public service systems in the U.S. – there are approximately 3,000 natural gas utilities and 3,888 electric utilities in the U.S – the more than 51,000 water systems are too decentralized to be managed and regulated efficiently.

It should be noted that the severe fragmentation of the U.S water industry is caused by, in part, the decades-long trend of urban and suburban development (Siegel, 2019). According to Siegel (2019),

> *"… from the end of World War II and the postwar economic boom until the early 1970s, real estate developers used cheaper land and lower taxes to build new communities near, but not in, urban centers. For reasons of identity, cost savings, and control, the developers and the communities they created often preferred to have a water utility of their own, rather than tapping into a large nearby system."* (p. 150).

The urban and suburban development plan for several decades in the U.S. has resulted in fragmented water system (Siegel, 2019). As shown on the table "U.S. Communities Water Systems" below, eighty-two percent of water systems (over 42,000) are "small" [16] and "very small" [17] systems serving fewer 3,300 people (EPA, 2016). In contrast, only seven percent of the

[16] The EPA designates drinking water systems serving fewer than 3,300 people as small systems.
[17] The EPA designates drinking water systems serving less than 500 people as very small systems.

community water systems provide drinking water for over 10,000 populations and 426 water systems (0.8%) serve populations of 100,000 or more.

With more than 51,000 community water systems, there is much duplication of effort that impedes operational efficiencies such as billing, customer services, and water testing (Duffy, 2013; Levin et al., 2002). Most of all, many of these systems, especially small systems, find it difficult to deliver safe drinking water (Siegel, 2019). With larger customer base, the water systems can adjust to regulatory changes of the Safe Drinking Water Acts; have specialized utility operators; and pay for new equipment and upgraded technology. In contrast, monitoring and water testing are already a burden on small systems (EPA, 2016). The cost of installing new treatment systems is sometimes unaffordable due to diseconomies of scale. It is also difficult for many of small systems to hire full-time experts to work for their operations (Levin et al., 2002). Unlike larger systems, many small water systems, thus, face difficulties (e.g., finical incapacity, limited technical and managerial capacities) in meeting the Safe Drinking Water Acts and in ensuring the quality of their water supplies (Teimann, 2006: p. 15).

Table 1. U.S Community Water System (2015).

System Service Population	Very Small <=500	Small 501–3,300	Medium 3,301–10,000	Large 10,001–100,000	Very Large >100,000	Total
Number of Systems	28,595	13,727	4,936	3,851	426	51,535
% Total Systems	55	27	10	7	0.8	100
Service Population	4,738,080	19,688,745	28,758,366	109,769,304	137,250,793	300,205,288
% Total Population	1.6	6.6	10	37	45.7	100
People/ System	166	1,434	5,826	28,504	322,185	5,825

Source: EPA 2015, as cited in 2015 State of the Water Industry, AWWA.

For that reason, the EPA has provided exemptions[18] from monitoring and water testing requirement and waives for compliance of the regulations targeted at small systems. Under the exemption rule, small systems serving fewer than 3,301 customers may have a waiver that allows one or more additional 2-year extension periods to achieve compliance if they can prove that they do not have the financial capacity to meet water regulations. As Siegel (2019) stated, the monitoring exemption, while it can alleviate the burden small systems face, may bring a risk that "the presence of a contaminant is not detected until after harm has occurred (p. 154)."

Small systems generally have higher rates of health-based violations compared to larger one. According to the report of Natural Resources Defense Council (NRDC, 2019), more than 80% of health-based violations in the country were committed by small systems. In addition, very small systems – those have less than 500 customers – had 50% of health-based violations, even though they serve only 4.7milion customers.

According to the EPA's drinking water action plan report, it also highlights that "economically disadvantaged communities and small drinking water systems are facing disproportionate risks as a result of underinvestment in drinking water infrastructure and limited technical, financial, and/or managerial capacity." (EPA, 2016: p. iii). Particularly, small water utilities serving poor communities that are already exacerbated by aging infrastructure confront additional challenges: they face restricted access to loans and grants due to lack of technical capability of reporting requirements and weak tax bases (Allaire, Wu and Lall, 2017; Vanderwarker, 2012). Taken together, these challenges represent environmental justice issues (EPA, 2016).

[1818] According to Variance and Exemptions Rule, "exemptions allow eligible systems additional time to build capacity in order to achieve and maintain regulatory compliance with newly promogulated National Primary Drinking Water Regulation (NPDWR), while continuing to provide acceptable levels of public health protection." (EPA, 2004).

As mentioned earlier, more attention has given to urban drinking water issues like the Flint water crisis because the large faulty system in an urban area can affect a great number of residents at once (EWG, 2019a). However, most health-based violations of safe drinking water acts are committed by small utilities. Obviously, consolidation strategies serve as one of ways to solve drinking water related problems (Duffy, 2013; Fedinick, Taylor, and Roberts, 2019; Siegel, 2019). Consolidation of smaller water systems would have access to improvement and capital in service and integrated water systems would provide good quality water by increasing the base of customers (Siegel, 2019).

Exclusive Institutions

The Safe Drinking Water Act was originally established in 1974 and amended in 1986 and 1996 by recognizing "source water protection, operator training, funding for water system improvements, and public information as important components of safe drinking water." (EPA, 2004). Especially, the Safe Drinking Water Act has emphasized the importance of public information and consultation – it recognizes that "everyone has a right to know what is in their drinking water, where it comes from, how it treated, and how to help protect it." (EPA, 2004). As the EPA's action plan (2016) also recognized, transparency and inclusiveness in decision-making process on drinking water depend on how better the public understands their drinking water about drinking water quality, water system operations, and the sustainable resources of safe water. Under the role and legal responsibility, the EPA provides public information materials: for example, annual summary reports of water system compliance with safety regulations of drinking water must be conducted and distributed to the public. All community water systems are also required to prepare and provide annual 'consumer confidence reports' about source and quality of drinking water they provide, including information detected chemicals and possible health effects (EPA, 2004).

Water and environmental agencies try not only to distribute public information regarding drinking water, but also to promise public participation during decision-making processes. The EPA proposes public meetings, cooperating with states, water systems, and environmental and civic organizations to enhance public engagement in the environmental decision-making process. For example, the public has a chance to be involved in developing source water assessment programs, planning in drinking water state revolving fund, and operator certification programs (EPA, 2004)[19].

Although water and environmental agencies have good intentions in water management and regulation with the democratic norm embedded in the environmental law – particularly public participation provisions (Cole and Foster, 2001), there are ongoing problems with the way they currently work – "rigidity and bureaucratic culture" that leads to exclusiveness in decision-making process (Contorno, Sarango and Harlan, 2018; Siegel, 2019). As the EPA's action plan (2016) also proposed,

> *"... there is a need to strengthen communication to the public, in an accessible and understandable format, of more timely information on drinking water quality and impacts*

[19] According to the EPA's report, the Safe Drinking Water Act that was amended in 1996 highlights public participation to ensure safe drinking water. Among roles and responsibilities under the law, 1) source water assessment programs, 2) drinking water state revolving fund, and 3) operator certification is cooperated with the public (EPA, 2004).

- Source water assessment programs is to assess sources of drinking water from rivers, lakes, and ground water wells and to identify potential sources of contamination and to determine how susceptible the sources are to these threats.
- Drinking water state revolving fund helps water systems make infrastructure or management improvements or to help systems assess and protect sources water.
- Operator certification programs are EPA-approved guidelines to ensure safety of the operators of community and non-community water systems.

to public health. What's needed is not just more information, but also better communication of the context and meaning of that information." (p. 18).

That is, water manager and government agencies need to discard their bureaucratic culture and to build just and inclusive governance that provides equal access to all the residents with meaningful involvement in the decision-making processes (Contorno, Sarango and Harlan, 2018).

For example, according to interviews of 45 leaders of community organizations (e.g. local nonprofit groups, watershed association) conducted by the Urban Water Innovation Network (UWIN), while local water management agencies have good relations with community groups, some of these agencies have failed to include vulnerable populations (e.g. minorities, low-income and non-English speaking populations) in important decision-making processes (Contorno, Sarango and Harlan, 2018). Regardless of what the exclusion intends or not, the marginalized populations are vulnerable to more powerful interests in environmental decision-making processes. One interview of a community leader was cited below from the UWIN's report (2018):

> *"… We've seen a lot of state agencies and planning agencies who, they'll have a planning meeting at 2pm in downtown Boston, and they expect people to come, and that's just never going to work – because low-income people of color are already overburdened by their economic status, and they need to keep their jobs, they need to bring food to the table, and if you want to engage them you need to meet them where they're at…"* (Contorno, Sarango and Harlan, 2018: p. 14).

While the ideal function of participatory promise in the decision-making process includes a wide range of interests, the identities of the participants, in real world, would have more influence on the outcome of the environmental decision (Cole and Foster, 2001). In the lack of inclusiveness, the decision makers are captured by the voice from wealthier groups with political powers (see Bullard, 1990).

There is the exemplary case occurred in Warren County in 1980. North Carolina state representatives decided that Warren County would be a site for landfill of contaminated soil, even though the county was not geographically central for this purpose (Exchange Project 2006). Given the demographic composition of Warren County as one of the poorest and most predominated African American counties in the state of North Carolina, the implications of environmental injustice cannot be ignored. Since the composition of the soil in Warren County was not appropriate for containing the waste and the residents relied on the surface water, there was significant concern for contaminated drinking water affected by the landfill (Geiser and Waneck, 1983). Even though civil right leaders and environmentalists across the county reacted against the decision, the governor of North Carolina ordered the construction efforts of the landfill at Warren County. Contamination continued for approximately twenty years after the construction, the landfill was finally cleaned up in 2003 – the cost was around $18 million (Lynch et al., 2017).

The facts of the Flint water crisis also highlight the exclusiveness in decision-making processes of water management. Given the demographic composition of the Flint resident, who are majority Black or African American and among the poorest of urban areas in the United States, they were not given equal access to, and meaningful engagement in, the environmental decision-making process. According to the Flint Water Advisory Task Force's (FWATF) report (2016), *"the Flint water crisis occurred when state-appointed emergency managers replaced local representative decision-making in Flint, removing the checks and balances and public accountability that come with public decision-making."* (p. 1).

After the switch to Flint River water from Detroit's water system in response to the city's financial difficulty, under state-appointed emergency management, water quality problems[20] were encountered (Mona Hanna-Attisha et al., 2016). Various state-appointed emergency managers, not locally elected officials, made numerous decisions, such as decision on use of the Flint River as a water source for the Flint residents and approval of a sole-contract for the treatment engineering firm (FWATF, 2016: p.40).

When the Flint residents voiced concerns about water quality and requested a return to the Detroit's system, the state-appointed emergency managers were dismissive of residents' expressed concerns in part because the water problems were manageable. The Michigan Governor's office also continued to depend on incorrect information and run the risk of over-reliance on a few staff in one or two departments in the Michigan Department of Environmental Quality (MDEQ) and Michigan Department of Health and Human Services (MDHHS), even though there were growing evidence from outside experts concerning the harms being generated (FWATF, 2016). The Governor's office changed course when MDEQ and MDHHS admitted the problem of lead in drinking water – the aging Flint water distribution system has a high percentage of lead pipes and lead plumbing, with lead service lines (Mona Hanna-Attisha et al., 2016)[21].

[20] Residents raised concerns about water color, taste, and order, and various health complaints such as skin rashes. Bacteria, including Escherichia coil, were detected in the distribution system, resulting in Safe Drinking Water Act violations. Additional disinfection to control bacteria spurred formation of disinfection byproducts including total trihalomethanes, resulting in Safe Drinking Water Act violations for trihalomethane levels (Mona Hanna-Attisha et al., 2016: 283).

[21] A study found that the rate of children in Flint with elevated levels of lead in their blood doubled as a result of the contaminated drinking water (Mona Hanna-Attisha et al., 2016)

At the same time, while the Flint residents' health and safety were threatened, the response to the crisis was to provide portable water to the residents as a 'temporary fix' (Brisman et al., 2018) [22]. The importation of water to the city most often came in the form of bottled water[23]. The flow of capital circulates between the sate-corporate interest that led Flint to provide bottled water and the state-corporate interests that engage in the further degradation of water and the commodification of water company (Brisman et al., 2018). Specifically, in 2001 and 2002, Michigan's state government granted bottling company, Nestle, a permit to pump up to 400 gallons of water per minute out of Lake Michigan for free – taking only small permitting fee to the State and private landowner. As the Flint water crisis has left residents dependent on bottled water, while the residents pay some of the highest water bills in the United States, Nestle was not required to pay for the extracted water. The company received $13 million in tax breaks and financial incentives from the state to locate the plant in Michigan (Ecowatch, 2016).

Summary

The chapter 2 described several challenges in drinking water management in the United States. Even though the United States water systems provide reliable water supply and wastewater services to the American populations, contaminants that pose a threat to public health are routinely found in the drinking water from cities to rural areas (Siegel, 2019). No one who is engaged in the drinking water management intentionally offers poor quality water. However,

[22] The importation of bottled water into Flint is just a temporary alternative that adds ecological harms and risk to Flint residents because of the inevitable difficulties of dealing with the massive increase in plastic waste owed to the influx of plastic water bottles Brisman et al., 2018: 192).

[23] Bottled water is sold at reduced or under-monitored quality at inflated rates. (Brisman and South, 2013, Siegel, 2019). Unlike tap water, bottled water is under the supervision of the Food and Drug Administration (FDA). While the bottled water industry earns $18.5 billion in annual sales in the U.S., the FDA has no institutional structure of oversight on bottled water. Bottling companies, as a result, are regulated with a self-policing honor system.

some of regulatory agencies, several operators in drinking water utilities, and a part of local governors and political leaders have carelessly or irresponsibly responded to drinking water contaminants (Siegel, 2019).

Based on the previous studies and reports, the nation's drinking water systems have faced several problems associated with 1) aging water infrastructure, 2) the slow approach to unregulated chemicals in drinking water, 3) fragmented community water systems, and 4) rigidity and bureaucratic culture of water manager and government agencies.

As the report of AWWA (2001) indicated, fixing and replacing broken water mains and the aged water pipes costs more than $1 trillion over the next 25 years. Especially, rural and low-income communities are suffering from poor quality water due to aging water infrastructure that cannot properly filter out the chemicals.

In addition, the EPA's slow steps in regulation of potential new contaminants in drinking water contribute to poor quality water. Even though there are more than 120,000 chemical compounds and products that may threaten drinking water, the EPA has only selected about ninety of them as hazardous enough to be regulated and failed to add any new chemicals – that are known of being dangerous with scientific evidence (e.g., the case of perchlorate) – to the EPA's regulated chemical contaminant list for drinking water since the passage of 1996 Amendments to the Safe Drinking Water Act (Seigel, 2019). Because of lack of clarity in the 1996 Amendments and the cost-benefit analysis in setting protective standards, the decision of whether to regulate a new chemical depends on political pressure that causes the delay of regulation.

The large number of the U.S. water systems (more than 51,000) is another impediment to operational efficiencies and delivery of safe drinking water. Most of the nation's water systems (around 80%) are small and very small utilities serving fewer 3,300 customers. These small systems are likely to face many difficulties (e.g., financial incapacity for the adoption of new technologies, replacement of broken pipes, and retention of full-time experts) in meeting the Safe Drinking Water Acts (Teimann, 2006).

For good quality drinking water, water and environmental agencies also need to create inclusive and just governance that includes a wide range of interests. As the Flint water crisis has demonstrated, the exclusiveness in decision-making process of water management may not only lose their transparency, but also threaten the drinking water safety (FWATF, 2016). It is important for water and environmental agencies to strengthen communication to the public in an accessible format and enhance public participation in the decision-making process (EPA, 2016).

The chapter 2 focuses on the problems related the United States' water systems. Next chapter provides the knowledge of drinking water injustice across the nation. Within the green criminology, informed by the political-economic framework, it explores causes of drinking water pollution. And then, unequal distribution of the risk of the contaminated drinking water across the United States is mentioned with the environmental justice perspective. Based on the political-economic framework, it states that the causes of drinking water injustice are related with three dimensions: 1) racialized urban planning, 2) profit-oriented water policies, and 3) exclusiveness of decision-making process in the water governance (Contorno, Sarango and Harlan, 2018).

CHAPTER THREE:

DRINKING WATER INJUSTICE

Green Criminology: Overview

Since the initial idea of a green criminology emerged – first suggested by Lynch (1990: 4) as "the study of crimes committed against humanity through environmental destruction" – there are varying definitions of green criminology and green crimes. Beirne and South (2007: p. xiii), for example, proposed that "a green crime involves the study of those 1) harms against humanity, 2) against the environment (including space) and 3) against non-human animals committed by both the powerful institutions (e.g., governments, transnational corporations, military apparatuses) and also by ordinary people." Based on the prior definitions of green criminology and green crimes, Lynch and Stretesky (2011: p. 2) proposed that "green criminology provides space within criminology to examine the nexus between environmental problems, the definition of harms against nature as crimes, the need to reconsider criminal justice practices and policy in relationship to the environmental harms they produce, the variety of victims environmental offenses create (for human and non-human species, as well as ecological segments such as wetlands, forest, air, and land, etc.) and the effect of environmental toxins on ecological systems and species' health and behavior."

This diversity of views about green criminology can embrace a wide range of studies and encompass different interpretation to the environmental crime – from the traditional perspective to the broader conceptualization of harm. Specifically, while many studies within green criminology pay attention to environmental harms that are legally defined as crimes – harms against nature (e.g., illegal dumping of waste water into a stream), and harms against nonhuman animals (e.g., wildlife trafficking, smuggling and poaching), other studies focus on human actions that harm ecosystems, yet are not typically criminal to the extent that they are not violations of criminal law – for example, ecological withdrawals and destruction driven by capitalist expansion (Stretesky, Long and Lynch, 2013). The latter working within green criminology that focuses on social harms regardless of legality (see Hillyard and Toms, 2007) contributes to various and serious environmental harms the criminal law does not address – these issues have been also overlooked within orthodox criminology (Lynch et al., 2017; McClanahan, 2014; White, 2009).

Political-Economic Perspective

Today, while green criminology has developed considerably and "provided the broad filed of criminology with a way to confront harms (whether defined as 'crime' or not) that affect the planet as a whole, particular natural environments and species other than humans" (Beirne et al., 2018: 295), it faces a problem – a lack of agreed upon definitions about what constitutes green criminology (Lynch et al., 2017; Eman, Mesko, and Fields, 2007). Moreover, green criminology has no single theory as such; it has many different substantive and theoretical dimensions that have been described as a green "perspective" (White, 2010: p. 411). That is to say, inadequate terminology and absence of commonly accepted definition has impeded efforts to develop a theoretical framework of green criminology as a new division of criminology (Lynch and Stretesky, 2011).

These theoretical problems facing green criminology have been addressed by employing a political-economic approach to green crimes and harms (Stretesky, Long and Lynch, 2013; Lynch et al., 2013) consistent with Lynch's (1990) original definition of green criminology. Such an approach focuses on human activities that result in green crimes within the theoretical framework on how society's economic organization impacts society's social structure, including the type and amount of ecological destruction, the nature of environmental regulations, and the social responses to green crime (Lynch et al., 2017). Thus, green criminology, informed by the political-economic perspective, attempts to examine green crimes – or "ecological destruction and ecological disorganization"[24] – caused by the overproduction/overconsumption focus of capitalism that dominates political-economic organization worldwide (Lynch et al., 2013; Lynch et al., 2017: p. 10-11; Lynch et al., 2019).

For example, green criminologists draw upon Alan Schnaiberg's Treadmill of Production (ToP) theory to provide the theoretical framework to understand green crime (Stretesky, Long, and Lynch, 2013; Lynch et al., 2013; Lynch et al., 2017). Schnaiberg (1980) introduced the ToP perspective that focuses on the contradiction between capitalism and nature. According to the ToP, capitalism must continually expand because the organizational feature of capitalism is designed for economic growth and accumulation of wealth, disregarding all adverse environmental side effects. Schnaiberg (1980) stated that capitalism results in ecological disorganization by consuming and polluting nature. The ecological system may be exploited – by the extraction and exploitation of natural resources, deforestation, mining – to produce commodities (Lynch et al., 2017).

[24] According to Lynch et al. (2017: 10), "ecological disorganization is a measure, determined on the basis of scientific studies, of the disruption of ecosystems and ecosystem functions by human activity. Disruptions may be direct, as when the extraction of raw materials (e.g., mining, drilling, timber harvests) pollutes or destroys environments. Or they may be indirect, as when clear-cutting a forest eventually causes a decline in species living there that play important roles in maintaining a healthy ecosystem."

As Schnaiberg (1980) stated, there are two main ways the capitalist system of expanding resource consumption causes ecological disorganization: 1) “ecological withdrawals” and 2) “ecological additions”. In general, ecological withdrawals refer to a mechanism for expanding the extraction of natural resources from the environment to increase the production of commodities (Lynch et al., 2017). The increase in withdrawals and production causes ecological disorganization because it shrinks the volume of nature’s production as well as limit the ability of the ecosystem to provide the conditions for life. Ecological additions consist of toxin byproducts that the capital system of production adds to the nature (Lynch et al., 2013; Stretesky, Long, and Lynch, 2013). Thus, the capitalist system of production – when human action interferes with nature’s production systems to make commodities – creates harms against nature (Lynch et al., 2013; Foster, Clark, and York, 2010). Within the core perspective of the “treadmill” of crime, various examples of harmful acts have been examined such as greenhouse gas emissions, chemical pollution, mining, deforestation, and factory farming (Stretesky, Long, and Lynch, 2013).

Environmental Justice Perspective

Green criminology, informed by the political-economic perspective, provides criminologists with interdisciplinary theoretical framework that adopt broad conceptualization of harm to explore the etiology of green crimes. The Schnaiberg’s ToP approach is especially suitable for green criminological applications because it provides a theoretical lens for explaining how and why green crimes occur (Lynch et al., 2017; Stretesky, Long, and Lynch, 2013). The political-economic approach to green criminological research also emphasizes a role of capitalism and power relations in the production of environmental harm. According to Stretesky, Long, and Lynch (2013), harmful activities for the purpose of increasing or supporting production result in social disorganization, which is usually exploited by dominant economic classes, stimulated and maintained by the state, and experienced badly by racial minorities and the poor.

The exposure to environmental problems is not equally distributed, but disproportionately affects different racial, class, and ethnic groups – the broad term for research that finds patterns of "differential victimization" relating to environmental harms is *environmental justice* (Lynch et al., 2017; White, 2010). Research has found that communities with higher percentage minority residents and high rates of poverty are associated with chemical accidents, pollution, hazardous waste sites, and other environmental hazards (Bullard 1990; Pastor, Sadd, and Hipp, 2001; Stretesky and Lynch, 1999; 2002; Sampson and Winter, 2016).

Nowadays, green criminologists focus on the association between the disproportionate exposure to environmental toxins that can affect criminal behavior, especially violence (Barrett, 2013; Lynch and Stretesky, 2014). Proximity to some chemicals, such as lead, increases the likelihood of brain impairment, generating behavioral disorders (e.g., learning disability, aggression, and impulsivity), leading to antisocial behavior, violence and crime (Barrett, 2013; Lynch et al., 2006). Consequently, environmental toxins possibly increase crime rates in low-income and minority communities through disproportionately high concentrations of chemicals that alter behaviors. In addition, green criminologists have explored the unequal enforcement of environmental laws. They examine how social demographics affect the distribution of environmental enforcement such as inspections and punishments (Lynch et al., 2017). For example, criminal monetary penalties against corporations located in poor and minority communities are smaller compared to white and affluent communities (Lavelle and Coyle, 1992; Lynch, Stretesky, and Burns, 2004a, 2004b). Konisky (2009) also found that chemical facilities situated in poor communities have few inspections of environmental enforcement staff so that such violations are less likely to be reported in low-income areas.

While scholars have described green criminology in diverse ways, scientifically measurable environmental harm, social equity, and power relations are commonly emphasized within green criminology (Lynch et al., 2017). Based on the political-economic framework of green criminology, contaminated drinking water problems deserve attention because it can pose an acute threat to the public health as environmental harm that is socially and historically constructed. An environmental justice perspective can be employed to help explain why the burden of the risk of drinking water pollution is not equally distributed.

The next section focuses on drinking water pollution with the political-economic perspective and explores the differential effects of the contaminated drinking water suffered by marginalized human populations.

Drinking Water Pollution and Environmental Justice

There are various types of threat to drinking water quality. As mentioned before, untreated sewage from commercial and industrial practices, agricultural runoff, industrial sources like oil and gas drilling can contribute to poor water quality. In addition to the contaminated water resource, the U.S. drinking water system faces many challenges such as aging infrastructure, limited funding to water utilities, fragmented water industry, and profit-oriented management (Contorno, Sarango, and Harlan, 2018; EPA, 2016). According to a 2017 Natural Resources Defense Council report (NRDC), in 2015, approximately 25% of U.S. residents (77 million population) were served by water utilities that violated the Safe Drinking Water Act (Fedinick et al., 2017). However, the risk of contaminated drinking water is not spread equally across the United States. As the Flint water crisis has shown, communities of color and/or poor are especially considering drinking water safety. For example, in California's Central Valley, Balazs et al (2011) found that community water systems serving larger percentages of Hispanic residents provide drinking water with higher nitrate levels. Numerous studies have also demonstrated that community water utilities serving a larger proportion of minority and poor population had higher frequency for health violations of drinking water acts compared to those serving majority white and wealthy communities (Balazs et al., 2011; Cory and Rahman, 2009; Fedinick, Taylor, and Roberts, 2019; Pilley et al., 2009; Schaider et al., 2019; McDonald and Jones, 2018)

Drinking water contamination is consistently detected in low-income communities and communities of color because they are less resourced (e.g., absence of tax bases and lower relative household incomes) and find it relatively difficult to obtain supports for water infrastructure improvements (Contorno, Sarango, and Harlan, 2018; Siegel, 2019). For example, Hispanic communities along the 2,000 mile U.S.-Mexico border, known as "colonias", face disparities in water-related infrastructure maintenance and lack of drinking water resources, due to lack of tax base and decades of disinvestment (Pilley et al., 2009). According to the Rural Community Assistance Partnership, around 30% of colonial residents did not have access to safe drinking water in 2015. These impoverished communities do not have access to other basic infrastructure and services, including sewer systems, solid waste disposal, and storm drainage (Fedinick, Taylor, and Roberts, 2019). According to a 2009 report of Federal Reserve Bank of Dallas (FRBD), in Texas colonias, approximately, 30% of residents live below the poverty level and average incomes, in some areas, are as low as $5,000 per year. These areas have long been subject to environmental injustice, but their water problems are largely invisible to the public.

Environmental justice studies also indicate that communities that are socially vulnerable and politically disempowered have been historically targeted by hazardous industrial facilities as their favorable places (Bullard, 1990; Bullard et al., 2008; Contorno, Sarango, and Harlan, 2018). These communities are concerned about water pollution caused by environmentally destructive activities like gas drilling, hazardous waste landfill, manufacturing, and intensive agriculture production (Taylor, 2014; Schaider et al., 2019). For example, according to a report by the Environmental Justice Health Alliance (EJHA) for Chemical Policy Reform, Coming Clean, and the Center for Effective Government (2018), disproportionate numbers of people of color and low-income residents lived close to high-risk chemical facilities areas, what is called 'fenceline zones'. These fenceline zone populations were more likely to face chemical releases or explosions that can often threaten water quality. They also faced higher risk of cancer and respiratory disease from toxic air pollution.

According to the EPA (2015), U.S facilities reported 20,432 hazardous substance spills from 2005 to 2014 – approximately, average 2,000 spills occur in each year. The chemical spills can pose a threat to the drinking water sources as well as human health condition such as nervous system dysfunction and cancer. The risk of the chemical spills is, however, not equally distributed. Majority non-white counties are more likely to face these toxic substance spills than majority white counties. One of the examples is a chemical incident occurred in Charleston, West Virginia in 2014. A chemical storage tank at Freedom Industries near Charleston leaked over 7000 gallons of the toxic chemical – 4-methycyclohexanemethanol (MCHM) – into the Elk River. Freedom Industries' tanks were located on the banks of the river. The Elk River provided drinking water to around 300,000 residents in nine counites of the West Virginia. After the incident, hundreds of residents in Charleston and other West Virginia suffered from their contaminated drinking water and illness (e.g., nausea, burned skin and eyes, vomiting, rashes). The chemical pollution incidents pose a public health threat, especially, to those living in poor communities and communities of color in Charleston.

In addition, agriculture is the largest water user in the United States, and many agricultural communities often contaminate waterways because of intensive agriculture and livestock production (Schaider et al., 2019). Even though federal water policy supports large-scale agriculture for local water resources such as dam construction for irrigation, it does not allocate enough money to improve safe drinking water to small systems in the same agricultural areas. Several studies indicate that financial assistance for water infrastructure and technological skills in a response to the agricultural contamination of source waters are not equally distributed across community water systems (Balazs et al., 2011; Cory and Rahman, 2009; Pilley et al., 2009). Originally, federal water subsides may support for a social purpose; however, much of the subsidies have been given to large-scale agriculture, instead of providing the benefits equally to small family farmers (Reisner, 1993). For example, California plants communities obtain federally subsidized irrigation water piped from hundreds of miles away, but poor households near the area cannot use their drinking water due to agricultural pollutions (Scott, 2010). Although much of water subsides go to large-scale farming, the agricultural businesses may disregard environmental harms (e.g., contaminated rivers, streams, and drinking water wells) caused by their industrial agricultural practices (Kimbrell, 2002; Scott, 2010).

Drinking Water Injustice Framework

The scope and nature of the drinking water-related challenges is complicated. Threats to drinking water safety come from contaminated water resources produced by industrial activities, unregulated pollutants in drinking water, aged infrastructure, and a bureaucratic culture of governance and management. However, the exposure to contaminated drinking water is not equally distributed, but as environmental justice research indicates, there are patterns of differential victimization related to the water problem.

This section focuses on why drinking water injustice exists with the political-economic perspective. The current condition of drinking water system in the United States has been historically affected by political-economic forces related to racial discrimination, a profit-oriented water policy and management, and lack of inclusive governance (Contorno, Sarango, and Harlan, 2018).

Legacies of Racial Discrimination

Larger structural processes, such as zoning practices, shape residential housing and industrial facility sites. One example is the zoning practice, which is primarily to protect public health, safety, and welfare of the people through the land-use regulation (Manntay, 2002). The zoning practice provides support for the segregation of land uses such as residential, commercial, and industrial place. Many municipalities in metropolitan regions, however, use the zoning practice to protect their political and economic self-interest and increase their property values (Wilson et al, 2008). The exclusionary zoning practices contribute to unequal developments within spatial areas limiting access of all residents to valued economic, social, and ecological resources (Lynch, 2016; Taylor, 2014; Wilson et al., 2008). As Lynch (2016) indicates, the geographic organization of the political economic power affects the distribution of valued resources across communities. That is, communities that have the political economic power acquire advantages (e.g., healthy environment, better medical care, better quality of schools and employments) over communities where such power is absent or limited. The exclusionary zoning practice is the way to benefit advantaged communities and disregard the needs and concerns of disadvantaged communities (Wilson et al., 2008).

EJ research has demonstrated the impacts of the discriminatory urban planning on minority and low-income communities. Decades of the exclusionary zoning practices indirectly promote residential segregation and manipulate the racial composition of a community (Taylor, 2014). Minorities, thus, were forced to live in certain areas of cities: Poor communities and communities of color are more likely to be found near noxious land uses such as manufacturing zones, waste transfer stations, wastewater treatment plants, and energy production facilities than white residential areas (Maantay, 2002).

Discriminatory urban planning is also responsible for drinking water injustice. According to the EPA's 2016 Drinking Water Action Plan, aging infrastructure and underinvestment in drinking water are growing challenges that pose serious risk to public health. As mentioned before (see the chapter 2), the drinking water infrastructure in the U.S was largely built in three great construction eras: The late nineteenth century, the 1920s and the post-World War II (Siegel, 2019). The aging infrastructure and its related problems are universal concerns (e.g., lead contamination in drinking water). Minorities communities, however, are more exposed to the burdens of associated with the aging water infrastructure, because they face institutional barriers due to local planning and zoning practices. That is, a lack of a tax base and decades of disinvestment for minorities communities resulted in inferior water infrastructure and made it difficult for the water service utilities to keep up with technological innovations, while wealthier, white communities keep attracting more resource for the investment (Balaz and Ray, 2014; Fedinick, Taylor, and Roberts, 2019; Schaider et al., 2019). Intentionally or unintentionally, minorities have been targeted for hazardous polluting facilities such as waste disposal, manufacturing, or gas drilling that may also deteriorate the local water infrastructure (Contorno, Sarango and Harlan, 2018).

Thus, uneven development of communities in the U.S in response to urban policy (e.g., exclusionary zoning practice) have led to unequal distribution of ecological disadvantage, and the adverse outcomes constitute forms of drinking water injustice. Drawing from these literatures, community water systems serving communities of color are more likely to commit more violations of safe drinking water acts, due to racialized urban planning that contributed to unequal distribution of water infrastructure and fewer resources to keep new treatment technology.

Barrier to Adequate Infrastructure for the Poor

In addition to racialized urban planning, water has been managed by a business model that seems to constitute a ‘profit over people’ approach – which is another cause of water inequity (Contorno, Sarango and Harlan, 2018: p. 12). Since the Safe Drinking Water Act was introduced in 1970, Congress gave responsibilities to “the governance triangle” including the EPA, the States, and the local water utilities (Siegel, 2019). The community water utilities or the local municipal water providers have obligation to meet all of the EPA’s regulations. The utilities are required to monitor the local water source to find whether there are contaminants above the permitted level. Once the pollutants are found in drinking water, the utilities are obliged to report the violations and to neutralize or remove them. These obligations imposed on the water utilities and local governments need local expenditures, although the federal government agree to cover some portion of the local expense under the Safe Drinking Water Act

(Siegel, 2019). In fact, the Safe Drinking Water Act have brought many obligations and financial burdens for municipalities and local water utilities, "with nothing in return but the intangible value of cleaner, safer water for the public" (Siegel, 2019: p. 36).

Based on the 'profit-over people' policy, there is, however, a misalignment between the better health outcomes and the profit of water utilities. Specifically, the utilities provide water that is "good enough" at the lowest cost possible, while regulations for the public health increase expenses by installing new equipment or technology (Sigel, 2019: 37). Many utilities and local governments tend to delay maintaining or replacing the ground old pipes, simply because of financial burden.

Finding money for infrastructure investment is challenging so that municipal officials are eager to save the cost of regulating containment in water at the local utilities, instead of providing high-quality drinking water through investment on system improvements (Siegel, 2019). Not only is it expensive, but also it takes years to complete a full upgrade. The water pipes are underground and largely invisible so that it is easy to overlook about them. As around 85% of the American water utilities are connected to municipal governments, municipal planning about water infrastructure is often influenced by the profit-driven water industry, rather than by the purpose of offering equitable distribution of clean water service (Contorno, Sarango and Harlan, 2018). Thus, water infrastructure does not take a top priority for the residents.

The most influential organization in the drinking water industry is the American Water Works Association, or AWWA. The origin purpose of AWWA is to help manage drinking water utilities for the public good. However, the organization's decisions regarding key policies in drinking water are affected by the economic interests of drinking water utilities. Siegel (2019), the author of 'Troubled Water", pointed out that based on interviews with AWWA executives, the organization constantly tries to work in support of the goals of water utilities to keep costs down by reducing the task that comes with regulation of contaminants. The AWWA's CEO said,

> *"The idea of an absolute standard of trying to achieve purity of water is not as simple as it sounds. Utilities strive for better, but there are complications."* (Siegel, 2019: p. 161).

As such, the AWWA tends to follow "the process of balancing benefit and cost" as the best strategy to manage drinking water. The AWWA has an institutional power that can halt or delay government regulations that would create new costs for utilities.

Consequently, as Siegel (2019) stated, "the water utilities end up delivering that 'good enough' water, with 'good' being defined by what is minimally demanded by the EPA and its state counterparts… Utilities would have an incentive to have the threshold for acceptable contamination set as high as possible, thereby making the utility's treatment costs as low as possible" (p. 37). The containment risk standards are established by the process of balancing benefit and cost to protect water utilities from financial burden. Given the economic cost of the regulation, water utilities receive minimal enforcement of the Safe Drinking Water Act (Contorno, Sarango and Harlan, 2018; Fedinick, Taylor, and Roberts, 2019; Siegel, 2019).

Community water utilities are generally funded and built at a local level, with some federal funding. According to the report of the National Resources Defense Council (NRDC), the fund for the water infrastructure improvement is about $19 billion in the Drinking Water State Revolving Fund (DWSRF) from 1998 to 2016, which has translated to over $32.5 billion in the DWSRF to water system improvement projects across the nation. However, even with the congressional funds for the water utilities to maintain the drinking water safety, such funding is not enough to meet states and cities' needs, especially in the type of loans and grants for infrastructure construction (Laufenberg, 1998; Vanderwarker, 2012). Municipalities are under pressure to keep up with the millions of dollars needed to restore deteriorating pipes, pumps, hydrants, meters and other systems (Chicago Tribute, 2017).

Under the market logic circumstance, the funding for infrastructure investments and technological and managerial capacity is often inequitable for low-income water systems (Vanderwarker, 2012). Economically disadvantaged communities are facing difficulties accessing water financing and have insufficient scale of funding to maintain a modern drinking water system, while wealthier communities take the priority of the funding for infrastructure improvements because they are able to bring perceived return on investment (Contorno, Sarango and Harlan, 2018).

Most economically disadvantaged communities suffer from declining and low-income populations, and absence of a strong tax base. Even when these communities can obtain grants and loans, they face a large cost burden of installing and operating a new treatment system because of the relatively small number of people who can afford to share the cost. Poor communities not only face difficulties for replacement of inferior water infrastructure, but also tend to have limited managerial capacity needed to support sufficient training and qualified water system operators. They suffer from both internal issues (e.g., inability to increase rates for customers) and external issues (e.g., capability to apply loans) (Schaider et al., 2019).

Lack of access to the water funding in poor communities, in some cases, results in higher water fees. According to 2017 the Chicago Tribune's report[25] on drinking water in Chicago and its suburbs, poor communities and majority black-communities paid more for water than the white and wealthy ones. Many black communities and/or poor towns have declining populations, which lead residents left behind to bear the cost of repair or replacement. These communities

[25] See, https://graphics.chicagotribune.com/news/lake-michigan-drinking-water-rates/loss.html

often face aged water mains that repeatedly leak or break that increase their water fee. Without sufficient funds to replace the inferior infrastructure, the black communities and poor populations confront the cost of lost water in their water bill.

Against Exclusive Institutions: Civic Engagement

No one who is working in water management and regulation is trying to provide poor quality water. The drinking water institutions, however, tend to have "a bureaucratic and technical culture, leading decision-making processes to be exclusive from the public (Contorno, Sarango and Harlan, 2018: p. v). Citizens should become aware of the exclusionary decision-making process of water management and collectively demand political leaders or participate directly in local decision making to ensure the access to safe and clean drinking water (Fedinick, Taylor, and Roberts, 2019). The Flint water crisis is the exemplary case that emphasizes the importance of civic engagement in their local water system. In Flint, a state-chosen emergency management organization decided to apply a more corrosive water source into inferior water systems without adequate corrosion control. Subsequently, the government officials did not immediately respond to the change in drinking water source (Davis et al., 2016). The crisis identifies problems that during the process, water/environmental institutions failed to include their community residents in the decision-making process. Exclusive operations of government and the local water utilities resulted in health threat to the community, which is empirically proved by one research that there is higher percentage of elevated lead blood level among children associated with the Flint drinking water crisis as compared to those living other areas (Hanna-Attisha et al., 2016).

Not every community has the resources to react and interact in response to environmentally sensitive situations (White, 2003). As communities are more aware of real and potential environmental risk, they tend to call for more response by public health agencies and organizations (Bogdonoff, Cooper-McDermott, and Foscue, 2003). One of such political participations to environmental risk is "Not-In-My-Back-Yard" (NIMBY) reaction. The NIMBY political response usually occurs in economically and politically affluent populations. That is, resources for NIMBY politics and reaction come from knowledge, time, and money (White, 2003).

However, the community capacity for such collective reaction and resistance against environmental risks is not perfectly attributable to socioeconomic status (Zahran, Hastings, and Brody, 2008). While political power and capacity largely depend on residential compositions, one cannot assume demographic factors (i.e., race/ethnicity, income, and education) level alone determine residential ability for collective action aimed at improving their circumstances (Letki, 2018). Cable and Cable (1995), for example, have demonstrated that even low-income people of color can mobilize effectively to resist the removal of industrial hazards, when they are equipped with a high level of civic engagement that is acquired from voluntarism and community-based organizations. Zahran, Hastings, and Brody (2008) also discovered the association between nonprofit organizations in a census tract as a measure of civic vitality and sitting of hazardous waste facilities. Regardless of economic status and race, the toxic waste facilities are less likely to be placed in areas with higher than average civic vitality. Hamilton (1995) found that the higher voter turnout, the lower likelihood of exposure to toxic releases emitted by hazardous facilities. Even though race and income played crucial roles in sitting decisions of waste facilities, voter turnout as a measure of the potential for collective action reduced the possibility of pollution output of facilities. That is, civic political reaction to environmental risks is partially independent of community demographic composition (Zahran, Hastings and Brody, 2008: p. 184).

The term of “civic engagement” is collective behaviors aimed for resolving issues of public concern through many forms such as volunteer work, nongovernment organizations, and electoral participation (Zukin et al., 2006). Sampson (2017) emphasizes the role of civic engagement in pursuit of sustainable urban ecosystems. Active citizen participation in community-based organizations enhances shared expectations and trust to collectively address the environmental concerns (Sampson, 2017). The density of nonprofit organizations, collective citizen participation and network connectivity among community organizations (e.g., school, law enforcement, and business) are also associated with community efficacy and health (Sampson, 2012). Ehrlich (2000) also defines civic engagement as collective efforts towards “making a difference in the civic life of our communities and developing the combination of knowledge, skills, values, and motivation to make that difference. It means promoting the quality of life in a community, through both political and non-political processes” (p. vi).

Levine (2016) found that nonprofit community-based organizations that are strongly associated with civic engagement superseded elected politicians as the legitimate representative of poor minority communities for their infrastructure development. That is, leaders of nonprofit community-based organizations are legitimately treated as the preferred representatives of their community’s interest. Nonprofit community-based organizations play critical roles in fulfilling public social provision and advocating for resources on behalf of disadvantaged communities.

According to Siegel (2019), in communities across the U.S., small nonprofit organizations operate to improve access to safe drinking water for local people. Most of these organizations need fundraising skills, financial support, and professional staffs. However, these gaps may be made up with special motivation: “The people whose drinking water is at risk are often family members, neighbors, and friends” (p. 203). One example is the Environmental Justice Health Alliance, which is serving politically powerless communities to help them develop the capacity to demand safe drinking water, cleaner air and removal of industrial hazards. The Crow Environmental Health Streeting Committee was also established to work for identifying and fixing drinking water problems on the Native American tribes’ reservation. Nonprofit community organizations help less-empowered residents to improve capacity to demand the implementation of protective regulations for safe drinking water (Siegel, 2019). Although bureaucrats in local water management agencies tend to overlook a voice from economically disadvantaged communities in decision-making processes (Contorno, Sarango and Harlan, 2018), communities with greater participation volunteer associations (e.g., volunteer water supervision organizations) will have more influence over decision-making process of their local water system and ensure good quality water (Sigel, 2019).

Summary

Safe and clean drinking water must be equally provided for all the people regardless of race, ethnicity, and class (White, 2008). Based on prior studies, however, communities that are already socially and politically marginalized are more vulnerable to drinking water related problems (Lauren, Sarango and Harlan, 2018; Schaider et al., 2019; Siegel, 2019; Switzer and Teodoro, 2017; Vnaderwarker, 2012). This study pays attention to the issue of environmental crime/justice that examines whether the compositions – racial/ethnic, poverty, and political capacity/civic engagement - of a community affect the probability of residents’ exposure to contaminated drinking water. Generally, criminologists have had little to say about these issues (Brisman et al., 2017), so that drinking water injustice deserves an attention to be theoretically and empirically discussed in green criminology. This study contributes to the way in identifying how race, money, and political power shape the distribution of contaminated drinking water as the environmental harm. Based on the previous research, next chapter details the methodology employed for this study.

CHAPTER FOUR:

METHODOLOGY

This study assesses violations of the Safe Drinking Water Act (SDWA)[26] committed by a community water system as the unit of analysis within the political-economic context. Community water systems, as a kind of public water systems, serve at least 15 service networks or 25 or more customers, and are subject to the regulatory standards. Reportedly, 96% of the U.S population are served by community water systems (VanDerslice, 2011).

In this study, violations and characteristics of community water systems that serve over 500 people are collected from the EPA's Safe Drinking Water Information System (SDWIS) between 2016 and 2018, because very small systems (serving fewer than 500 people) are more likely to report violations of the SDWA inadequately (Allaire, Wu, and Lall, 2017; Rubin, 2013). The data set in this study contains 21,845 community water systems (serving more than 500 residents) of the total 52,100 in the nation[27].

Chapter four indicates the methodology used for this study. To begin, the associations to be tested and hypotheses statements are mentioned. The conceptualization and operationalization

[26] The SDWA was enacted in 1974 to authorize the EPA to regulate drinking water quality. The EPA sets national health standard to protect drinking water at the federal level. States are primarily responsible for regulating public water systems to meet adherence with the standards. When the water systems fail to ensure an EPA-set drinking water standard, drinking water violation can be reported. The EPA regularly collected data on drinking water violations and publicly provide the information through the SDWIS (Siegel, 2019).

[27] The number of public water system in the US is approximately 155,693 in the US. Of the public water system, 52,100 (33.5%) are community water systems and 103,583 (66.5%) are non-community systems, including transient systems and non-transient systems (EPA, 2008).

of independent, dependent, and control variables follow. And then, details on the analytic method are provided.

Research Questions & Hypotheses

Spatial Clusters of SDWA Violations

H1: SDWA violations are distributed non-randomly across geographic locations, presenting spatial clusters (hot spot locations of violations).

First hypothesis is to assess whether health-based violations of SDWA are randomly distributed across the nation. Prior literature suggests that while the United States has good drinking water quality overall, drinking water systems have faced several challenges such as aged water pipes. However, poor communities of color take disproportionate burden of the concern, and they are highly exposed to poor quality of drinking water across the United States due to legacy of segregation and unequal investment on water infrastructure (Allaire, Wu, and Lall, 2017; Contorno, Sarango, and Harlan, 2018; Vanderwarker, 2012). To understand how drinking water inequities are shaped by the political-economic perspective, it is necessary to empirically identify the presence of spatial clusters of SDWA violations across geographic locations.

The first step in the spatial analysis is to test null hypothesis 1 – spatial randomness of SDWA violations. Assuming that spatial randomness is rejected, SDWA violations is not randomly distributed across the nation, suggesting spatial clusters of the violations – counties with high frequency of the violations are likely to be surrounded by one another with high neighbors.

Relationship between SDWA Violations and Community Characteristics

This study is designed to address the research question: Is there a relationship between SDWA violation and community characteristics? Regarding this research question, five hypotheses are explicated:

H2: As percentage of Hispanic residents in a community increases, the number of health-based violation of the SDWA in a water system serving the community also increases.

H3: As percentage of Blacks residents in a community increases, the number of health-based violation of the SDWA in a water system serving the community also increases.

H4: As poverty rate in a community increases, the number of health-based violation of the SDWA in a water system serving the community also increases.

H5: As proportion of nonprofit community organization in a community decreases, the number of health-based violation of the SDWA in a water system serving the community increases.

H6: As average of voting rate in a community decreases, the number of health-based violation of the SDWA in a water system serving the community increases.

These five hypotheses are informed by political economic approach and environmental justice literature and race. With respect to race and ethnicity, because previous research has identified there are more threats to drinking water safety (e.g., exclusionary zoning practice, sitting of hazardous polluting facilities on minority areas, and underfunded water infrastructure) in communities of color (Balaz and Ray, 2014; Contorno, Sarango, and Harlan, 2018; Fedinick, Taylor, and Roberts, 2019; Schaider et al., 2019), hypotheses 2 and 3 anticipate higher rates of drinking water act violations in predominately black and Hispanic communities than other communities.

Along with racial discrimination in zoning and urban construction, the profit-oriented policy on drinking water gives a series of barriers for poor communities (Contorno, Sarango, and Harlan, 2018; Siegel, 2019; Vanderwarker, 2012). Wealthier communities are prioritized for infrastructure improvements, where there is an expected return on investment. Community water systems serving poor communities are more likely to commit drinking water quality violations than those for wealthy communities because of insufficient infrastructure investment (Copeland, 2010). Thus, hypothesis 4 anticipates a higher rate of drinking water act violations in poor communities compared to other communities.

Hypothesis 5 and 6 estimates whether communities with lower levels of civic capacity have less health-based violations because civically organized communities are more likely to have political influence over decision-making process in local policies and give political mobilization to resist environmentally unfavorable policies (Hamilton, 1993, 1995; Zahran, Hastings and Brody, 2008).

Based on prior research, resources for civic capacity are measured by density of nonprofit community-based organizations and voter turnout (Cable and Cable, 1995; Hamilton, 1993; 1995; Hird and Reese, 1998; Pellow, 2004; Levine, 2016; Konisky, 2009). Those communities with higher level of civic engagement are more likely to live in areas with lower environmental risks (Konisky and Schario, 2010). By examining hypotheses 5 and 6, it is expected that communities with higher proportion of nonprofit organizations and higher voting rate as the potential for civic engagement have lower rate of the drinking water regulation violations.

Relationship between Noncompliance and Community Characteristics

This study also addressed related questions regarding the length of SDWA violation status. For example, if a relationship between drinking water violation and socioeconomic characteristics of a community emerges, the relationship between the length of noncompliance with the Safe Drinking Water Act and community characteristics is also tenable. Drawing on previous research, it is predicted that:

H7: As percentage of Hispanic residents in a community increases, the average length of noncompliance per a community water system serving the community is also longer.

H8: As percentage of Blacks residents in a community increases, the average length of noncompliance per a community water system serving the community is also longer.

H9: As poverty rate in a community increases, the average length of noncompliance per a community water system serving the community is also longer.

H10: As proportion of nonprofit community organization in a community decreases, the average length of noncompliance per a community water system serving the community is also longer.

H11: As average of voting rate in a community decreases, the average length of noncompliance per a community water system serving the community is also longer.

Hypotheses 7 and 8 consider the relationship between the average length of noncompliance and racial/ethnic vulnerability with respect to the environmental justice perspective. With previous research based on the political economic perspective (Lynch 2016), drinking water systems serving minority communities tend to have long-term noncompliance because lack of tax base and decades of disinvestment for these communities lead to inferior water infrastructure and made it difficult for the utilities to be equipped with a technological upgrade. Under the structural barrier communities of color face, violations remained uncorrected longer (see also Fedinick, Taylor, and Roberts, 2019).

Hypothesis 9 explores whether the water utilities serving poor communities tend to spend more time out of compliance with the law. Because water infrastructure plans are often influenced by the profit-oriented policy, access to the water funds is difficult for low-income community water systems. In addition, utilities or local governments located in poor communities tend to delay maintaining or fixing the aging water pipes due to financial burdens (Siegel, 2019). Poor community's water systems may have fewer resources to keep new treatment technology in response to the drinking water contamination. Based on the background, hypothesis 9 anticipates long-term noncompliance of the water utility serving poor communities.

Hypotheses 10 and 11 test whether communities with lower amount of civic engagement are associated with slower enforcement actions of water systems. As the previous studies (Contorno, Sarango, and Harlan, 2018; Fedinick, Taylor, and Roberts, 2019) indicated, civic engagement may give environmental pressure on out-of-compliance water systems to comply the regulations quickly, delivering good quality of drinking water to the residents. That is, widespread participation in community-based organization and collective action has a protective effect against inadequate enforcement of SDWA. In other words, when communities have the least amount of civic participation as measured by proportion of nonprofit organization and voting rate, they are also more likely to face slower and inadequate enforcements of water systems.

Measures and Variables

Dependent Variables

1) Number of Health-based Violations of the Safe Drinking Water Acts

The first dependent variable in this analysis is the number of health-based violations of the Safe Drinking Water Acts (SDWA) by each community water system between 2016 and 2018. The data in drinking water quality violation are based on self-reported information of community water systems submitted by primary agencies to EPA.

The Safe Drinking Water Information System (SDWIS) federal report search website[28] provides the SDWA violation data. SDWIS is a database managed by EPA to help states to protect public health, which is generally used for enforcement and compliance. The SDWIS report includes the violation data per community water system that are grouped into the three categories such as 1) health-based violations, 2) monitoring and reporting violations, and 3) other violations.

Under the SDWA, the National Primary Drinking Water Regulations (NPDWR) have been set to protect public health by reducing the levels of contaminants in drinking water, which specify legally enforceable standards and treatment techniques that apply to community water systems.[29]

[28] See EPA, "Safe Drinking Water Information System (SDWIS) Federal Reporting Services," https://www.epa.gov/ground-water-and-drinking-water/safe-drinking-water-information-system-sdwis-federal-reporting.

[29] The NPDWR regulates various types of contaminants in drinking water such as microorganisms, disinfectants, disinfectants, disinfection byproducts, inorganic chemicals, organic chemicals, and radionuclides (see detailed information by EPA, "National Primary Drinking Water Regulation Table," https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulation-table).

The health-based violation of SDWA data includes three types of violations[30] :

(1) Maximum contaminant levels (MCLs) violations: exceedances of the maximum containment levels – the highest level of contaminant allowed in drinking water.

(2) Maximum residual disinfectant levels (MRDLs) violations: exceedances of the maximum residual disinfectant levels – the highest level of disinfectants allowed in drinking water.

(3) Treatment technique (TT) requirement violations: failing certain processes intended to reduce the level of a contaminant in drinking water.

In this study, the health-based violation data was limited to community water systems (above 500 customers) that are in active during 2016 and 2018. The data was downloaded from 2019 quarter 1 dataset of the SDWIS. The number of SDWA violations was measured by the total number of valid value (as "yes" for the binary "Is Health-Based" field) indicated by each water system, when it reported to violate at least one among MCLs, MRDLs, and TT types during January 1. 2016 to December 31. 2018.

2) Length of Noncompliance

The second dependent variable in this study is the length of time out of compliance per community water system between 2016 and 2018. The term of "Out of Compliance" means community water systems are currently in violation of one or more of the SDWA[31]. Generally, SDWA enforcement actions for out-of-compliance water systems include the primary agency's informal responses (e.g., warning letters, visiting) for a first-time violation – and its formal responses (e.g., citations, administrative orders with or without penalties, and

[30] See EPA, "SDWA Data Download Summary and Data Elementary Dictionary," https://echo.epa.gov/tools/data-downloads/sdwa-download-summary

[31] See EPA, "SDWA Data Download Summary and Data Elementary Dictionary," https://echo.epa.gov/tools/data-downloads/sdwa-download-summary.

filing criminal charges)[32], if a violation continues or repeats. SDWIS provides "SDWA compliance status" data, which are quarterly recorded for types of SDWA violation and its enforcement actions including both informal and formal reactions.

In this study, the SDWA compliance status data was limited to community water systems that was active between the 2015 quarter 4 and the 2019 quarter 1. The cases were not included in the data set if noncompliance status was recorded before the start date of the study period (January 1, 2016). For cases that the compliance status dates were past the end date of the study period (December 31, 2018), were excluded from the study. The length of noncompliance was determined by the total period date when community water systems have "returned to compliance" since a specified violation date and hence met the requirements of the SDWA, during January 1. 2016 to December 31. 2018. Limiting the data in this way may create some bias in the cases included in the analysis.

Independent Variables

SDWIS also provides county-level locations served by each community water system. Since the demographics information about customers of a community water system is not publicly available, counties served by each system can be matched with the geographic names in the U.S Census Bureau American Community Survey to find possible association between SDWA violations and community characteristics. That is, US Census demographic data for a county are linked to the violation data from community water systems serving the region. The community demographics used in this analysis are county-level US census variables, which were obtained from the American Community Survey data in the year of 2016.

[32] See EPA, "Safe Drinking Water Act (SDWA) Resources and FAQs", https://echo.epa.gov/help/sdwa-faqs#Q2

This study examines how three dimensions of community characteristics - 1) racial/ethnic proportion, 2) poverty, 3) civic engagement. Each is hypothesized to be associated with drinking water system's violations of the SDWA. By doing so, it makes at least three contributions to the previous studies as indicated below.

First, consistent with the previous literature (Contorno et al., 2018; Schaider et al., 2019; Vanderwarker, 2012), communities of color are more likely be exposed to the SDWA violations due to decades of racialized urban planning that contributed to unequal distribution of water infrastructure that exist across communities currently. The variables used to examine the hypothesis are (1) the proportion of Black residents in a county and (2) the proportion of Hispanic residents in a county by using the 2012-2016 American Community Survey data[33], 5-year estimates (U.S. Department of Commerce, Bureau of Census 2016).

Second, this study analyzes the logic of economics that are hypothesized to lead to drinking water injustice. Given the inequitable distribution of fund for water systems, poor communities are associated with higher number of drinking water violations and slower response to compliance with the law. A measure of "the percentage of families and people whose income past 12 months is below the poverty rate" is used to find the economically disadvantaged effect. The data comes from the American Community Survey data in 2012-2016, 5-year estimates.

Lastly, this study explores the hypothesis that civic engagement is independently associated with drinking water violations. Communities with the least amount of civic engagement are more likely to have higher rate of violation and long-term of incompliance. To examine these hypotheses, based on previous studies, I employ two measures of resources for civic engagement: 1) non-profit organizations proportion, and 2) average voting rate (2012 and

[33] The date was accessed from https://www.census.gov/acs/www/data/data-tables-and-tools/data-profiles/2016/.

2016) in the presidential election (Levine, 2016; Sampson, 2017; Zahran, Hastings and Brody, 2008). A measure of registered non-religious non-profit organization per 1,000 is created using the National Center of Charitable Statistics per county from 2015 Business Master File of Inter Revenue Service[34], divided by 2015 American Community Survey population estimates[35]. The voting rate data[36] is obtained from Election Administration and Voting Survey implemented by the U.S. Election Assistance Commission.

Control Variables

1) Community Drinking Water System Characteristics

Characteristics of community water systems are also associated with SDWA violations (Allaire, Wu, and Lall, 2017; Schaier et al., 2019). Water system characteristics of interest in this analysis include type of source water (ground or surface) and ownership type (private or public) and the utility size.

The utility size categories are defined based on population serve by a given system. In this study, three categories of the utility size are defined by the EPA designations: small utilities (501-3300 people), medium (3,301-10,000), and large (more than 10,000). These data come from the EPA's SDWIS between 2016 and 2018.

[34] The IRS data is accessed at the Urban Institute, NCCS Data Archive. Retrieved from https://nccs-data.urban.org/data.php?ds=bmf.
[35] See U.S. Census Bureau, *Current Population Survey*, *2015*: *Volunteer Supplement*. Retrieved from https://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/36411.
[36] For the voting rates, see U.S. Election Assistance Commission*, 2012 Election Administration and Voting Survey: A Summary of Key Findings*, Retrieved from https://www.eac.gov/assets/1/6/2012ElectionAdministrationandVoterSurvey.pdf.; U.S. Election Assistance Commission, *The Election Administration and Voting Survey: 2016 Comprehensive Report*. Retrieved from https://www.eac.gov/assets/1/6/2016_EAVS_Comprehensive_Report.pdf.

2) Urbanization

Previous studies indicate that rural areas and less urbanized areas are related to a higher likelihood of violations (Allaire, Wu, and Lall, 2017; Fedinick, Taylor, and Roberts, 2019; Siegel, 2019). Community drinking water systems in rural areas are more likely to be impacted by financial difficulty and have less capacity to meet the water quality regulations because of declining residents and lower income.

There are multidimensional concepts for a rural place. Previous literature employs many measures to distinguish rural from urban areas, based on such as population density, geographic isolation, and small population size threshold (Cromartie and Bucholtz, 2008). This study also employs four rural/urban controls into the equation.

First, the proportion of county residents residing in rural areas is included in this analysis. The Census Bureau does not exactly define "rural", but "rural areas include all geographic areas that are not classified as urban" (U.S Census Bureau, 2016)[37]. We obtain the proportion of households in rural areas from the U.S. Census Bureau for each county (2010 estimates).

Second, this study creates a rural county "dummy" variable by using the Beale Code. The Beale Code provides a rural-urban continuum indicator that categorizes counties by their degree of urbanization and nearness to metropolitan areas, ranging from 0 to 9 (Butler and Beale, 1994). The code of 0 means a county is placed in a central metropolitan area with at least one million residents. The codes of 8 and 9 mean counties are completely rural or have fewer than 2,500 urban residents. To distinguish degree of rurality from urbanity in this study, the Beale Code is reconstructed into two groups – "rural county" and "urban county". The rural county group

[37] The Census Bureau uses a definition based on population density and other measures of dense development when defining urban areas. Since the urban/rural classification is built on blocks and tracts, a county's population can be a combination of urban and rural (The Census Bureau, 2016).

includes the codes of 8 and 9, while the urban county group contains the codes 0 to 7. The Beale Code date is obtained from the Economic Research Service, the Department of Agriculture.[38]

Third, as the Federal Office of Management and Budget (OMB, 2014) adopted standard for delineating “metropolitan (metro) counties” by the population size and “nonmetropolitan (nonmetro) counties” by degree of urbanization and adjacency to a metro area/areas[39], a metro counties “dummy” (vs. nonmetro) variable is included in the analysis to control for urbanization effect.

Forth, population density by county is included in the analysis. Population density measured by persons per square mile can compare settlement intensity across county-level areas. A county’s population density can be related to degree of urbanization. This study uses data from the 2016 American Community Survey.

3) Built Environment Effect

Community’s built environment affects the quality of drinking water (Balazs and Ray, 2014). The built environment means human-modified spaces where people live, work, and recreate. For example, farming is a part of the built environment (Balazs and Ray, 2014). Agriculture uses the largest water in the nation and is one cause for water contamination (EPA, 2005; Vanderwarker, 2012). The farming practices (e.g., fertilizer use) may affect local water resources such as the contamination of streams and drinking water wells even though farms receive federal water subsidies (Siegel, 2019). Likewise, the human-modified spaces often affect water quality.

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[38] See “*Rural-Urban Continuum Codes*.” Retrieved from https://www.ers.usda.gov/data-products/rural-urban-continuum-codes.aspx.
[39] See “*Metropolitan Area Designations by OMB: History, 2010 Standards, and Uses*.” Retrieved from https://www.everycrsreport.com/files/20140606_R42005_cc88d5c754b797d095e0880142d7c28aa739d871.pdf.

Given the background, the 2015 County Typology Codes are used to control for the effect of the built environment on drinking water quality. The 2015 County Typology Codes classify all U.S. counties to diverse categories of economic dependence, such as farming and mining[40]. The 2015 County Typology Codes provide dichotomous variables indicating that it is classified as a farm-dependent county (coded 1), when farming accounted for 25% or more of the county's earnings or 16% or more of the employment averaged over 2010-2012. The mining-dependent county indicator (coded 1) means 13% or more of the county's earning or 8% or more of the employment averaged over 2010-2012.

4) State and Region Effect

Previous literature suggests that agency enforcement decisions of environmental laws are also affected by state politics (Lynch, Stretescky, and Burns, 2004; Scholz and Wang, 2006; Konisky and Schario, 2010). Under the SDWA, the public water systems including community water systems are supervised, within each state's authority, to comply safe drinking water standards.

To capture possible state political factor related to environmental enforcement, this study contains the average League of Conservation Voters (LCV) voting scores for the state's delegation to the U.S House of Representatives to measure elite-level environmental attitudes, during 2016 to 2018. The LCV provides their annual National Environmental Scorecard, which presents the consensus of around 20 environmental and conservation organizations. The LCV's scorecard is used to rate members of Congress on environmental, public health, and energy issues. The LCV's scorecard is based on scale of 0 to 100, calculated by diving the number of

[40] The 2015 County Typology Codes data come from Economic Research Service of the U.S. Department of Agriculture. Retrieved from http://www.ers.usda.gov/data-products/county-typology-codes/documentation.aspx.

pro-environmental votes cast by the total number of votes scored.[41] By including the average LCV voting score, this study controls for the state political condition that may influence community water system's regulatory enforcement decisions.

To account for possible regional variation in both racial demographic patterns and SDWA violence incidence, four regional indicator "dummy" variables (Northeast, South, Midwest, and West) are also included.

Statistical Software and Methods

Data were analyzed using Stata 16 (StataCorp., 2019) and GeoDa (Anselin, Syabri, and Kho, 2006). Bivariate and multivariate techniques was conducted by using Stata 16.

First, descriptive statistics was used to provide sample characteristics (e.g., means and standard deviations) for each variable using Stata 16. Next, the Moran's I statistic was applied to identify spatial clusters of SDWA violations across the nation using GeoDa. The spatial weights and the spatial lag variable creation were also performed using GeoDa.

After that, two regression models were applied to assess the effects of independent variables on each dependent variable. To estimate the model for SDWA violations and community characteristics, a zero-inflated negative binominal regression equation (ZINB) was applied using Stata 16. Because SDWA violation can only have positive integer values, a linear regression model is not suitable for count dependent variables (Long and Freese, 2001). If count outcomes are analyzed using a linear regression model, it will cause heteroskedasticity issue that affects the size of standard error estimates. To avoid the statistical problem, this study used the ZINB that is designed for count dependent variables. The other reason is that the dependent

[41] See the detailed information for the National Environmental Scorecard, https://scorecard.lcv.org.

variable has large number of zeros – 86.2% of water systems reported a zero number of violations during the given period. ZINB is specifically designed to respond to count dependent outcomes that contain excess zeros (Long and Freese, 2001).

When the second dependent variable, the length of noncompliance, was assessed, ordinary least squares regression was employed due to the continuous nature of the variable. As the distribution of length of noncompliance had a skewed variable, it was transformed using the natural log to have a more normalized data set (Allison, 1999). The detail explanation regarding analytical methods used will be provided in the chapter five.

Limitations

There are limitations that need to be addressed. First, violation records from the EPA Safe Drinking Water Information System are known to be underestimates of actual occurrence (Allaire, Wu, and Lall, 2017). The EPA has a system to allow small utilities to have exemptions from testing and waivers for addressing contaminated water if they can prove they face the necessary financial capacity to reduce the contaminated levels (Siegel, 2019). The threat of contaminated water is not uncovered until after harm has happened. Therefore, the number of health based safe drinking water act violations are likely to be much greater than reported in this study.

Second, our analysis using county-level demographics is challenging for identifying community characteristics served by each community water system. The most appropriate unit of analysis in environmental justice studies are considerably debated (Liu, 2001; Lynch et al., 2004); some studies prefer census tracts (Atlas, 2001; Stretesky and Hogan, 1998) while others insist ZIP codes as approximate units of community characteristics (Lavelle and Coyle, 1992;

Ringquist, 1998). Since community water systems are not required to gather demographic data about customers, county-level demographics that systems directly provide water are available in our study to find possible relationship between the water quality violations and community characteristics. The demographics of the population served by the community water systems may vary with available geographic units.

CHAPTER FIVE:

ANALYSIS AND RESULTS

Chapter five provides the analysis results for this study. Before the results for the tests of hypotheses are provided, preliminary analyses were conducted, and descriptive statistics of the sample are also presented. After that, the results for the tests of hypotheses are discussed.

Preliminary Analyses

Descriptive Data

Descriptive data for all variables are provided in Table 2.[42] The average number of Safe Drinking Water Acts Violation (SDWA) per community water system between 2016 and 2018 was 0.6572. The mean proportion of Black and Hispanics served by those systems were 9.69% and 11.6%, respectively. The mean poverty rate was 11.79% across the nation. The average voting rate was 58.73%, and the mean proportion of non-profit organization per 1,000 by county was 4.19.

With respect to ownership of community water system, 16.69% of the system were privately owned, while 83.31% of the system were publicly owned (federal, state, or local). Community water system size in the data includes 58.79% small systems (serves more than 500

[42] The presented table for the variables is for the case of SDWA violation. The actual number of observations in the analysis varies by the dependent variables. Descriptive statistics for the case of length of noncompliance are provided in the appendix section.

and less than 3,300 people), 22.06% medium systems (3,300-10,000 people), and 19.15% large systems (>10,000 people).

Table 2. Descriptive Statistics for the Variables in the Study (n=21,845).

Variable	Mean	SD	Min	Max
SDWA violations	.657	3.099	.00	69
Proportion of Black	9.699	12.935	.00	86.20
Proportion of Hispanic	11.607	14.540	.00	99.00
Poverty rate	11.795	11.070	.870	44.320
Average of voting rate (2012&2016)	58.734	8.684	27.90	92.50
Proportion of nonprofit organization	4.169	2.022	.70	28.00
Ownership: private	.167	.373	.00	1.00
Ownership: public	.833	.373	.00	1.00
System size: small	.588	.492	.00	1.00
System size: medium	.221	.415	.00	1.00
System size: large	.192	.192	.00	1.00
Primary water source: surface	.380	.485	.00	1.00
Primary water source: ground	.620	.485	.00	1.00
County typology: farming	.068	.252	.00	1.00
County typology: mining	.072	.258	.00	1.00
Proportion of rural residents	42.897	30.834	.00	100
Metro county (metro=1, nonmetro=0)	.580	.494	.00	1.00
Rural County Group (rural=1, urban=0)	.079	.270	.00	1.00
Population density	417.015	919.396	.30	34127.00
State-level				
League of Conservation Voters (LCV)	37.53	24.457	.00	97
Region (dummy coded)				
Midwest	.264	.441	.00	1.00
West	.166	.372	.00	1.00
South	.476	.499	.00	1.00
Northeast	.093	.291	.00	1.00

With respect to water source, 38.03% of community water system served surface water to people, while 61.97% of the system provided groundwater to consumers. Based on the county typology, the proportion of the system serving in a farming and a mining dependent county was 6.8% and 7.2%, respectively. The average proportion of rural residents served by community water system was 42.89%, while the percentage of water systems operating in metro counties was 58%. When counties were categorized by “rural county group” and “urban county group” based on the Beale Code, the proportion of water systems located in rural county group was 7.9%. The average population density (population per square mile of land area) served by community water system was 417.01. The average environment attitude score at the state-level, was 37.53. Finally, 47.6% of community water systems were in the South region, while 9.3% of these were in the Northeast.

SDWA Violations by Contaminant Type

EPA sets the National Primary Drinking Water Regulations (NPDWR) to protect against both naturally occurring substances and man-made contaminants found in tap water based on the SDWA (EPA, 2004). The NPDWR covers several types of contaminants in drinking water that pose threats to public health, such as disinfection & disinfection byproduct, inorganic chemical, microorganism, radionuclides, and organic chemical.

To calculate numbers of SDWA violations by contaminant type, the health-based violations of the SDWA were aggregated using the “Contaminant Name” section in the SDWIS data from January 1, 2016 to December 31, 2018. Based on the NPDWR, SDWA violations were categorized and summed by five types of contaminants.

Figure 3 indicates that there are 15,164 health-based violations of the SDWA by contaminant types during the study period. Among the types, disinfection and disinfection byproduct violations are the most prevalent; 9,928 occurred between 2016 and 2018. In drinking water treatment process, disinfectants such as chlorine are added into water supply to neutralize water-borne bacteria – Chlorine is the most widely used disinfectant chemical in the nation (CDC, 2016).[43] However, chlorination of drinking causes different types of disinfection byproducts that can harm human health such as increased cancer risk and miscarriages. Since source water around the country have become widely polluted (Siegel, 2019), there is a great concern regarding the formation of disinfection byproducts, especially when surface water sources (e.g., rivers, lakes, and streams) are transported from treatment plants to the tap. The surface water sources are likely to include organic substances that react with chlorine to produce disinfection byproducts in the water treatment process. According to EPA's report (2002), aging water pipes are also likely to create additional form of disinfection byproducts such as corrosion byproducts and sediment deposits.

Inorganic chemical violations were also prevalent; 2,138 occurred, during the study period. Inorganic contaminants in water may be caused by human activities such as mining and agriculture. Amounts above the Maximum Contaminants Levels (MCL) of inorganic chemicals may cause negative effects on the kidneys, nervous system, circulatory systems, bones, or skin (Fedinick, Taylor and Roberts, 2019).

There were 1, 951 microorganism violations during the study period. Microorganism are related with various types of bacteria, viruses and protozoa that are categorized as pathogens.

[43]See the detail information of Disinfection By-Products (Centers for Disease Control and Prevention: https://www.cdc.gov/safewater/chlorination-byproducts.html#five)

Human and animal waste products are the main contributors to pathogens in water through failing onsite wastewater systems, agricultural and urban runoff (Hoornbeek, 2011).

Next, 1,102 radionuclides violations were reported between 2016 and 2018. Radionuclides, such as radium, polonium, radon, and uranium, come from naturally occurring sources (e.g., soil, rock) and man-made substances (e.g., road construction materials, medical treatments) (Fedinick, Taylor and Roberts, 2019).

Organic chemical violations were the least frequent form of violation, only 45 occurred during the study period. Organic chemicals contain petroleum, grease, and many types of chemicals used in manufacturing processes and agriculture in the form of pesticides and insecticides (Hoornbeek, 2011).

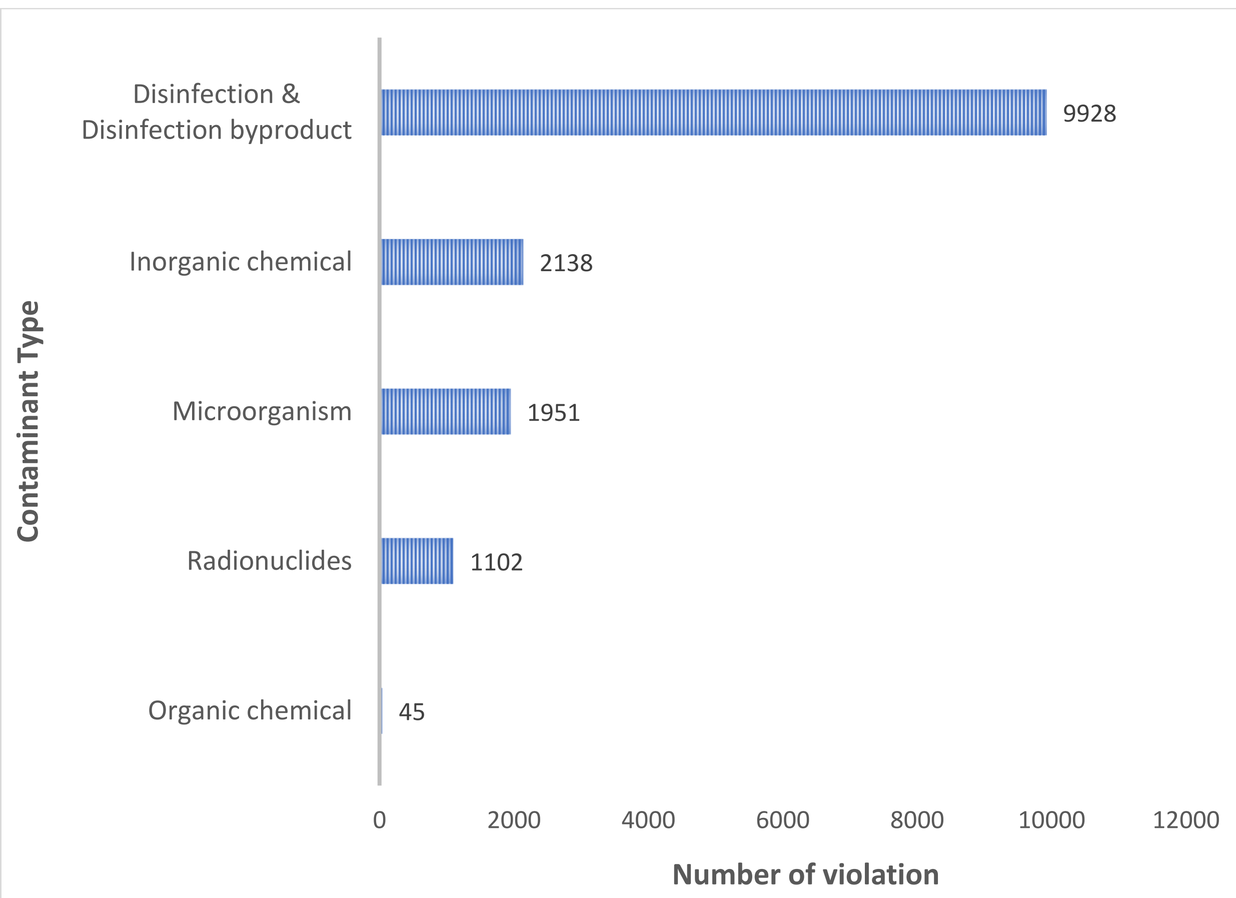

Figure 3. Number of SDWA Violations, 2016-2018, by Contaminant Type.

SDWA Violations by Rule Name

The table 3 presents the number of SDWA violations categorized by rule name. To consider the number of SDWA violations by rule name, the number of SDWA violations were aggregated using the "Rule Code" data section in the data set. The total number of community water systems with SDWA violations were also summed under each rule. Populations served by individual water system with SDWA violations under each rule were summed to find the total numbers of the people that are potentially affected by contaminated drinking water.

First, between January 2016 and December 2018, 15,164 health-based violations were committed by 3,431 water systems among all the sample cases (N = 21,845). It is estimated that 74,012,899 residents were possibly exposed to unsafe drinking water provided by community water systems with SDWA violations.

The most frequent violation is the Stage 2 Disinfectants and Disinfection Byproducts Rule, which represented 9,334 violations by 1,505 water systems during the study period. The Stage 2 Disinfectants and Disinfection Byproducts Rule[44] is established to improve public health protection by reducing exposure to microbial pathogens and disinfectants/disinfectants byproducts, which are known to have potential health effects such as cancer and nervous system dysfunction in infants (Fedinick, Taylor and Roberts, 2019).

The second most commonly reported violation involved violations of the Arsenic Rule; 1,218 occurred in 137 water systems. Arsenic is a one of the inorganic contaminants, which is regulated under the 2001 updated arsenic standard by 2001, which lowered the contamination

[44] For the detailed information, see https://www.epa.gov/dwreginfo/stage-1-and-stage-2-disinfectants-and-disinfection-byproducts-rules#rule-history.

level to 10 parts per billion (ppb) from the existing standard of 50 ppb. [45] Chronic exposure to arsenic is related to health effects such lung cancer, developmental defects, blindness, and skin lesions (Cory and Rahman, 2008; Fedinick, Taylor and Roberts, 2019).

Next, both Radionuclides Rule and Total Coliform Rule are also commonly violated, with 1,102 and 746 reported, respectively. EPA set the Radionuclides Final Rule in 2000[46] to protect customers of community water systems from exposure to radionuclides in drinking water which include contaminants such as radium, gross alpha, beta particles, and uranium. Elevated level of radionuclides in drinking water can cause health problems such as cancer and kidney malfunctions (Fedinick, Taylor and Roberts, 2019). Total Coliform Rule[47] was set in 1989 to regulate total coliform level in drinking water. Total Coliform contains many types of bacteria that do not have a harmful impact on human health, but some types of bacteria (e.g., E. coli) can cause gastrointestinal diseases such diarrhea, cramps, nausea, and vomiting (Allaire, Wu, and Lall, 2018).

[45] In 2001, the Arsenic Rule set lower level of arsenic in drinking water from the prior standard of 50 parts per billion (ppb) to 10 ppb, to protect consumers from the effects of long-term exposure to arsenic; see the detailed information - https://www.epa.gov/dwreginfo/chemical-contaminant-rules.
[46] For the detailed information, see https://www.epa.gov/dwreginfo/radionuclides-rule.
[47] The Total Coliform Rule (TCR) was set in 1989 to meet both a health goal (Maximum Contaminant Level Goal, MCLG) and legal limits (Maximum Contaminants Levels, MCL). EPA regulated the MCLG for the total coliforms at zero. (see, https://www.epa.gov/dwreginfo/revised-total-coliform-rule-and-total-coliform-rule).

Table 3. Number of Health-Based Violations, 2016-2018, by Rule Name.

Contaminants Type	Rule Name	Number of Violations	Number of Systems with Violations	Population Served by Systems with Violations
	Total	15,164	3,431	74,012,899
Inorganic chemical	Arsenic Rule	1218	137	597,864
	Inorganic Chemicals	279	40	362,101
	Lead and Copper Rule	247	161	2,130,812
	Nitrates Rule	394	106	1,831,837
Microorganism	Long-Term 1 Enhanced Surface Water Treatment Rule	486	195	4,863,867
	Long-Term 2 Enhanced Surface Water Treatment Rule	218	44	13,814,548
	Revised Total Coliform Rule	210	187	2,511,774
	Surface Water Treatment Rule	291	149	3,444,803
	Total Coliform Rule	746	521	9,848,116
Radionuclides	Radionuclides Rule	1102	150	770,770
Disinfections & Disinfections byproduct	Stage 1 Disinfectants and Disinfection Byproducts Rule	594	221	1,470,503
	Stage 2 Disinfectants and Disinfection Byproducts Rule	9334	1505	32,221,228
Organic chemical	Synthetic Organic Contaminants	13	6	65,704
	Volatile Organic Chemicals	32	9	78,972

Spatial Distribution of SDWA Violations

The Figure 4 shows a spatial distribution of SDWA violations per community water system in a county during the study period. There are 2,956 counties shown in the map, excluding 129 counties that are excluded due to missing values.

As the map indicates, the frequency of drinking water quality violations varies across geographic areas. Based on the standard deviation of SDWA violations per county during 2016 to 2018, there are 84 counites (2.8% of the total counties) as the high-prevalent-violation areas in red, with 33.513 standard deviations above the average number of SDWA violations. Most of these counties are found in the South and Southwest regions, including California, New Mexico, Oklahoma, Texas, and Louisiana.

Next, 98 counties (3.3.%) were categorized as the less high prevalent violation areas in orange. Many of them seem to be close to or surrounded by the counties in red – the most prevalent violation areas, while the others are sparsely located in the Northeast region. Considering the spatial distribution of SDWA violations shown in this map, South and Southwest regions seem to have community water systems that report safe drinking water quality violations frequently.

The next section is followed by hypothesis tests including spatial analysis of SDWA violations, which will provide empirical evidence for spatial clusters (hot spots) of the drinking water quality violation using spatial autocorrelation statistic. After that, regression analyses are conducted, focusing on effects of community characteristics on the SDWA violation frequency and the length of SDWA noncompliance.

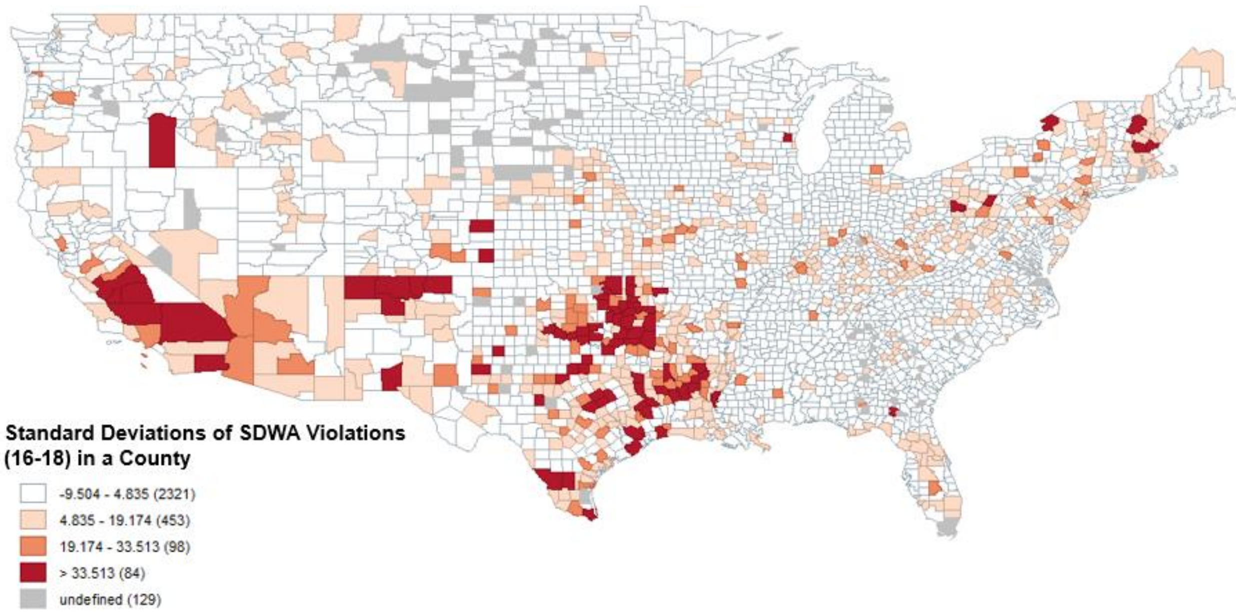

Figure 4. Spatial Distribution of SDWA Violations, 2016-2018.

Hypothesis Tests

Spatial Clusters of SDWA Violations

To test this first hypothesis, "*SDWA violations are distributed non-randomly across geographic locations, presenting spatial clusters (hot spot locations of violations)"*, the spatial distribution of SDWA violations across counties was analyzed via local spatial autocorrelation. Spatial autocorrelation means a situation in which values on a variable of interest are systematically associated with a geographic area (Anselin and Rey, 2014; Baller et al., 2001).

In this study, spatial autocorrelation is accessed by means of a global Moran's I statistic[48]. The first step in the analysis is to examine the null hypothesis of spatial randomness.

[48] Moran's I is the most commonly applied test statistic for spatial autocorrelation. The Moran's I test is a misspecification test that has power against a host of alternatives, including spatial error autocorrelation, residual correlation caused by a spatial lag alternative, and even heteroskedasticity (Anselin and Rey, 2014).

Specifically, the spatial null hypothesis states that: there is no spatial dependence related to a given feature across a geographic location.

By estimating the spatial dependence and relative magnitude between a given county and neighboring counties, spatial clustering of counties is identified. Values of the Moran's I range from -1 to +1. A significant and higher positive value of this statistic means higher, positive spatial autocorrelation (i.e., similar values spatially clustered together), whereas a significant and lower negative value means high negative spatial autocorrelation (values clustered by dissimilar values). A value close to zero means no spatial clustering. Therefore, to be a statistically significant spatial cluster of SDWA violations, a county includes high prevalence of violations committed by its community water systems and would be surrounded by other counties that include a high prevalence of violations. Counties are used as the geographic unit of analysis.

Formally, Moran's I is

$$I = \frac{1}{s^2} \frac{\sum_i \sum_j (y_i - \bar{y})(y_j - \bar{y})}{\sum_i \sum_j w_{ij}}$$

where w_{ij} is an element of a row-standardized spatial weight between county i and j, y is the total number of SDWA violations per water system by county, and $\bar{y}$ is the average SDWA violence occurrence in the sample during the study period.

Among 3,085 counties, 129 counties are excluded in this analysis, due to missing values. Thus, the total number of counties used in the estimate was 2,956. By examining the Moran's I statistic for SDWA violations between 2016 and 2018, the coefficient is 0.370 (see Figure 5). The result was statistically significant at the 0.05 level[49], which rejects the null hypothesis of

[49] It is analyzed based on a permutation approach with 999 random permutations.

spatial randomness. In other words, the results indicate spatial clustering. It signifies spatial autocorrelation in the distribution for the number of SDWA violations per community water system in each county. Thus, the result suggests that the SDWA violation is not randomly distributed across geographic locations and counties that have more prevalence of violation per community water system tend to be significantly closer in proximity to one another.

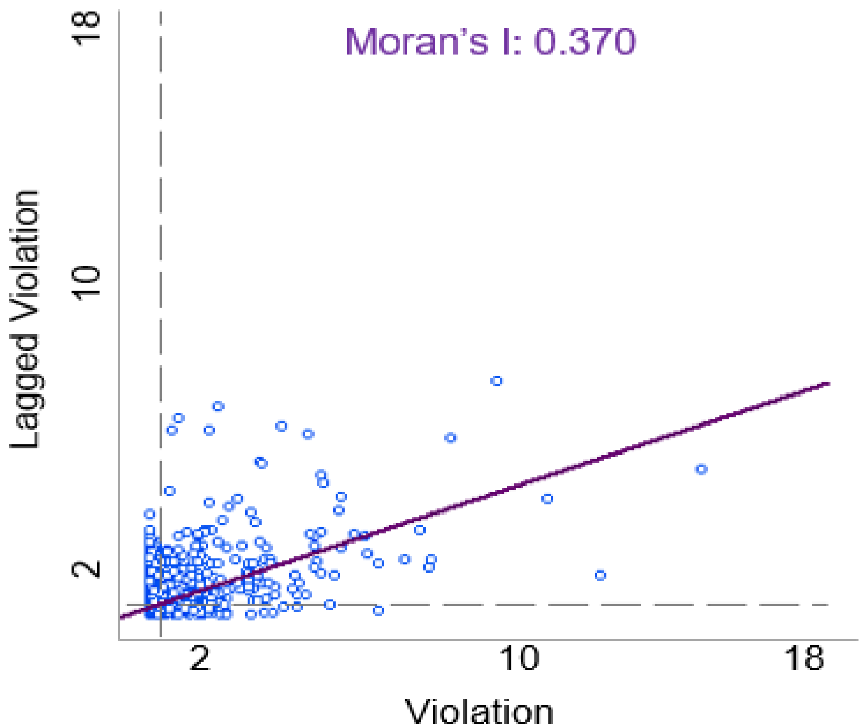

Figure 5. Moran Scatter Plot of SDWA Violations, 2016-2018.

Although the Moran's I statistic is a "global" statistic of spatial autocorrelation – that means it concerns the complete data sets – it does not provide the pattern of the dependence or specify the presence of clusters and spatial outliers (Baller et al, 2001; Ruther, 2013). To find insights into spatial clusters for SDWA violations, a local indicator of spatial association (LISA), so called *the local Moran's I statistic*, can be applied. The local Moran's I is a decomposition of the global Moran's I value into the contribution of each county. In addition, it allows comparisons between the local Moran's I values for each county, indicating spatial clusters of high prevalence of the SDWA violation counties surrounded by counties that also have high prevalence of the SDWA violation or low prevalence violation counties with other low violation counties (Anselin, 1995).

A modified Moran scatterplot map is provided in Figure 6, which is a combination of the information in a Moran scatterplot map and the significance of the local Moran's I statistic[50] (Anselin and Bao, 1997; Baller et al., 2001). This map indicates clusters of high prevalence of the SDWA violation counties in red, and clusters of low prevalence of the SDWA violation counties in blue (both positive spatial autocorrelation); counties with white are not part of significant clusters. Counties with a high prevalence of SDWA violations surrounded with counties with low prevalence, and the counties with low prevalence surrounded by counties with high SDWA prevalence are regarded as non-clustered in this study.

As shown in Figure 6, the "High-High" clusters category is indicated as the clustering of SDWA violation among 143 counties. Those counties are located in Oklahoma, Texas, Arizona, New Mexico, Arkansas and California. The "Low-Low" category is found in the North-East parts of the country: The total number of counties for LL clusters is 216.

[50] Moran scatterplot map provides geographic locations with significant local indicator of spatial association (LISA) and a color category for spatial association in the Moran scatterplot to which location pertains (Anselin and Bao, 1997).

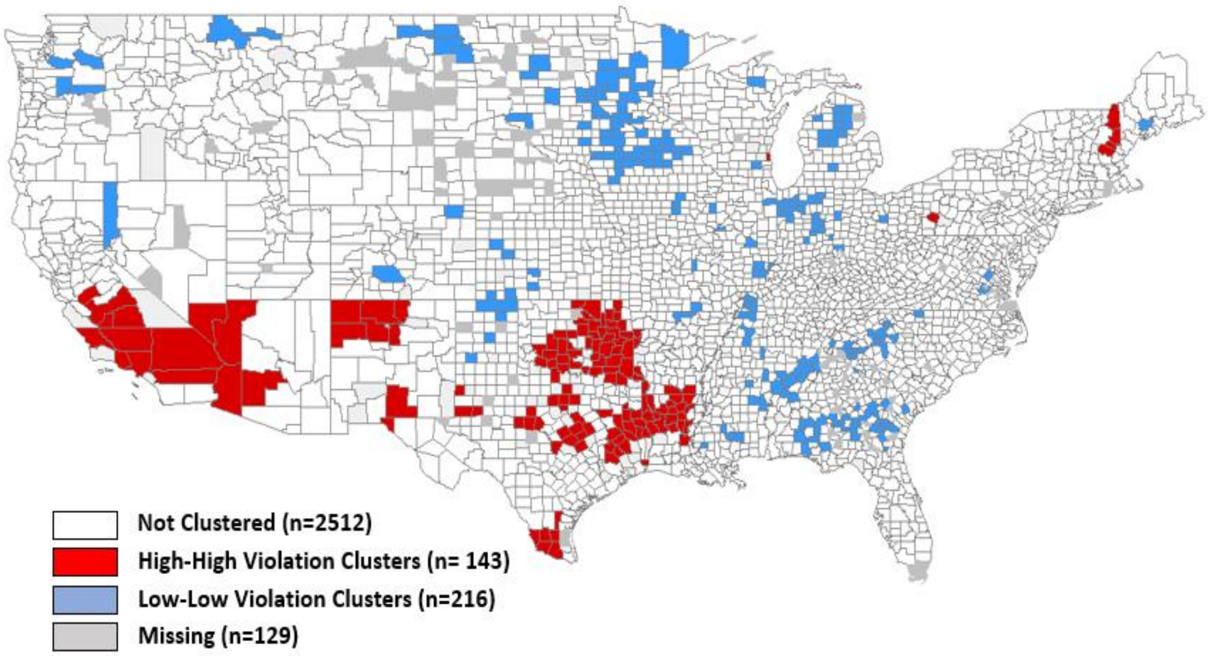

Figure 6. Spatial Clusters of SDWA Violations, 2016-2018.

Using the two different clusters categories (HH clusters and LL clusters), we can compare the mean of independent variables (such as race/ethnicity, poverty, and civic engagement) applied in this study using a two-independent sample *t*-test. As Table 4 indicates, the mean proportion of Hispanics was greater in HH clusters compared to LL clusters (18.815% vs. 5.855%, $p < 0.001$). while the mean proportion of Blacks between HH-and LL-clusters is not statistically significant *(*$p > 0.05$*).* When the mean proportion of Whites between HH-and LL-clusters is compared – even though this study does not include the White proportion variable – the observed difference in mean proportion of Whites was smaller in HH clusters than LL clusters (61.727% vs. 81.639, $p < 0.001$). indicating Whites are more likely to live in clusters with lower levels of SDWA violations.

In addition, the observed differences in mean poverty rate between two groups is also statistically significant: mean poverty rate in HH clusters is greater compared to LL clusters

(19.621% vs. 16.329%, $p < 0.001$). The observed differences in the mean proportion of registered non-profit organization and the mean voting rate are statistically significant between HH clusters and LL clusters; the mean proportion of registered non-profit organization in HH clusters (3.397% vs. 5.094%, $p < 0.001$) and the mean voting rate (51.513% vs. 60.755%, $p < 0.001$) in HH clusters are smaller compared to LL.

Table 4. Comparison of Variables between HH Clusters and LL Clusters.

Variables	*HH clusters (n=143)*	*LL clusters (n=216)*	*Mean difference*	*t Score*
% Black	9.825	8.958	.866	.588
% Hispanic	18.815	5.855	12.959	7.683***
% White	61.727	81.639	-19.912	-10.223***
% Poverty	19.621	16.329	3.292	4.994***
% Nonprofit org.	3.397	5.094	-1.697	-6.679***
% Voter turnout	51.513	60.755	-9.241	-10.128***

*** p<.001

These results indicate that SDWA violations are not randomly distributed across counties and the distribution/location of those clusters are associated with certain correlates. Spatial clusters for violation were also found using the local Moran's I statistic. That is, there are violation hotspots or communities that experience a higher number of violations. In addition, it was observed that counties that have a higher frequency of violations tend to be surrounded by counties that also have a high frequency of violations. Spatial clusters of violations particularly appear in Southwest region (i.e., Oklahoma, Texas, Arizona, New Mexico, Arkansas and California).

Even though the geographical hot spots of SDWA violations indicate a clustering of these location, those counties comprise take a small proportion – only 4.6% among all counties.

Despite their small number, these communities reflect the nation's water challenges and other inequities (see, Anderson, 2008; London et al., 2018). Some of them continue to confront lack of basic infrastructure (e.g., sewage and wastewater disposal systems) as well as vital service (e.g., adequate law enforcement and fire protection). For example, in San Joaquin Valley, California, disadvantaged unincorporated communities (i.e., poor communities located outside urban areas) face water insecurity (Balazs et al., 2011; Durst, 2014). During 1999 and 2001, community water systems serving larger proportion of Latinos and renters in the San Joaquin Valley were more likely to provide nitrate-contaminated drinking water (Balazs et al., 2011). According to a 2018 report by the US Water Alliance, about 350,000 residents lack access to clean water in the San Joaquin Valley. Poor communities of color in the area are disproportionately affected by contaminated drinking water – the conditions the valley's residents have faced are described as 'Third World areas in a First World country' in a report in the *New York Times* (Del Real, 2019), and in academic studies (Anderson, 2008; London et al., 2018; Marsh et al., 2010).

Relationship between SDWA Violation and Community Characteristics

Result from the test of hypothesis 1 revealed that the health-based violation of SDWA is more prevalent in some locations, which suggests SDWA violations are not randomly distributed. Even though the bivariate results provide the presence of environmental inequity across counties – for example, mean proportions of Hispanic and poverty are higher in the high-high clusters of SDWA violation compared to low-low clusters – spatial differences in SDWA violation occurrence, however, may be also affected by other factors such as source water quality, water system's ownership and size, urbanization, differences in state-level politics (Allaire, Wu, and Lall, 2018). The next hypothesis tests in this study were designed to discover the existence of vulnerability characteristics of communities and water systems in related to violation incidence through zero-inflates negative counts model. The unit of analysis in this model is the community water system.

Since the violation of SDWA can only take on positive integer values, a model for count dependent variables is appropriate. A linear regression model can result in inefficient, inconsistent, and biased estimates when models designed for count outcomes are analyzed (Long and Freese, 2001). It can lead to heteroskedasticity that impacts the size of the standard error estimates. That in turn is likely to result in bias in hypothesis statistics and confidence intervals (Allison, 1998). To avoid this issue, it is safer to use analytic methods that are specifically designed for count outcomes as Poisson regression (PRM), negative binomial regression (NBRM), and variations of these models for zero-inflates counts (ZIP and ZINB).

In this study, the zero-inflated counts model (ZINB) fits the data best. The dataset in this study indicates that the variance (s^2=9.6085) greatly exceeded the means of SDWA violations (M=0.6571), which suggests a possible violation of the property of the Poisson distribution (i.e., PRM). Poisson models assume that the means and variance are equal, referred to as "equidispersion." Since the variance is considerably greater than the mean, this situation is referred to as "overdispersion", indicating that the negative binomial regression approach (i.e., NBRM) is more appropriate. There is, however, another important thing to consider about the appropriate model for count dependent variables in this study: There are large number of zeros in health-based violations of SDWA. In fact, 86.2% of community water systems reported a zero number of violations during the study period. This is also problematic because it cannot be discerned if a zero in the dataset indicates no violation during a given period, or results because of issues with identifying and reporting violations, since the violations are often either underreported or inaccurately reported by some water systems (Allaire, Wu, and Lall, 2018; Siegel, 2019).

As a result, the zero-inflated negative binomial regression procedure (i.e., ZINB), introduced by Lambert (1992), respond to count dependent variables that present excess zeros than one would expect based on a Poisson and negative binomial distribution (Long and Freese, 2001). This study estimates the models for violations of SDWA using a ZINB regression equation and provides evidence that the ZINB model fit this dataset best among count models.

Above, the health-based violations of SDWA in this study appeared to be spatially dependent. That is, it has the potential for the error term that is autocorrelated, which may lead to bias in standard error estimates and increase the probability of type I or II statistical errors (Anselin, 1988). This analysis employs a spatial lag to control for spatial autocorrelation in the regression models. A spatial lag can be considered as a "weighted average of neighboring values" (Anselin, 2004). In this case, "neighboring" defines counties that share contiguous boundaries and vertices. The "values" used to represent this variable were the prevalence of SDWA violations per community water system of given neighboring counties. This study uses GeoDa statistical software to generate the spatial lag variable using US county boundary shape file. A first-order contiguity-based spatial weights matrix was created using the queen criterion that includes neighbors that share contiguous boundaries and vertices (Anselin and Rey, 2014). After that, the spatial weights file was utilized to have the weighted average of occurrence of the SDWA violations during 2016 and 2018 in neighboring counties per each county. Because the unit of analysis in this study is a community water system, the spatial lag value is reentered into each community water system along with the county-level served location.

In this study, multicollinearity was also examined. Although multicollinearity does not violate any underlying assumption of regression model (i.e., the least squares estimates are best linear unbiased estimates), it can distort the standard error and regression coefficients. That is, when independent variables are highly correlated with other variables, this can inflate the standard errors and lead to erroneous conclusion (Allison, 1999). To detect multicollinearity in this data, variance inflation factor (VIF) scores were examined among independent variables. VIF scores that exceed 10 are substantially problematic for multicollinearity (Kennedy, 1985). However, other researchers suggest that VIF scores should be below 5 (Walker and Madden, 2012). Based on the criteria, it shows that multicollinearity will not have a substantial problem in this data. All VIF's in the models fell under 5, and the mean of VIF was 1.80. VIF's collinearity diagnostic for all models are provided in Appendix B.

Following these statistical diagnostics tests, the ZINB regression equation predicting violation of SDWA was conducted.[51] Table 6 indicates the result of the negative binomial proportion of the model. In this model, the main findings are that SDWA violation occurrence has a positive and significant association with percentage of Hispanic resident ($p < 0.001$). Thus, these results indicate that water systems serving communities with a higher Hispanic population are more likely to commit SDWA violations. Counter to the hypotheses, several independent variables are not statistically significant in that model: percentage of Black resident, percentage of poverty, percentage of nonprofit organization, and percentage of voter turnout.

[51] The ZINB model estimates the probability of observed SDWA violations per community water system by including a logit and a negative binominal distribution. The negative binomial model for the probability of SDWA violation is only reported and primarily discussed in this section. The logit regression model contained in the ZINB model is presented in the appendix section.

Table 5. Zero-Inflated Negative Binominal Regression (n=21,854).

	SDWA violations	
	b	SE
% Black	.001	.003
% Hispanic	.017***	.003
% Poverty	.010	.008
% Nonprofit org.	2.96×10^{-4}	.017
% Voter turnout	.002	.005
Size		
Medium (Small omitted)	-.011	.079
Large	-.106	.096
Ground water (Surface omitted)	-.164*	.074
Private (Public omitted)	-.174†	.010
Farm-dependent county	.263*	.126
Mining-dependent county	.165	.105
Density	-1.61×10^{-4}**	.001
% Rural residents	.004*	.002
Rural county	-.172	.138
Metro	-.062	.081
LCV score	-.003	.002
Region (South omitted)		
Northeast	-.007	.184
Midwest	-.176†	.103
West	-.425***	.115
Spatial lag: Weighted county-level violation	.028***	.002
Model Diagnostics		
Chi-square (d.f.)	560.34 (20)***	
Likelihood ratio test	1.476***	
Vuong test	7.92***	

†<0.10 * p<.05 ** p<.01 *** p<.001

The result in Table 5 also indicates that violation occurrence is affected by water source. Community water systems that provide drinking water from ground water sources have a lower probability of violations compared to surface water providers ($p < 0.05$). Water systems located in farm-dependent counties show higher likelihood of SDWA violations ($p < 0.05$). Population density had a negative and significant association with violation occurrence ($p < 0.01$), while percentage of rural residents was positively related to SDWA violation ($p < 0.05$). That is, water systems in less densely populated and less urbanized areas appear to be more vulnerable to violations.

Lastly, to find whether the model (i.e., a zero-inflated negative binomial count model, ZINB) fits this data better than other count models (a zero-inflated Poisson model, ZIP and a negative binomial regression model, NBRM), two tests can be done: likelihood-ratio (LR) test and Vuong test.

First, the LR test examined a null hypothesis that the value of the overdispersion parameter (log alpha) equals zero to find whether a ZINB fit the data better than a ZIP model (Long and Freese, 2001). The LR test result indicates that this parameter (log alpha=1.476) is statistically significant ($p < 0.001$), indicating the null hypothesis that alpha equals zero should be rejected. Thus, the ZINB model in this study significantly improves the fit over the ZIP model.

Second, the Vuong test is conducted to compare the ZINB to the standard negative binomial model, NBRM. The Vuong test reports a z-score of 7.96, which is statistically significant ($p < 0.001$). The result indicates that the ZINB model fits this data better than the NBRM model (Long, 2001). Overall, these tests indicate that the ZINB model fits this data better than other count models.

Relationship between Noncompliance and Community Characteristics

Next, we turn to test the relationship between length of noncompliance per system and community characteristics. Since length of noncompliance can be measured after violations of SDWA during the study period (January 1, 2016 to December 31, 2018), the number of cases (i.e., community water systems) in this model is considerably smaller than that of the first model, which reduces to 1,861 from 21,845.[52] Figure 7 indicates the distribution of days of noncompliance during the study period. The figure also includes the average length of noncompliance, 308.58 days with a standard deviation of 235.66 days. The minimum length of noncompliance is one day, and the maximum length is 1,185 days. The result shows that for many of the water systems, illegal contamination persists for more than a year.

As shown in Figure 7, the distribution of length of noncompliance appears to be a skewed variable, which means the regression residuals are also skewed. To resolve the skewed nature of the variable, it is transformed[53] using the natural log (Allison, 1999).

To diagnose the plausibility of heteroscedasticity, the Breusch-Pagan test statistic for heteroscedasticity of residuals was estimated. The test result indicates that it rejects the null hypothesis of homoscedasticity (constant error variance): That is, heteroscedasticity exists in this OLS regression model. While heteroscedasticity does not result in any bias in the coefficient estimate, it provides biased standard errors that make test statistics as well as confidence intervals inaccurate. One solution to heteroscedasticity is to apply *robust standard errors* (Allison, 1999). Therefore, to solve the violation of homoskedasticity this regression model is conducted with the use of robust standard errors.

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[52] In this dataset, the total number of community water systems with SDWA violations were 3,010. However, water systems with unresolved open violations during the study period – that means "Returned to compliance" date is unknown in the state-reported information – are excluded in this analysis.
[53] Logarithmic transformation is a convenient tool of transforming a skewed variable into a more normalized dataset.

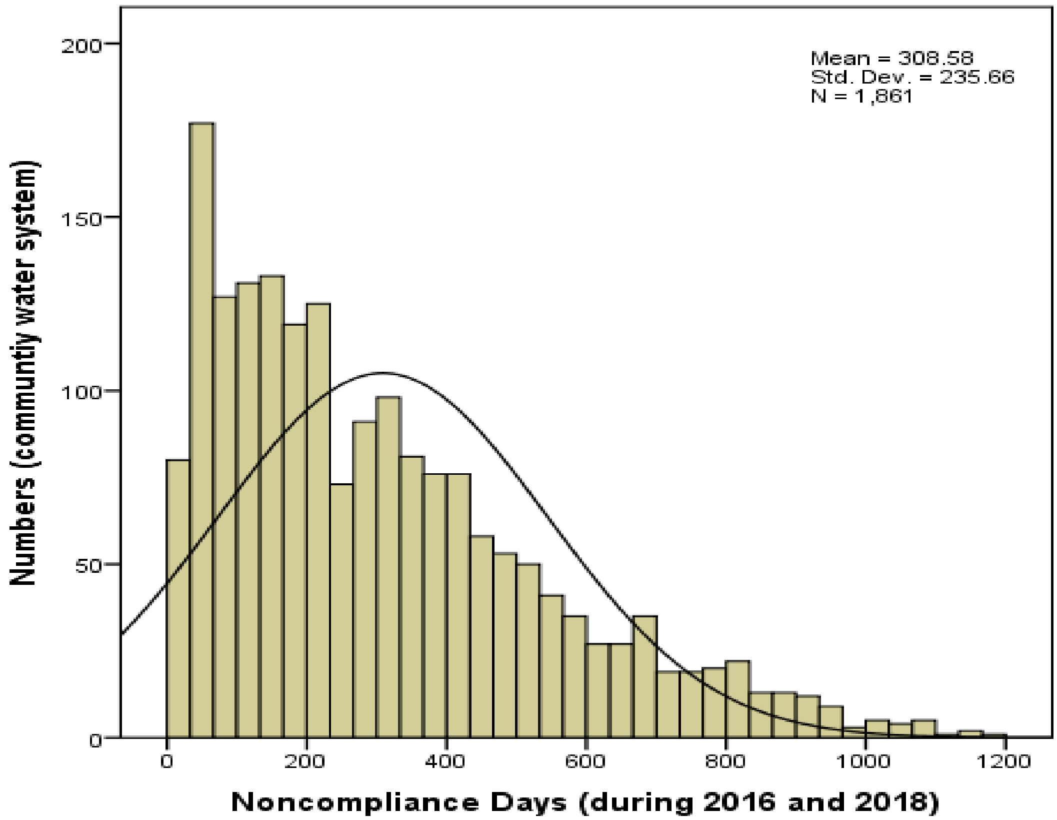

Figure 7. Length of Noncompliance among Community Water Systems.

Another assumption for the accuracy of hypothesis testing is that errors are normally distributed (i.e., normality assumption). The violation of normality assumption does not affect coefficient estimates but provides bias in confidence intervals. The errors cannot be observed directly, so the accuracy of this assumption is indirectly assessed when we examine the residuals (Allison, 1999). When the residuals are approximately normally distributed, we can assume that the errors are normally distributed. To check normality assumption, the procedure compares the observed residuals to the normal distribution by using a *kernel density* graphical method, which shows that the observed residuals are normally distributed, and assumes the error term in the population is likely to be normally distributed. The kernel density graph is provided in the appendix section.

Results of the OLS model predicting the length of SDWA noncompliance are shown in Table 6. Main findings indicate that percent Black, percent Hispanic, percent nonprofit-organization, and percent voter-turnout variables are statistically related to time compliance actions toward SDWA. In other words, counties with a higher prevalence of the variables noted above, have longer time to correction of a violation.

The length of enforcement actions for SDWA has a positive association with percentage Black ($p < 0.05$) and Hispanic residents ($p < 0.001$). That means water systems serving communities with higher Black and Hispanic population are more likely to take longer to be corrected. This may suggest inadequate enforcement actions toward SDWA compliance in Black and Hispanic communities, suggesting the existence of environmental injustice related to SDWA enforcement. The results also indicate that length of noncompliance is negatively related with percentage of nonprofit organization ($p < 0.05$) and voter turnout ($p < 0.05$). When community water systems violate the SDWA, those located in a county with lower capacity of civic engagement tend to take longer length of time to meet the regulatory compliance. Counter to the hypothesis, poverty variable is not associated with the length of noncompliance.

Table 6. Ordinary Least Squares Regression (n=1,861).

	Length (log) of Noncompliance	
	b	Robust SE
% Black	.005*	.002
% Hispanic	.009***	.002
% Poverty	-.007	.006
% Nonprofit org.	-.027*	.014
% Voter turnout	-.007*	.003
Size (Small omitted)		
Medium	-.036	.058
Large	.012	.069
Ground water (Surface omitted)	-.153**	.049
Private (Public omitted)	.064	.069
Farm-dependent county	.233**	.081
Mining-dependent county	-.003	.070
Density	-.1.71 × 10^{-4}**	.001
% Rural residents	.002*	.001
Rural county	-.163†	.092
Metro	-.150*	.061
LCV score	-.005**	.001
Region (South omitted)		
Northeast	.028	.132
Midwest	-.030	.066
West	-.210*	.091
Constant	6.06***	.228
Chi-square (d.f.)	8.99 (19)***	
Adj R square	.090	

†<0.10 * p<.05 ** p<.01 *** p<.001

When considering control variables in the model, the length of time out of compliance is related to water source. It was discovered that surface water providers have longer length of time out of compliance compared to ground water systems ($p < 0.05$). Water systems serving a farm-dependent county have a longer length of time to correcting SDWA noncompliance ($p < 0.01$). The finding indicates that water systems serving rural communities tend to take longer to correct a noncompliance enforcement action: community water systems located in less densely population ($p < 0.01$), higher proportion of rural residents ($p < 0.05$), and nonmetro counties ($p < 0.05$) are likely to take longer length of time to comply the regulation. In addition, the length of noncompliance for community water systems is also associated with states' politics; water systems in states with lower League of Conservation Voters scores (LCV) tend to have longer length of time to achieve regulatory compliance ($p < 0.01$). That is, the less environmental concern in a location measured by the LCV, the longer it takes to correct a compliance issue.

Conclusion

In the chapter five, preliminary analyses, descriptive statistics, and results for hypotheses tests were provided. The descriptive statistics for US drinking water quality violations indicate that there were 15,164 SDWA violations with 74,012,899 people possibly affected during 2016 and 2018.

Table 7 presents a summary of the results for each hypothesis test. By using spatial pattern of SDWA violations, the SDWA violation is not randomly distributed across the nation. Regionally, hot spots of SDWA violations are identified in the Southwest and the South, including counties in Oklahoma, Texas, Arizona, New Mexico, Arkansas, and California. The proportion of Hispanic residents appear positively associated with SDWA violations, while other independent variables are not associated with SDWA noncompliance. When examining the relationship between length of noncompliance per system and community characteristics, both Black and Hispanic population are associated with slower enforcement actions toward SDWA compliance. The average length of noncompliance appears negatively and significantly related with nonprofit organization and voter turnout. That is, community water systems serving communities with lower capacity of civic engagement tend to take longer to ensure compliance with enforcement actions. Poverty is not statistically related to both likelihood of SDWA violations and the length of noncompliance. The implications of these findings are discussed in chapter 6.

Table 7. Summary of Hypotheses Tests.

Hypothesis	Supported?	
	Yes	No
H1: *SDWA violations are distributed non-randomly across geographic locations, presenting spatial clusters (hot spot locations of violations).*	X	
H2: *As percentage of Hispanic residents in a community increases, the number of health-based violation of the SDWA Community water system serving the community also increases.*	X	
H3: *As percentage of Blacks residents in a community increases, the number of health-based violation of the SDWA Community water system serving the community also increases.*		X
H4: *As poverty rate in a community increases, the number of health-based violation of the SDWA Community water system serving the community also increases.*		X
H5: *As proportion of nonprofit community organization in a community decreases, the number of health-based violation of the SDWA Community water system serving the community increases.*		X
H6: *As average of voting rate in a community decreases, the number of health-based violation of the SDWA Community water system serving the community increases.*		X
H7: *As percentage of Hispanic residents in a community increases, the average length of noncompliance per a community water system serving the community is also longer.*	X	
H8: *As percentage of Blacks residents in a community increases, the average length of noncompliance per a community water system serving the community is also longer.*	X	
H9: *As poverty rate in a community increases, the average length of noncompliance per a community water system serving the community is also longer.*		X
H10: *As proportion of nonprofit community organization in a community decreases, the average length of noncompliance per a community water system serving the community is also longer.*	X	
H11: *As average of voting rate in a community decreases, the average length of noncompliance per a community water system serving the community is also longer*	X	

CHAPTER SIX:

DISCUSSION AND CONCLUSION

This study explored health-based violation of SDWA across the nation during 2016 and 2018. During that time, there were 15,164 SDWA violations causes by community water systems that serve more than 500 customers. The most frequent violation type is disinfection and disinfection byproducts (DBPs) violations, representing 65.4% (9,928) of all violations. There are many factors that influence concentration of disinfection byproduct in drinking water such as organic material in source water, temperature, and other mixtures of chemicals, and aging water infrastructure (Evans, Campbell, and Naidenko, 2020). To note, the widespread prevalence of DBPs violations is also partially attributed by regulatory changes (Allaire, Wu, and Lall, 2018).

Although community water systems intend to provide safe drinking water through disinfection and treatment processes – the common way of disinfection is to add chlorine[54] to drinking water suppliers since 20th century – disinfected drinking water with chlorine results in formation of unexpected byproducts such as the trihalomethanes (THMs) and haloacetic acids (HAAs) that were observed to be associated with bladder cancer risk in epidemiology studies (Evans, Campbell, and Naidenko, 2020). To be protective of human health, EPA has set limits on the amount of DBPs[55] in drinking water provided by water systems through three stages. After the new federal regulations for DBPs, the Stage1 Disinfectants and Disinfection Byproducts

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[54] Chlorine is applied to keep safe drinking water in treatment processes from drinking water supplier to the consumer's tap water by eliminating waterborne bacteria and viruses (see CDC, https://www.cdc.gov/safewater/chlorination-byproducts.html)
[55] EPA has determined that TTHM standard should be lowered from 100 mg/L to 80mg/L after the State 1 Disinfectant and Disinfection Byproducts Rule (see EPA, https://www.epa.gov/dwreginfo/stage-1-and-stage-2-disinfectants-and-disinfection-byproducts-rules).

Rule, were implemented in 2002-2004, dramatic increase in DBPs violation appears. Subsequently, when the Stage 2 Disinfectants and Disinfection Byproducts Rule became enforceable after 2013, DBPs violence occurrence[56] continues to increase (Fedinick, Taylor, and Roberts, 2019). Under the new regulatory stages of DBPs, community water systems need treatment costs to comply. During the adjustment process, compliance with new water quality regulation can be a challenge for water systems, especially those serving poor communities of color and rural areas due to limited treatment capabilities (Allaire, Wu, and Lall, 2018). Thus, the recent implementation of revised regulation of DBPs resulted in the most widespread frequency of incompliance. To note, the likelihood of the violence become greater especially in minority communities outside urban areas because of insufficient waster infrastructure and lack of financial resources (Allaire, Wu, and Lall, 2018; Siegel, 2019; Fedinick, Taylor, and Roberts, 2019).

Ethnic Disparity in Safety of Drinking Water

As the result of the first hypothesis test indicated, populations that are exposed to unsafe drinking water are clustered in certain areas. At the county level, there is a "contaminated drinking water belt" in the nation that runs along parts of the Southwest and South regions. Specifically, by using the local Moran's I statistic, 143 counties are detected as "High-High" clusters of SDWA violations, which are concentrated in California's Central Valley, the Texas colonias, and in the rural South.

[56] According to the report by the Natural Resources Defense Council, during 2016 and 2019, the most frequent violations were DBPs, coliform and improper treatment of surface water (Fedinick, Taylor, and Roberts, 2019).

Notably, some of the intense hot spots have large proportion of Hispanics. Ethnic disparities in exposure to unsafe drinking water become apparent when we compare spatial clusters of SDWA by quartiles of percent Hispanic residents across the nation. Figure 8 shows that as the higher Hispanic quartile, as the more clusters of SDWA violations appears. In addition, the hot spots appear to move toward the Southwest regions as the quartiles with Hispanic population increases.

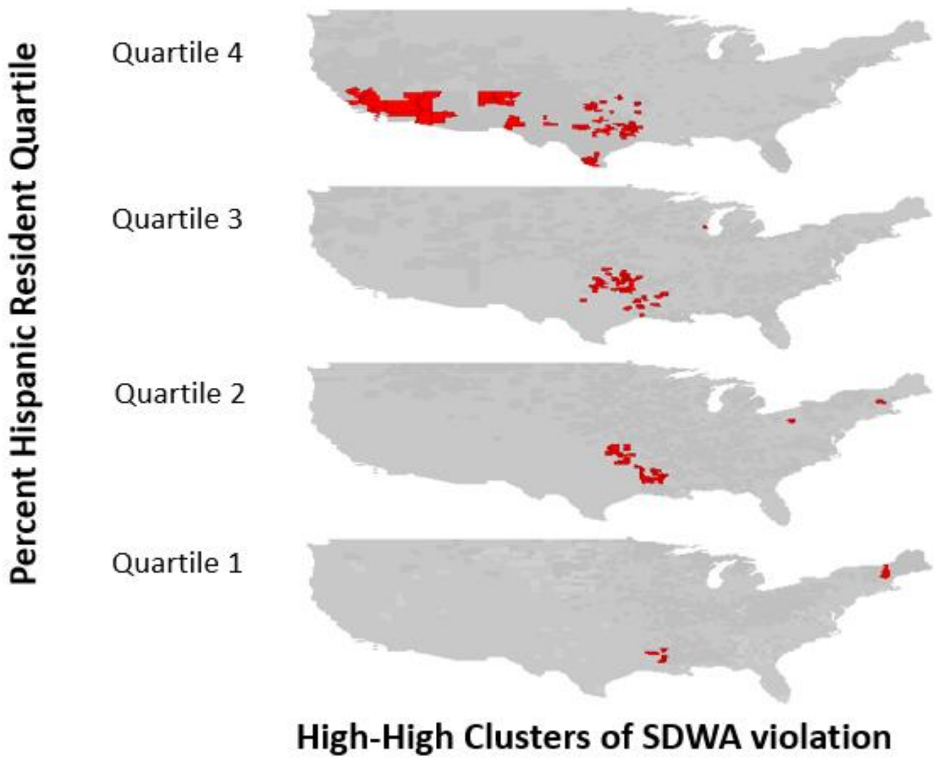

Figure 8. Clusters of SDWA Violation by Quartiles of Percent Hispanic Resident.

The findings based on the tests for hypotheses two through six also indicated that the proportion of Hispanics was a significant predictor of SDWA violations: the larger the share of Hispanic residents living in a county, the higher the frequency of SDWA violations community water systems (see also Figure 9). Prior studies provide support for the association we observed between the proportion of Hispanics and the frequency of SDWA violation by water systems (Balazs et al., 2011; Pilley et al, 2009; Schaider et al., 2019).

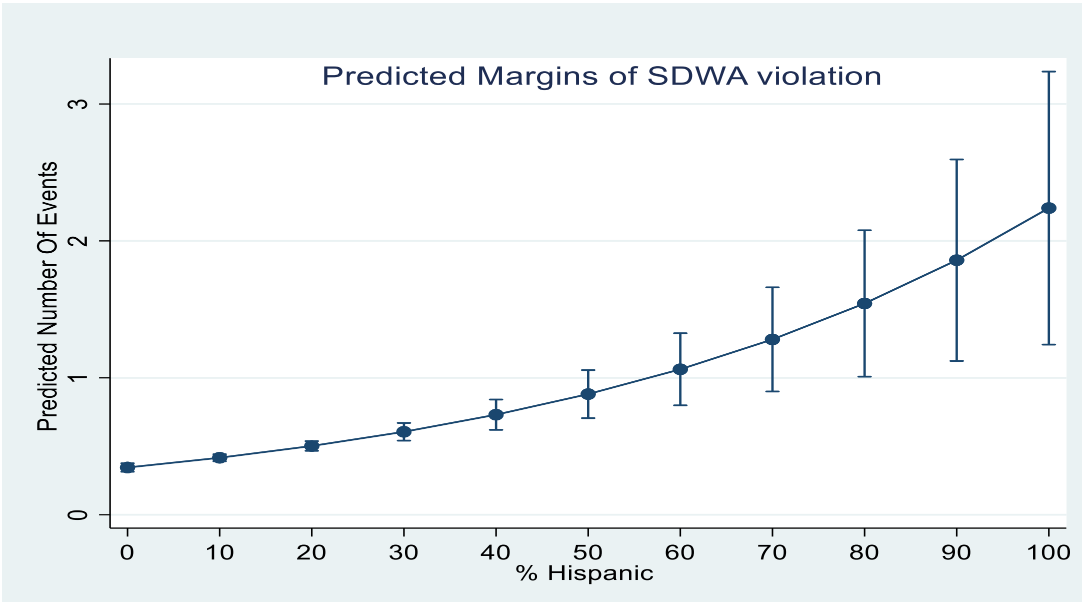

Figure 9. Marginal Effect of Percent Hispanic Resident on SDWA Violation Frequency.

According to previous researchers, one reason why predominately Hispanic communities are more like to be exposed to unsafe drinking water is due in part to the agricultural contamination of source waters (Schaider et al., 2019). Many agricultural communities (e.g., rural California) tend to have a high proportion of Hispanic farmworkers, and in many such areas, drinking water is often polluted by intensive agriculture and livestock production with insufficient wastewater treatment and disposal utilities.

However, the current disparities in access to safe drinking water have been associated with a historically attributed interaction between political, economic, and social forces and factors (London et al., 2018). That is, to fundamentally understand why many Hispanic communities are disproportionately exposed to unsafe water, the historical practices such as exclusionary urban planning need to be addressed. Today water challenges such as lack of access to clean water, aging water pipes, and soil tainted by septic tanks in communities along with the U.S.-Mexican border, known as *colonias*, intersect with the legacy of segregation (Del Real, 2019). In the 1960s, local and federal governments adopted a racial zoning practice that caused poor communities of color to be treated as risky investments. Continuing today, the "selective annexation" practice, or so called municipal 'underbounding', which have replaced the racial zoning policy, is used to divert investment away from neighbors that are already socially and politically disempowered (e.g., low-income residents in rural areas, communities of color, and immigrants) from funding in favor of existing urban towns. Consequently, many of formerly redlined communities are still poor and lack sufficient infrastructure (Anderson, 2008).

According to a recent report by U.S Water Alliance (London et al., 2018), there is empirical evidence that the persistent effects of discriminatory urban planning left rural communities in California (e.g., San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare, and Kern Counties in the San Joaquin Valley) exposed to drinking water insecurity. Rural areas such as Matheny in Tulare County and Fairmead in Madera County in the San Joaquin Valley that were once settled by black farmworkers in the 20th century, have more recently been transformed, and are now largely inhabited by Hispanic residents. However, the historical barriers to infrastructure investment continue, even as new Hispanic residents move in (Del Real, 2019).

There is one example – the process of selective annexation in the Madera County's housing project and city planning that was implemented in 1969. The urban planning project focused on the development of metropolitan areas, along with exclusion of "rural slums" where were predominate Hispanic families. City planners steered new development into neighboring towns to promote residential growth by providing infrastructure investment such as public water systems, recreation, and roadway facilities, what was called a “Bull’s Eye” approach. While the Bull’s Eye approach was an efficient way to reduce the cost of expanding towns both for the county and for private investors, it marginalized rural colonies that already lacked basic infrastructure because local investment in these areas was estimated too costly (U.S. Water Alliance, 2019).

There are grants and incentives from federal and state funding offered by United States Department of Agriculture (USDA) to help such vulnerable communities. However, these supports could not provide enough incentives to address discriminatory practices such as selective annexation. According to a report by California State Water Resources Control Board (CWB, 2016), [57] the City of Tulare (in the Southern San Joaquin Valley) refused to connect their water system to Matheny Tract, one mile away from Tulare, even after the State provided about $5 million to encourage safe water suppliers to connect to the residents of Matheny. Residents in Matheny, mostly composed of historically less-empowered Hispanic populations, were exposed to unsafe level of arsenic in its drinking water. In 2015, the State Water Board’s Division of Drinking Water ordered mandatory consolidation into the larger system so that the City of Tulare must supply water to the residents of Matheny.

The discriminatory practices may have ceased, but disadvantaged communities that were historically shaped by segregation still face ecological threats such as unsafe drinking water (London et al., 2018). Decades of disinvestments for rural areas and minorities communities (e.g., rural California’s water pipes, and isolated colonias in Arizona, New Mexico and Texas) endure inferior water infrastructure such as old pipes and fewer resources to keep adequate

[57] California Water Resources Control Board’s Media Release, 2016. Retrieved from https://www.waterboards.ca.gov/press_room/press_releases/2016/pr4116_tulare_consolidation.pdf.

wastewater treatment and disposal systems (Balaz and Ray, 2014; Fedinick, Taylor, and Roberts, 2019; Schaider et al., 2019).

The Higher the Concentration Minorities, The Longer Noncompliance Length

As the results for the tests of hypothesis seven to eleven indicated, there are racial and ethnic disparities in the enforcement of drinking water quality regulations. That is, those serving communities with higher proportion of African American residents as well as Hispanic residents tend to take longer to be returned to compliance. In addition, civic engagement factors are also associated with slower enforcement of SDWA.

Environmental Injustice in Regulatory Enforcement

To note, our findings do not disclose intentional racial/ethnic discrimination at work in the SDWA enforcement. However, it provides supports for previous works with the environmental justice perspective that contextualizes environmental factors that harm public health and examine how race, color, and class are associated with the distribution of environmental enforcement (Clark, 2018; Lavelle and Coyle, 1992; Lynch, Stretesky, and Burns, 2004a, 2004b; Lynch et al., 2017; Konisky 2009).

Figure 10 indicates racial/ethnic disparity in the enforcement of drinking water qulity violations – as the share of a county's Black population served by a water system increases, the length of noncompliance goes longer as well, all other variables held constant. In regard to countys' Hispanic populations, a similar pattern, – but more inclinded slope in comparision to Black's one – is observed. When we consider the association between noncompliance length and white populations after controlling other factors, – though its finding has not been shown in the previous OLS regression model – there is, however, an opposite direction shown in the figure: the higher the proportion of white residents served by a water system, the faster they see compliance actions.

This finding suggests that governors seem to at least allow out-of-compliance-water systems to remain in noncompliance longer if they have higher percentages of people of color. As considering prior studies that provide empirical evidence for the unequal enforcement along racial/ethnic lines (Konisky, 2009; Lynch, Stretesky, and Burns, 2004a, 2004b), there is also existence of institutional racial and ethnic bias in social control to drinking water quality violations.

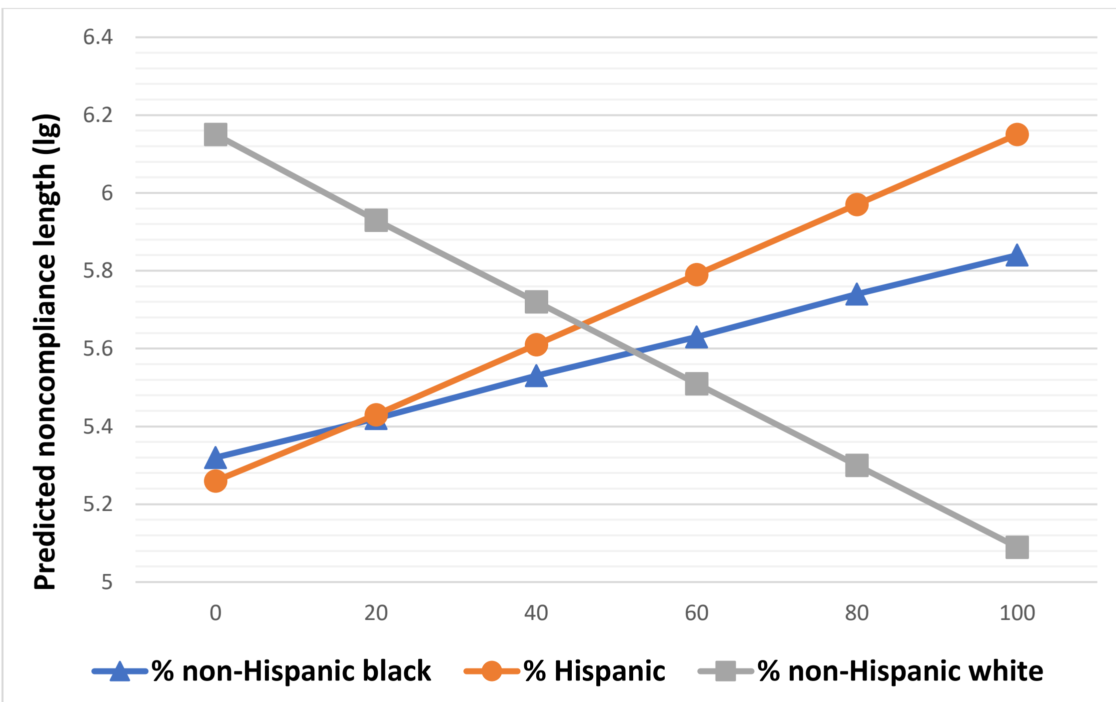

Figure 10. Predicted Length (lg) of Noncompliance by Race/Ethnic Composition.

Within the context of environmental injustice, Bullard (2001) made a similar point that the nation's environmental laws and regulations are not equally enforced across individuals and geographic locations, citing a study from National Law Journal that:

> "*There is a racial divide in the way the U.S. government cleans toxic waste sites and punish polluters. White communities see faster action, better results, and stiffer penalties than communities where blacks, Hispanics and other minorities live. … These findings suggest that unequal protection is placing communities of color at special risk."* (p. 157).

Why does such unequal enforcement of environmental regulations continue to exist? With the critical race perspective, Pulido (2017) argues that existence of discriminatory control for environmental hazards based on social grouping (e.g., race, class, and gender) reveals the racialized nature of capitalism. Devaluation of blacks or nonwhite is the centrality of capitalism, so called 'racial capitalism' (see also Pulido, 2017). Especially, poor communities of minorities have the least value and power, sometimes regarded as "outcast surplus" population (i.e., no value to capital) in the capitalist system: It is a matter of power and control by a social group in the capitalist system that reinforces and protects the dominant group's worldview (e.g., individualism and meritocracy) – and applies this view to others and marginalizes those who are deviant from that norm (see also DiAngelo, 2018). Whites take a privileged position in the institutions of society, establishing a set of policies and cultural practices – and differentially bring advantages for the dominant group that is backed by legal authority and institutional control (DiAngelo, 2018).

Based on the critical race perspective, especially with Pulido's intersectional insight between racism and capitalism, potential health impact of environmental outcome on communities of color – like long-term exposure to unsafe drinking water – are usually less important than the well-being of the dominant group (e.g., white communities). Whether it is consciously or unconsciously, the unequal differentiation of human value, reflected in the capitalist society, inevitably produces institutionalized racial and ethnic discrimination in environmental protection and treatment (Pulido, 2016; 2017).

Using the integrated lens of green/state criminology and radical criminology, Lynch (2016) made a similar note that "the political economic power of structure of capitalism" (p.248) results in unequal distribution of community advantages and disadvantages (CAD) within society (for examples of unequal distribution of CAD impacted by racially discriminatory policies in American cities see Rothstein (2017)), in which the failure of the government to use its power to address unequal dispersion of ecological disadvantage communities face appears to be one of forms of green/state crime and injustice such as different types and levels of governor's reaction to community toxic exposure. Importantly, the institutional failure of environmental regulations in disadvantaged communities causes adverse health consequences (for example, the consequence of elevated blood lead levels in children impacted by Flint drinking water crisis see, Hanna-Attisha et al., (2016)) – and contributes to pervasive health disparities related with concentrated ecological harms across the nation (Bullard and Wright, 2012; Lynch, 2016).

EJ scholars have, thus, challenged the dominant environmental protection paradigm[58] by emphasizing the transformative politics and grassroot movements from top-down approach to bottom-up approach (Bullard and Wright, 2012) and from a pyramid structure to a web structure (Cole and Foster, 2001). Using the racial/ethnic equity perspective, the environmental justice

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[58] According to Bullard and Wright (2009: p. 23), *"the dominant environmental protection paradigm institutionalize unequal enforcement; trades human health for profit; places the burden of proof on the victims and not on the polluting industry; legitimates human exposure to harmful chemicals, pesticides, and hazardous substances; promotes risky technologies; exploits the vulnerability of economically and politically disenfranchised communities; subsidizes ecological destruction creates an industry around risk assessment and risk management; delays cleanup actions; and fails to develop pollution prevention as the overarching and dominant strategy".*

framework attempts to find root causes of unequal protection or differential exposure and remove environmental discrimination in connection to other social discriminatory issues such as racial zoning and housing discrimination (Bullard and Wright, 2012; Lynch 2016; Taylor, 2014). With the EJ framework, the unequal enforcement of SDWA will be discussed in the next section.

Unequal Enforcement of SDWA

The unequal treatment for communities of color is possibly related to the intersection of discriminatory practices and limited access to federal/state resources, based on the previous literature. As mentioned above, the historical and living legacy of segregation embedded in communities of color that are already overburdened with environmental hazards endures a higher proportion of water systems that deliver unsafe drinking water due to disinvestment of water infrastructures (Fedinick, Taylor, and Roberts, 2019). Even though federal grant funding projects (e.g., the Rural Community Assistance Partnership) has been enacted to support water systems serving vulnerable communities since the early 1970s, the water policy could not solve the unequal distribution of basic water infrastructure because it has largely focused on technological solutions to water problems through large-scale water developments such as irrigation and flood prevention (Vanderwarker, 2012) and less discussed "reparations" that restore historically marginalization of communities of color (Steinberg, 1993; Del Real, 2019). The federal water policy overlooked the persistent water contamination and disproportionate lack of access to resources that such disadvantaged communities have confronted.

At the local level, investments on restoration of aging water systems are generated by the local tax base, so such investment is limited, particularly, in small communities of color with limited financial capacity (Siegel, 2019). The water systems in those communities, consequently, are left to rely on state and federal support. Since the federal water infrastructure funding could not offer loans and grants to all the systems in need[59] (Laufenberg, 1998; Vanderwarker, 2012), such funding is competitive and not always feasible, as far as there are more than 51,000 water systems nationwide today.

In this context, disadvantaged communities confront barriers to access the benefits of federal and state environmental programs such as Drinking Water State Revolving Funds (DWSRF) to support their water systems to comply with SDWA rules, because they have lack of qualified workforce in their systems to meet the funding criteria[60] with extensive engineering and reporting requirements for the grants and loans (Balazs and Ray, 2014; Siegel, 2019). As an empirical study also indicated, communities of color were less likely to take an advantage of grant to reconstruct modern wastewater treatment systems (Imperial, 1999). Thus, such disadvantaged communities face harder time to prioritize investments in reparation for out-of-compliance-water systems, and at the same time, the inequitable distribution of infrastructure funding under the federal/state programs makes such systems take longer to be returned to comply with the health standards (Vanderwarker, 2012).

The prolong regulatory failure of SDWA rules has also reflected a lack of commitment of local water/environmental agencies to solve water inequities (Wilson et al., 2010). As the Flint's crisis has been shown, lax enforcement for unsafe drinking water (i.e., Flint residents drank contaminated drinking water for more than a year) has disproportionate effects on the politically less-empowered residents who are already burdened by environmental hazards and historically

[59] For example, 2016 congressional funds were about $99.4 million that are not enough to satisfy the current need for the tribal communities, $2.7 billon (Natural Resources Congress, 2016). In addition, the 2018 American Water Association estimated that $ 1trillion over the next 25 years is needed to fix the aged water infrastructure across the nation (EPA, 2018).

[60] Typically, applicants must prove that they have adequate technical, managerial, and financial capacity to manage the water systems to obtain the funding (CWB, 2020).

inadequate sewer/water treatment systems for decades (Fedinick, Taylor, and Roberts, 2019). The report of the Michigan Civil Rights Commission (2017) itself acknowledged that the Flint's crisis was partially due to lack of serious attention to residents' concerns about the water. Anna Clark, who is a journalist of *The Poisoned City* (2018), also concluded that the crisis is a case of the environmental racism and wrote: "People in Flint were frustrated by the unlikelihood of the state dismissing their complaints had they lived in wealthier and whiter communities." (Clark, 2018: p.206).

This is not just the case in the Flint water system. The local governments routinely fail to react immediately to chronic drinking water problems, particularly Hispanic rural communities (Fedinick, Taylor, and Roberts, 2019; London et al., 2018). For example, in 2012, even though Lanare community in California's Central Valley was eligible for federal and state funds to address contaminated drinking water caused by agricultural runoff and naturally occurring arsenic, the state Department of Public Health did not enact to disperse the money immediately. Due to the state's lack of financial accountability and its unspent federal funds, $455 million, the U.S. EPA gave a notice to cut off additional funds including $260 million in loan payment (Garrison, 2013)[61]. As a recent report by Urban Water Innovation Network (2018) points out, there is an ongoing water-related problem caused by the exclusive institution and austerity policies that some of local environmental agency and water systems failed to include communities with political marginalization in the decision-making process (Lauren, Sarango and Harlan, 2018). Local government's negligent enforcement and exclusionary decision-making process leave marginalized residents to cope with long-term exposure to unsafe drinking water as best they can – for example, by buying expensive home water filters or bottled water for drinking

[61] https://www.latimes.com/local/la-xpm-2013-jun-16-la-me-drinking-water-20130617-story.html

and cooking purposes (Balazs and Ray, 2014; Fedinick, Taylor, and Roberts, 2019; Siegel, 2019; U.S. Water Alliance, 2019). Some of households in California spend up to 10% of their income to buy bottled water due to limited access to safe drinking water, according to a 2018 report[62] in *the New York Times*.

In contrast, strong civic involvement can be one of solutions to the water systems' long-term noncompliance of SDWA rules. As this study's finding indicated, local civic engagement factors measured by proportion of nonprofit organizations and voter turnout can determine the length of exposure to unsafe drinking water. Communities that have more grassroots political voice can be costly for water systems and government agencies. As Clean Water Action (CWA), one of non-profit organizations, stated that *"city officials are especially nervous about the possibility of protests or newspaper articles reporting on failing to address lead pipe problems."* (Siegel, 2019: 202), such ongoing pressure makes local water government agencies more responsive to address the water-related problems and immediately enact protective regulations like CWA's projects that have been coordinated with other NGOs as well as government agencies for lead pipes removal in Boston communities and cleaning nitrates and arsenic in water in the Central Valley of California (Siegel, 2019).

Implications for Policy

Affordable Funding and Equitable Access

Several policy implications are suggested based on the findings. The first thing is to detect vulnerable communities that have limited access to safe drinking water as well as are

[62] See, the detailed information at https://www.nytimes.com/2018/08/21/opinion/environment/safe-drinking-water-for-all.

exposed to polluted source water. Identification of communities under the ongoing risk of unsafe drinking water is helpful for decision-makers to implement specific goals and prioritization of financial/technological support to resolve inequity and environmental injustice. Recently, California has established a good example of priority-setting policies[63] that could be a model for the nation to fulfill the human right[64] to water – "*every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes*."

In 2019, the Safe and Affordable Funding for Equity and Resilience Program (SAFER), under the California Senate Bill 200, was designed to identify high-risk water systems and support local financial/technical assistance to historically under-resourced communities working with local government agencies for sustainable water systems. This program includes an additional $130 million each year by 2030 to help vulnerable communities and small systems with violation of SDWA (CWB, 2020). According to a report in *the New York Times*, the state of California also established a new pair of bills to address the water inequity in 2019. Senate Bill 844 raises taxes on the use of water pollutants like fertilizer manufacturers and large agriculture operations and the other Bill 845 is to apply a "voluntary 95-cent-per-month tax" by water customers to fund safe drinking water programs that would be prioritized to disadvantaged communities at the risk of contaminated drinking water such as arsenic and uranium (Firestone and De Anda, 2018). As such, larger, diverse, and stable funds can help to achieve both a short-

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[63] The State Water Boards in California that was created aided by the Legislature and stakeholders in 2012, can draw from various sources of funding such as the General Fund Appropriation (Under Assembly Bill 72), Drinking Water State Resolving Fund, Bond Funding, and Safe and Affordable Drinking Water Fund. Retrieved from https://www.waterboards.ca.gov/publications_forms/publications/factsheets/docs/faq_safe_drinking_water_program_overview_factsheet.pdf.

[64] The Water Code as Section 106.3 under the Assembly Bill 685, California the first state in the country to legislatively conduct its commitment to the human right to water. Retrieved from ttps://www.waterboards.ca.gov/water_issues/programs/hr2w/.

term goal by providing safe drinking water delivery temporarily by installing proper treatment systems as well as long-term solutions with new water infrastructure replacement and the consolidation of water systems. The limitation of this program/policy, however, is its voluntary nature.

With variety of sources available, developing a simple application/process for the funding can help local communities, particularly for those who are both under-resourced and understaffed, access easily. Although many opportunities to obtain funding are provided, there are still complexed processes and requirements to be eligible for the funding. According to the 2016 EPA's action plan, a "one-stop" on-line water infrastructure funding portal will be created to assist small water systems and low-income communities with identifying funding sources and financing approaches (EPA, 2016). Working with federal governments, state and local officers can offer a more centralized online portal where the applicants can search for appropriate funding guideline, predevelopment projects, or other planning requirements, and make applications in a uniformed process nationwide.

Consolidation of Community Drinking Water Systems

As mentioned before, the U.S. water system network is too fragmented – more than 51,000 water suppliers – compared to other utilities such as 3,800 electric utilities. In all, over 90 % of these systems provide drinking water to less than 10,000 customers – and more than half of them serve 500 people or fewer. These smaller water systems face many challenges such as high cost of providing water, lower capacity, and lack access to updated technologies (Siegel, 2019). Water system consolidations can help disadvantaged communities to access improvement in service by improving efficiency of using source water, building system capacity, and increasing the base of ratepayers.

Consolidation includes a broad spectrum of potential responses that includes both physical and non-physical considerations (Nylen, Pannu, and Kiparsky, 2018). Depending on conditions, in practice, small water systems are connected to neighboring higher capacity system(s); in other cases, more than two systems are combined to create one system; or systems remain physically separate but share financial, workforce, or technical capacity (U.S. Water Alliance, 2019).

If consolidation is the appropriate solution that ensures community benefits and water equity, state and local government should implement mandatory consolidation orders, like "inclusionary zoning" ordinances[65] perspective. For example, in April 2016, the California State Water Board has implemented first mandatory consolidation between city of Tulare and Pratt Mutual Water Company in Tulare County under "Senate Bill 88" that was passed in June 2015, authorizing the state board to "order consolidation with a receiving water system where a public water system, or a state small water system within a disadvantaged community, consistently fails to provide an adequate supply of safe drinking water." [66]

At the same time, the authorities should provide funding incentives and additional liability protection for consolidations and regionalization. To develop and ensure successful consolidations, various legal services for the consolidation process should be provided as well as

[65] It is a kind of public policy (i.e., zoning ordinances) that integrate low-income households into middle class neighborhoods to solve the isolation of poor families in urban cities and their absence from affluent suburbs: for example, the ordinance forces developers to set aside a port of units in new urban planning for low-income households. Montgomery County, Maryland gave a good example of inclusionary zoning policy (Rothstein, 2017)
[66] Senate Bill 88. Retrieved from http://www.leginfo.ca.gov/pub/15-16/bill/sen/sb_0051-0100/sb_88_bill_20150624_chaptered.htm.

joint learning opportunities to share knowledge of benefits and burdens of consolidation among community members are also necessary (Nylen, Pannu, and Kiparsky, 2018).

Protective Regulations and Effective Enforcement

To secure and provide safe drinking water, it is basically important to prevent contamination of sources of drinking water. However, during the former Trump's administration, many of environmental laws and regulations for water pollution were rolled back or weakened (Popovich, Albeck-Ripka, and Pierre-Louis, 2021). For example, water pollution protections for wetlands and waterways under the Clean Water Act (CWA) were weakened and a rule for limiting toxic discharge from coal plants into public waterways was also loosened. In addition, the new regulations of SDWA on lead and copper in drinking water – doubled the amount of time allotted to remove lead pipes in water systems with serious level of lead (i.e., from 14 years to 33 years for full replacement) – were weakened to prevent contamination of drinking water (Friedman, 2020). The Biden administration is expected to nullify many of Trump-era rollbacks by executive orders, even though some rules will be difficult to change and take months or years to be replace.

It is important to strengthen protective regulations and effective enforcement actions that better consider the integrated connection between the CWA and the SDWA, which helps address polluted source water that has disproportionately impacted disadvantaged communities (Allaire, Wu, and Lall, 2018). For example, the "green infrastructure" movement that more relies on natural systems such as wetlands to improve water quality as well as quantity should be widely encouraged across the nation (Beckman, 2014). As the Natural Resources Defense Council also insisted, EPA and states should aggressively use the section 311 of CWA – that protects water contaminations caused by large amounts of hazardous chemicals – and the section 1431 of SDWA– that immediately prevents risks to public health from drinking water pollution (Fedinick, Taylor, and Roberts, 2019).

Furthermore, under the Biden-era administration that emphasizes the importance of environmental protection, congress should amend the 1996 Amendment of SDWA to enact a more protective standard to the degree that is feasible to remove the unregulated contaminants from drinking water rather than burdensome cost-benefit analysis (Siegel, 2019).

Community-Based Cooperation and Partnership

Community water governance has a crucial key in ensuring safe drinking water inequity. There are many drinking water community organizations that are gathered up to assist politically powerless community to resist ongoing health risks. Such organizations can provide more opportunities for residents to participate in local water boards and help them to understand the complex water system. As the founder of Clean Water Action, David Zwick insisted[67], awakened residents are always necessary to strengthen protective regulations for politically disempowered communities to demand a right to safe drinking water.

Importance of civic participation should be emphasized in all levels of governments, water systems, private keyholders and civil society for sustainable water systems. There is an example that can increase community members in civic engagement through the community-based approach – so called *EPA's Environmental Justice Collaborative Problem-Solving Model* (CPS Model). The CPS model[68] has been introduced in 2004 to provide insights on how

[67] https://www.cleanwateraction.org/features/memoriam-david-zwick
[68] For the detailed information about the CPS model, see https://www.epa.gov/sites/production/files/2016-06/documents/cps-manual-12-27-06.pdf.

community organizations are able to work together with other keyholders to address environmental issues in local communities (EPA, 2008). This model has seven elements (see Figure 11) that can be used in distressed communities to achieve environmental justice – all people are treated equally regardless of race/ethnicity and socioeconomic factors. Likewise, the community-led initiatives for solving drinking water injustice will be more successful by dedicating to certain goals that are included in the CPS model:

- Empowerment: Community organizations can become involved directly in collaborative processes with other keyholders to identify water-related problems.
- Strategic planning: Community organizations can engage a diverse array of stakeholders to set up short-term and long-term goals and plans for sustainable/equitable community water system.
- Education: Community organizations can offer information and mentoring for residents in interested in community water governance.
- Inclusive governance: Collaborative problem-solving process provides opportunities for community organizations to serve meaningfully in decision-making processes regarding drinking water related policies/regulations.
- Sustainable water systems: The collaboration of a diverse array of stakeholders realizes the vision that all residents easily access safe drinking water – as well as builds "community resilience initiative" to address challenges such as climate change risks.

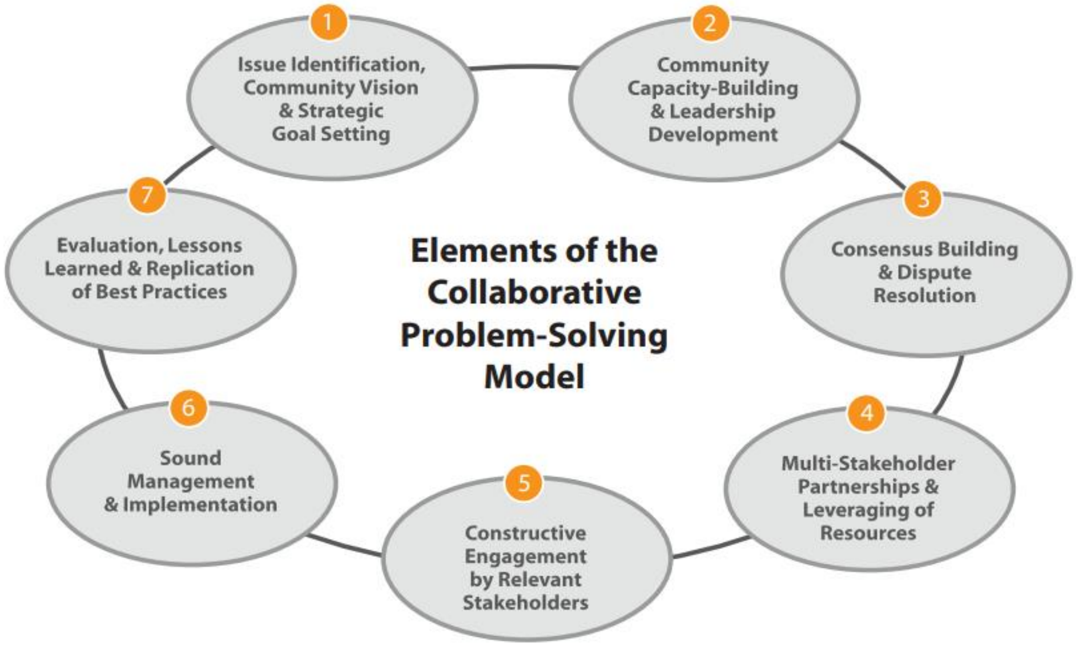

Figure 11. EPA's EJ Collaborative Problem-Solving Model.

Source: EPA's Environmental Justice Collaborative Problem-Solving Model, 2008.

Directions for Future Study

The US drinking water systems have faced 'the dawn of the replacement ear'. The aged water infrastructure not only causes drinking water disruptions but also may affect the quality of drinking water. Especially, low-income rural populations suffer from contaminated drinking water because aged water treatment facilities are not able to adequately filter out chemicals in water such as nitrates (AWWA, 2001). This study does not account for the age impact of water system on the SDWA violation. Future study should explore how the age variable of water system impacts the results of the current analyses – likelihood of drinking water quality violation and length of SDWA noncompliance.

This study applied OLS model for length of noncompliance, the second dependent variable. The date period of noncompliance takes non-negative integer values, which can be also analyzed using count regression models such as the Poisson regression model and negative binomial regression model. Even though this study diagnosed the plausibility of heteroscedasticity – that may be caused by the linear regression model applied for the count outcomes – by using the Breusch-Pagan test statistic and applied *robust standard errors* to solve the issue (Allison, 1999), future study can use of other statistical methods such as count regression models to explore the relationship between days of noncompliance and community structure levels.

Beyond community water systems, future study should be done on the safety and contamination of U.S. private wells. According to the United States Geological Survey (USGS), about 42 million households depend on private wells (Dieter and Maupin, 2017). However, the private wells are not regulated by SDWA[69] – any kind of water testing is not required.

In 2009, the USGS also indicated, based on a sampling of about 2,100 wells across the nation, 23% of them were polluted by chemical contamination – at a level of a potential health risk (USGS, 2009). Among various types of contaminants in those wells, high concentration nitrate pollutant was found, especially in agriculture areas, which come from excessive fertilizer use and can be transmitted through groundwater. In addition, in Wisconsin, approximate 6% of the state's private wells (i.e., 42,000 out of 676,000) were contaminated with serious level of nitrates, or E. coil bacteria that may threaten human health (Healy, 2018; Wisconsin Council Report, 2018).

With lack of environmental inspections/regulations and preferential treatment for big industry, it is expected that contamination in the wells disproportionately impacts low-income rural communities via polluted source water and chemical spills. Based on the earlier studies,

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[69] According to the EPA's website, *"EPA does not regulate private wells nor does it provide recommended criteria or standards for individual wells."* Retrieved from https://www.epa.gov/privatewells.

future research needs to focus on national trends in contaminated drinking water wells as well as find whether environmental injustice exists in communities relying on the private wells.

In addition, another future study needs to focus on climate changes and its related problems for drinking water. Climate-related risks were not a primary focus in 1970s when water policy foundations and related acts such as CWA and SDWA were established (Beckman, 2014). However, the risk of climate change and its related severe weather events place growing stress on the nation's aging water infrastructure (Lauren, Sarango and Harlan, 2018; Vanderwarker, 2012). It is expected that climate change dramatically reduces water access and increases flooding, which will intensity water-related public health threat: for example, as the Katrina case indicated, heavy rain can exceed wastewater treatment capacity, causing health hazard to people (Bullard and Wright, 2009); higher temperature and changing flows will also worsen poor quality source water – by creating toxic conditions in ground and surface water combined with more use of fertilizer and pesticides due to changing conditions (Beckman, 2014).

With a predicted increase in climate change risks, we need to focus on how the impact of climate change will exacerbate the existing drinking water inequality. Specifically, vulnerable communities, such as communities of color and poor rural populations, that currently have unequal access to water infrastructure and live closer to toxic facilities will be more affected by human-caused climate change. Further attention needs to be paid at exploring how the historically-marginalized communities would be more exposed to unsafe drinking water that is compounded by disparities in political and economic decision-makers for climate change preparedness. By doing so, climate equity-oriented policies will be also suggested to contribute to water justice as well as sustainability.

Conclusion

Drinking water systems in the United States confront several challenges such as aging water infrastructure, polluted source water, fragmented water systems, and exclusive governance. The burdens, however, are not equally distributed across the nation. Disadvantaged communities such as minority communities and low-income populations are disproportionately affected by drinking water-related problems.

This study focuses on drinking water quality violations and slow enforcement actions of SDWA during 2016 to 2018. Based on the political-economic perspective, it examines three main hypotheses: 1) whether SDWA violations are distributed randomly across geographic locations; 2) whether compositions of a community including race/ethnicity, poverty, and civic engagement are related to the exposure to contaminated drinking water; 3) and whether these factors are also associated with unequal enforcement of drinking water quality regulations.

The main findings are indicated: first, SDWA violations are concentrated in California's Central Valley, the Texas colonias and rural South; second, water systems serving communities with a larger proportion of Hispanic residents tend to have a higher frequency of SDWA violations; third, while the average length of water system's noncompliance appears longer in communities with higher proportion of Black and Hispanic residents, out-of-compliance water systems return to comply the standard quickly as communities have a higher capacity of civic engagement.

This study provides a complete picture of the national inequities for safe drinking water access, which fills the gap in the prior literature that is limited in terms of geographical scope. The empirical findings in this study also strengthens the environmental justice demand that US drinking water policies should be reformed at structural level for all, free from discrimination, bias, or inequality. It also contributes to the importance of infrastructure reparations that particularly focuses on disadvantaged communities that were historically shaped by segregation.

Drinking water related problems, especially drinking water quality violations, extend beyond the definition of criminal law that is a primary concept in orthodox/traditional criminology (Lynch et al., 2018). As the U.S. Water Alliance's report (2019) argued, this is not an abstract concern for those who are victimized by contaminated drinking water, but an existential, everyday threat to human healthy and rights, which may often cause more victims and damage than street crimes (Lynch, Michalowski, and Groves, 2006; Allaire et al, 2017). With a harm-based definition of crime, these adverse consequences caused by contaminated drinking water deserve attention for criminological studies. Specifically, using radical criminological lens, disproportionate impact of contaminated drinking water on vulnerable communities is a form of social and economic injustice that is reflected by unequal distribution of community advantage/disadvantages under the spatial organization of capitalism (Lynch, 2016). Within the context of green/state crime perspective, failure in state policies and regulations for safe drinking water can result in the health disparities in vulnerable communities.

In addition, this study expands the environmental justice issues by examining how community water system's duration of SDWA noncompliance is affected by a racial/ethnic component that has not been adequately explored in the green criminological literature. It is expected that the finding of racial and ethnic disparities in regulatory enforcement of environmental laws and policies in this study brings an important implication for the future green criminology.

Finally, rather than just focusing on who is at fault for America's drinking water problem, this study also emphasizes the importance of solving it at broader structural levels with diverse stakeholders' engagement and collaboration (such as all levels of government, utilities, nonprofit organizations, and local communities) toward equitable and sustainable drinking water systems.

REFERENCES

Ackerman, F. (2007). *High-Risk Economics: Gambling on Cost-Benefit Analysis for Arsenic Standards*. Comment, Global Development and Environment Institute, Medford, MA.

Allaire, M., Wu, H., & Lall, U. (2017). National trends in drinking water quality violations. *Proceedings of the National Academy of Sciences of the United States of America*.

Allen, L. (2012). Water quality. In *A Twenty-First Century U.S. Water Policy* Edited by Christian-smith J. & Gleick, P.H. (2012) 167-194. New York: Oxford University Press.

Allison, P. (1999). *Multiple Regression*: *A Primer*. Thousand Oaks, CA: Pine Forge Press.

American Society of Civil Engineers. (2017). *Infrastructure Report Card: A Comprehensive Assessment of America's Infrastructure*. Reston, VA: American Society of Civil Engineers.

American Water Works Association. (2001). *Dawn of the Replacement Ear: Reinvesting in Drinking Water Infrastructure*. Denver: American Water Works Association.

Anderson, M. (2008) Cities inside out: Race, poverty, and exclusion at the urban fringe. *UCLA Law Review*, 55:1095-1160.

Andreen, W., & Jones, S. C. (2008). *The Clean Water Act: A Blueprint for Reform*. Center for Progressive Reform, White Paper 802. Washington DC: Center for Progressive Reform. Retrieved from http://www.progressivereform.org/cleanWater.cfm.

Anselin, L. (1988). *Spatial Econometrics*. Boston. Mass: Kluwer Academic.

Anselin, L. (1995). Local indicators of spatial association-LISA. *Geographical Analysis*, 27:93-115.

Anselin, L., & Bao, S. (1997). Exploratory spatial data analysis linking SpaceStat and ArcView. *Recent Developments in Spatial Analysis*. Edited by Fischer, M., & Getis, A. Berlin: Springer-Verlag.

Anselin, L., & Rey, S. (2014). Modern Spatial Econometrics in Practice. GeoDa Press, IL: Chicago.

Associations of State Drinking Water Administrators (2019). *Court Extends EPA's Deadline for Final Perchlorate Regulation*. Retrieved from https://www.asdwa.org/2019/10/04/court-extends-epas-deadline-for-final-perchlorate-regulation.

Atlas, M. (2001). Rush to judgement: An empirical analysis of environmental equity in U.S. Environmental Protection Agency Enforcement Actions. *Law Sociological Review*, 35:633-682.

Balazs, C., & Ray, I. (2014). The drinking water disparities framework: On the origins and persistence of inequities in exposure. *American Journal of Public Health*, 104(4):603-611.

Baller, R., Anselin, L., Messner, S., Deane, G., & Hawkins, D. (2001). Structural covariates of U.S. county homicide rates: Incorporating spatial effects. *Criminology*, 39(3): 561-590.

Barrett, K. L. (2013). *Assessing the Relationship Between Hotspots of Lead and Hotspots of Crime*. PhD diss., University of South Florida.

Baurick, T., Younes L., & Meiners, J. (2019). *Propublica* Oct. 30. 19. Published online as Welcome to "Cancer Alley," Where Toxic Air Is About to Get Worse. Retrieved from https://www.propublica.org/article/welcome-to-cancer-alley-where-toxic-air-is-about-to-get-worse.

Beckman, D. (2014) The threats to our drinking water. *The New York Times.* Aug. 6. Retrieved from https://www.nytimes.com/2014/08/07/opinion/the-threats-to-our-drinking-water.html .

Beirne, P., & South, N. (2007). *Issues in Green Criminology: Confronting Harms against Environments, Humanity and Other Animals*. Cullompton, UK: Willan.

Bogdonoff, E., Cooper-McDermott, K., & Foscue, K. (2003). In pursuit of healthy and livable communities. *Our Backyard: A Quest for Environmental Justice*. Edited by Visgilio, G. and Whitelaw. D, 161-180. Oxford, UK: Rowman & Littlefield.

Brisman, A., & South, N. (2013). A green-cultural criminology: An exploratory outline. *Crime Media Culture*, 9(2): 115-135.

Brisman, A., McClanahan, B., South, N., & Waters, R. (2018). *Water, Crime, and Security in the Twenty-first Century: Too Dirty, Too Little, Too Much*. London, UK: Palgrave Macmillan Publications.

Bullard, R. D. (1990). *Dumping in Dixie: Race, Class, and Environmental Quality*. Boulder, CO: Westview Press.

Bullard, R. D. (2001). Environmental justice in the 21st century: Race still matters. *Phylon,* 49(3):151-171.

Bullard, R. D., & Wright, B. (2009). Race, place, and the environment in post-Katrina New Orleans. In *Race, Place and Environmental Justice after Hurricane Katrina: Struggles to Reclaim, Rebuild and Revitalize New Orleans and the Gulf Coast*. Edited by Bullard, R. D., & Wright, B. 19-48. Philadelphia: Westview Press.

Bullard, R. D., & Wright, B. (2012). *The Wrong Complexion for Protection: How the Government Response to Disaster Endangers African American Communities.* New York: New York University Press.

Butler, M. & Beale, C. (1994). *Rural-Urban Continuum Codes for Metro and Non-Metro Counties, 1993*. Staff report no. 9425. Washington D.C: U.S. Department of Agriculture.

Cable, S. & Cable, C. (1995). *Environmental problems, grassroots solutions: The politics of grassroots environmental conflict.* New York: St. Martin's Press.

California Senate Bill No. 88 (2015). Retrieved from http://www.leginfo.ca.gov/pub/15-16/bill/sen/sb_0051-0100/sb_88_bill_20150624_chaptered.htm.

California Water Boards. (2016). *Tulare County Focus of First State Water Board Mandatory Water Company Consolidation.* State Water Resources Control Board's Media Release. Retrieved from https://www.waterboards.ca.gov/press_room/press_releases/2016/pr4116_tulare_consolidation.pdf

California Water Boards. (2020). *Frequently Asked Questions Safe and Affordable Funding for Equity and Resilience Program.* State Water Resources Control Board's Fact Sheet. Retrieved from https://www.waterboards.ca.gov/publications_forms/publications/factsheets/docs/faq_safe_drinking_water_program_overview_factsheet.pdf

Centers for Disease Control and Prevention (2016). *Disinfection By-Products*. Retrieved from https://www.cdc.gov/safewater/chlorination-byproducts.html.

Cerreno, A., Panero, M., & Boehme, S. (2002*) Pollution Prevention and Management Strategies for Mercury in the New York/New Jersey* Harbor. New York Academy of Sciences: New York, NY.

Clean Water Action (2021). In Memoriam: David Zwick. *Clean Water Action: News & Updates*. Retrieved from https://www.cleanwateraction.org/features/memoriam-david-zwick.

Cole, L. W., & Foster, S. R. (2001). *From the Ground Up: Environmental Racism and the Rise of the Environmental Justice Movement.* New York: New York University Press.

Cooley, H. (2012). Municipal Water Use. In *A Twenty-First Century U.S. Water Policy* Edited by Christian-smith J. & Gleick, P.H. (2012) 167-194. New York: Oxford University Press.

Copeland, C. (2010). *Water Quality Issues in the 111th Congress: Oversight and Implementation.* CRS Report R40098. Washington, DC: The Congress of the United States.

Cory, D. C., & Rahman, T. (2009). Environmental justice and enforcement of the Safe Drinking Water Act: the Arizona arsenic experience. *Ecological Economy,* 68:1825-1837.

Dardis, D. (2010). *Louisiana's Oil: Understanding the Environmental and Economic Impact.* Southeastern Louisiana University. Retrieved from https://www2.southeastern.edu/orgs/oilspill/wetlands.html.

Davis, M. M., Kolb, C. R., Rothstein, E. & Sikkema, K. (2016). *Flint Water Advisory Task Force: Final Report*, commissioned by the Office of Governor Rick S., State of Michigan, March 2016.

Del Real, J. (2019). How racism ripples through rural California's pipes. *The New York Times*. Nov. 29. Retrieved from https://www.nytimes.com/2019/11/29/us/water-racism-california.html.

DiAngelo, R. (2018). *White Fragility: Why It's So Hard for White People to Talk about Racism*, Boston, Massachusetts: Beacon Press.

Dieter, C. A., & Maupin, M. A. (2017). Public supply and domestic water use in the United States, 2015. *U.S. Geological Survey Open-File Report* 2017-1131. Retrieved from https://doi.org/10.3133/ofr20171131.

Downey, L. (1998). Environmental injustice: Is race or income a better predictor?. *Social Science Quarterly*, 79(4):766-778.

Durst, N. J., (2014). Municipal annexation and the selective underbounding of colonias in Texas's lower Rio Grande Valley. *Environment & Planning A: Economy and Space*, 46(7): 1699-1715.

Earthworks. (2019). 1897 Mining Law – Reform Requirements. Accessed March 27, 2020. Retrieved from https://earthworks.org/issues/1872_mining_law_reform_requirements/

Ecowatch. (2016). *Nestle Pumps Millions of Gallons for Free While Flint Residents Pays for Poisoned Water*. Access March 18. Retrieved from https://www.ecowatch.com/nestle-pumps-millions-of-gallons-for-free-while-flint-residents-pay-fo-1882175373.html.

Editorial. (2015). What the Gold Mine Disaster Tells Us. *The New York Times*. Aug. 13: A20.

Ehrlich, T. (2012). Civic responsibility and higher education. *American Council on Education/Oryx Press Series on Higher Education.* Washington, D.C.

Eman, K., Mesko, G., & Fields, C. B. (2009). Crimes against the Environment: Green Criminology and Research Challenges in Slovenia. *Journal of Criminal Justice and Security*, 11(4): 574-592.

Environmental Justice Health Alliance for Chemical Policy Reform. (2018). *Life at the Fenceline: Understanding Cumulative Health Hazards in Environmental Justice Communities*. Workgroup for Public Policy Reform.

Environmental Working Group. (2019a). *The Dirty Secret of Government Drinking Water Standards.* Washington, DC: Environmental Working Group, Retrieved from https://www.ewg.org/tapwater/state-of-american-drinking-water.php.

Environmental Working Group. (2019b). *Nitrate in U.S. Tap Water May Cause More Than 12,500 Cancers a Year: EWG's Peer-Reviewed Study Estimates Cases in Each State*. Washington, DC: Environmental Working Group.

Evans S., Campbell, C., & Naidenko, O. (2020). Analysis of cumulative cancer risk associated with disinfection byproducts in United States drinking water. *International Journal of Environmental Research and Public Health*, 17(6):1-22.

Exchange Project. (September 2006). *Real People-Real Stories: Afton, NC (Warren County).* Department of Health Behavior and Health Education. University of North Carolina at Chapel Hill. Accessed March 3, 2020. Retrieved from https://exchangeproject.unc.edu/files/2018/08/Real-People-Afton-long-story-07-0426.pdf.

Fedinick, K. P., Taylor, S., & Roberts, M. (2019). *Water Down Justice.* Natural Resources Defense Council. 2019. Retrieved from https://www.nrdc.org/resources/watered-down-justice

Firestone, L., & DeAnda, S. (2018). Safe drinking water for all. *The New York Times*. Aug. 21. Retrieved from https://www.nytimes.com/2018/08/21/opinion/environment/safe-drinking-water-for-all.html?searchResultPosition=1

Flint Water Advisory Task Force. (2016). *Final Report*. Lansing, MI: Flint Water Advisory Task Force. Retrieved from https://www.michigan.gov/documents/snyder/FWATF_FINAL_REPORT_21March2016_517805_7.pdf.

Forster, J. B., Clark, B., & York, R. (2010). *The Ecological Rife: Capitalism's War on the Earth*. New York: New York University Press.

Friedman, L. (2020). E.P.A. to promote lead testing rules as Trump tries to burnish his record. *The New York Times.* Sept. 27. Retrieved from https://www.nytimes.com/2020/09/27/climate/trump-environment-lead.html.

Garrison, J. (2013). Funding to improve drinking water has come at a slow drip. *Log Angeles Times.* Jun. 16. Retrieved from https://www.latimes.com/local/la-xpm-2013-jun-16-la-me-drinking-water-20130617-story.html.

Geiser, K., & Waneck, G. (1983). PCBs and Warren county. *Science for the People*, 15(4):13-17.

Gleick, P. H. (2012). The water of the United States: Freshwater availability and use. In *A Twenty-First Century U.S. Water Policy* Edited by Christian-smith, J., & Gleick, P. H. (2012) 3-22. Oxford University Press, New York.

Hamilton, J. T. (1993). Politics and social costs: Estimating the impact of collective action on hazardous waste facilities. *The Rand Journal of Economics*. 24(1):101-125.

Hamilton, J. T. (1995). Testing for environmental racism: Prejudice, profits, political power?. *Journal of Policy Annual Management*. 14(1):107-132.

Hanna-Attisha, M., LaChance, J., Sadler, R.C., & Schnepp, A. C. (2016). Elevated blood lead levels in Children Associated with the Flint drinking water crisis: A spatial analysis of risk and public health response. *American Journal of Public Health*, 106(2): 283-290.

Hayes, T. B., Collins, A., Lee, M., Mendoza, M., Noriega, N., Struart, A. A., & Vonk, A. (2002). Hermaphroditic, demasculinized frogs after exposure to the herbicide atrazine at low ecologically relevant doses. *Proceedings of the National Academy of Sciences USA*, 99: 5476-5480.

Healy, J. (2018). Rural America's own private Flint: Polluted water too dangerous to drink. *The New York Times.* Nov. 3. Retrieved from https://www.nytimes.com/2018/11/03/us/water-contaminated-rural-america.html.

Hillyard, P., & Tombs. S. (2007). From crime to social harm? *Crime, Law and Social Change*, 48(1-2): 9-25.

Hoornbeek, J. (2011). *Water Pollution Policies and the American States: Runaway Bureaucracies or Congressional Control?* New York: State University of New York Press.

Jaeger, J. W., Carlson, I. H., & Porter, W. P. (1999). Endocrine, immune, and behavioral effects of aldicarb (carbamate), atrazine (Triazine), and nitrate (fertilizer) mixtures at groundwater concentrations. *Toxicology and Industrial Health*, 15(1-2):133-151.

Jones, S., & Atkin, E. (2018). Rural America's drinking water crisis. Feb. 12. *The New Republic*. Retrieved from https://newrepublic.com/article/147011/rural-americas-drinking-water-crisis.

Kennedy, P. (1985). *A Guide to Econometrics.* London: Basil Blackwell.

Anselin, L. (2004). *Spatial lag.* Accessed Dec. 10, 2020 Retrieved from https://geodacenter.asu.edu/spatial-lag.

Konisky, D. (2009). Inequities in enforcement? Environmental justice and government behavior. *Journal of Policy Analysis and Management,* 28(1): 102-121.

Kortenkamp, A., Faust, M., Scholze, M., & Backhaus, T. (2007). Low-level exposure to multiple chemicals: Reason for human health concerns? *Environmental Health Perspectives,* 115(S-1): 106-114.

Lambert, D. (1992). Zero-inflated Poisson regression, with an application to defects in manufacturing. *Technimetrics*. 34(1): 1-14.

Langlois, V. S., Carew, A. C., Pauli, B. D., Wade, M. G., Cooke, G. M., & Trudeau, V. L. (2010). Low levels of the herbicide atrazine alter sex ratios and reduce metamorphic success in Rana PIPIENS Tadpoles raised in outdoor mesocosms. *Environmental Health Perspective,* 118(4): 552-557.

Lauren, C., Sarango, M., & Harlan, S. L. (2018). *Environmental justice and sustainable urban water systems: Community voices from selected cities in the United States*. Boston, MA : Northeastern University Press.

Lavelle, M., & Coyle, M. (1992). Unequal protection: The racial divide in environmental law. *National Law Journal*, 15(3): S1-12.

Levin, R. B., Epstein, P. R., Ford, T. E., Harrington, W., Olson, E., & Reichard, E. G. (2002). U.S drinking water challenge in the twenty-first century. *Environmental Health Perspectives*, 110(1):43-52.

Levine, J. R. (2016). The privatization of political representation: Community-based organizations as nonelected neighborhood representatives. *American Sociological Review*, 81:1251-1275.

Liu, F. 2001. *Environmental justice analysis: Theories, methods and practice*. Boca Raton, FL: Lewis.

Long, J. S. (1997). *Regression Models for Categorical and Limited Dependent Variables*. Sage Publications.

Long, J., & Freese, J. (2001). *Regression Models for Categorical Dependent Variables Using State*. A Stata Press Publication.

Lynch, M. J., Long, M. J., Stretesky, P. B., & Barrett, K.L. (2017). *Green criminology: Crime, justice, and the environment*. California: University of California Press.

Lynch, M. J. (1990). The greening of criminology: A perspective for the 1990s. *Critical Criminologist*, 2(3): 3-4, 11-12.

Lynch, M. J. (2016). The ecological distribution of community advantage and disadvantage: Power structures, political economy, communities, and green-state crime and justice. *Critical Criminology*, 24:247-262.

Lynch, M. J., & Stretesky, P. (2014). *Exploring Green Criminology: Toward a Green Criminology Revolution*. Farnham, UK: Ashgate.

Lynch, M. J., & Stretesky, P. B. (2011). Similarities between green criminology and green science: Toward a typology of green criminology. *International Journal of Comparative and Applied Criminal Justice*, 35(4): 293-306.

Lynch, M. J., Michalowski, R., & Groves, W. B. (2006). *A Primer in Radical Criminology*. New York: Criminal Justice Press.

Lynch, M. J., Stretesky, P., & Burns, R. (2004a). Determinants of environmental law violation fines against oil refineries: Race, ethnicity, income, and aggregation effects. *Society and Natural Resources*, 17(4): 333-347.

Lynch, M. J., Stretesky, P., & Burns, R. (2004b). Slippery business: Race, class and legal determinants of penalties against petroleum refineries. *Journal of Black Studies*, 34(3): 421-440.

Lynch, M. J., Stretesky, P. B. & Long, M. A. (2017). State and green crimes related to water pollution and ecological disorganization: Water pollution from publicly owned treatment works (POTW) facilities across US states. *Palgrave Communications*. 3, 17070.

Maantay, J. (2002). Zoning law, health, and environmental justice: What's the connection? *The Journal of Law, Medicine & Ethics*, 30(4), 572-593.

Mack, E. A., & Wrase, S. (2017). A burgeoning crisis? A nationwide assessment of the geography of water affordability in the United States. *PLoS ONE* 12(1). Retrieved from http://e0169488. Doi:10.1371/journal.pone.0169488.

Marsh, B., Parnell, A. M., & Moss J, A. (2010). Institutionalization of Racial Inequality in Local Political Geographies. *Urban Geography*, 31(5)L 691-709.

McClanahan, B. (2016). Green and grey: Water justice, criminalization, and resistance. *Critical Criminology*, 22(3): 403-418.

McClendon, M. J. (1994). *Multiple regression and causal analysis*. Itasca, IL: Peacock.

McDonald, Y. J., & Jones, N. E. (2018). Drinking water violations and environmental justice in the United States, 2011-2015. *American Journal of Public Health*, 108:1401-1407.

Mohai, P., Pellow, D., & Timmons, R. J. (2009). Environmental justice. *Annual Review of Environment and Resources* 34:405-430.

National Drinking Water Regulations. (1986). 42. U.S. Code § 300g-1(b)(3)(C)(i)(V).

Natural Resources Congress. (2016). *Water Delayed Is Water Denied: How Congress Has Blocked Access to Water for Native Families*. House Committee on Natural Resources. Retrieved from https://naturalresources.house.gov/imo/media/doc/House%20Water%20Report_FINAL.pdf.

Nylen, N. G., Pannu, C., & Kiparsky, M. (2018). *Learning from California's Experience with Small System Consolidations: A Workshop Synthesis.* Center for Law, Energy & the Environment, UC Berkeley School of Law, CA: Berkeley. Retrieved from https://doi.org/10.15779/J2BW6Q or law.berkeley.edu/learning-from-consolidations.

Pastor, M. J., Sadd, J., & Hipp, J., (2001). Which came first? Toxic facilities, minority move-in, and environmental justice. *Journal of Urban Affairs*, 23(1):1-21.

Pilley, A. K., Jacquez, S., Buckingham R. W., Rao, S. P., Sapkota, K., & Kumar, S. (2009). Prevalence of arsenic contaminated drinking water in southern New Mexico border colonias [Abstract]. In: *American Public Health Association 137th Annual Meeting and Exposition on Water and Public Health*, 7-11 November 2009, Philadelphia, PA.

Popovich N., Albeck-Ripka, L., & Pierre-Louis K. (2021) The Trump administration rolled back more than 100 environmental rules. Here's the full list. *The New York Times.* Jan. 20. Retrieved from https://www.nytimes.com/interactive/2020/climate/trump-environment-rollbacks-list.html.

Pulido, L. (2016). Flint, environmental racism, and racial capitalism. *Capitalism Nature Socialism*, 27(3):1-16.

Pulido, L. (2017). Geographies of race and ethnicity Ⅱ: Environmental racism, racial capitalism, and state-sanctioned violence. *Progress in Human Geography*, 41(4):524-533.

Rahman, M. F., Yanful, E.K., & Jasim, S.Y. (2009). Endocrine disrupting compounds (EDCs) and pharmaceuticals and personal care products (PPCPs) in the aquatic environment: Implications for the drinking water industry and global environmental health. *Journal of Water and Health*, 7(2): 224-243.

Ringquist, E. J. (1998). A question of justice: Equity in environmental litigation, 1974-1991. *Journal of Politics*. 60:1148-1165.

Rubin, S. (2013). Evaluating violations of drinking water regulations. *Journal of American Water Resource Association*, 105: E137-E147.

Ruther, M. (2013). The effect of growth in foreign born population shares on county homicide rates: A spatial panel approach. *Regional Science* 93:1-23.

Sampson, R. J. (2012). *Great American City: Chicago and the Enduring Neighborhood Effect*. Chicago: University of Chicago Press.

Sampson, R. J. (2017). Urban sustainability in an age of enduring inequalities: Advancing theory and ecometrics for the 21st-centruy city. *Proc Natl Acad Sci USA*, 114(34): 8957-8962.

Sampson, R. J., & Winter, A. S. (2016). The racial ecology of lead poisoning: Toxic inequality in Chicago Neighborhoods, 1995-2013. *Du Bois Review*, 13(2): 261-283.

Schaider, L. A., Swetschinski, L., Campbell, C., & Rudel, R. A. (2019). Environmental justice and drinking water quality: Are there socioeconomic disparities in nitrate levels in U.S. drinking water?. *Environmental Health* 18:3-15.

Schnaiberg, A. (1980). *The Environment: From Surplus to Scarcity*. New York: Oxford University Press.

Siegel, S. (2019). *What's Wrong with What We Drink: Troubled Water*. St. Martin's Press, New York.

Sigman, H. (2002) *Letting states do the dirty work: State responsibility for federal environmental regulation*. Working Papers, Department of Economics, Rutgers, The State University of New Jersey, No. 2002-28.

Stackelberg, P., Furlong, E., Meyer, M., Zaugg, S., Henderson, A., and Reissman, D. (2004). Persistence of pharmaceutical compounds and other organic wastewater contaminants in a conventional drinking-water treatment plant. *Science of the Total Environment,* 329 (1-3): 99-113.

Steinberg, T. (1993). That world's fair feeling: Control of water in 20th century America. *Technology and Culture*, 34:401-409.

Stretesky, P., & Lynch, M. J. (2002). Environmental hazards and school segregation in Hillsborough county, Florida, 1987-1999. *Sociological Quarterly,* 43(4): 553-573.

Stretesky, P., & Hogan. M. (1998). Environmental justice: An analysis of Superfund sites in Florida. *Sociological Problems* 45:268-287.

Stretesky, P., and Lynch, M. J. (1999). Environmental justice and the prediction of distance to accidental chemical releases in Hillsborough county, Florida. *Social Science Quarterly*. 80(4): 830-846.

Stretesky, P., Long, M. A., & Lynch, M. J. (2013). *Treadmill of Crime: Political Economy and Green Criminology*. Abingdon, UK: Routledge.

Switzer, D., & Teodoro, M. P. (2017). The color of drinking water: class, race, ethnicity, and safe drinking water act compliance. *Journal of American Water Works Associations*, 109(9):40-45.

Taylor, D. E. (2014). *Toxic Communities: Environmental Racism, Industrial Pollution, and Residential Mobility*. New York: New York University Press.

Ternes, T. A., Meisenheimer, M., McDowell, D., Sacher, F., Brauch, H. J., Haist-Gulde, B., Preuss, G., Wilme, U., & Zulei-Seibert, N. (2002). Removal of pharmaceuticals during drinking water treatment. *Environmental Science and Technology*, 36 (17): 3855-3863.

U.S. Department of Commerce, Bureau of the Census. (2016). *2012-2016 American community survey (ACS) 5-year data profile*. Washington, DC: U.S. Department of Commerce, Bureau of the Census.

U.S. Environmental Protection Agency. (2008). *EPA's Environmental Justice Collaborative Problem-Solving Model.* Washing, DC: Environmental Protection Agency. Retrieved from https://www.epa.gov/sites/production/files/2016-06/documents/cps-manual-12-27-06.pdf.

U.S. Geological Survey (2009). *Contaminants in 20 percent of U.S. Private Wells*. Retrieved from https://www.usgs.gov/media/audio/contaminants-20-percent-us-private-wells.

U.S. Water Alliance. (2019). *Closing the Water Access Gap in the United States: A National Action Plan*. U.S. Water Alliance.

U.S. Environmental Protection Agency (2002). *Effects of Water Age on Distribution System Water Quality*. Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency (2008). *FACTOIDS: Drinking water and ground water statistics for 2007*. Washington, DC: U.S. Environmental Protection Agency, EPA 816-K-07-004.

U.S. Environmental Protection Agency (2015). *Review of State and Industry Spill Data: Characterization of Hydraulic Fracturing-Related Spills.* Washington, DC: U.S. Environmental Protection Agency, EPA 601-R-14-001. Retrieved from https://www.epa.gov/sites/production/files/2015-05/documents/hf_spills_report_final_5-12-15_508_km_sb.pdf .

U.S. Environmental Protection Agency. (2018). *Drinking Water Infrastructure Needs Survey and Assessment.* Washing, DC: Environmental Protection Agency.

U.S. Environmental Protection Agency (2016). *Drinking Water: EPA Needs to Take Additional Steps to Ensure Small Community Water Systems Designed as Serious Violators Achieve Compliance, Report No. 16-P-0108.* Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency (2019). *Integrated Risk Information System (IRIS) Program Outlook: A Message from the IRIS Program*, April 2019. Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (2003). *Introduction to EPA's Drinking Water Source Protection Programs.* Washington, DC: U.S. Environmental Protection Agency, Drinking Water Academy. Retrieved from https://cfpub.epa.gov/watertrain/pdf/swp.pdf.

U.S. Environmental Protection Agency. (2004). *Understanding the Safe Drinking Water Act*, EPA 816-F-04-030. Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (2020). *Basic Information about Source Water Protection.* Washington, DC: U.S. Environmental Protection Agency. Retrieved from https://www.epa.gov/sourcewaterprotection/basic-information-about-source-water-protection.

U.S. Geological Survey (2017). Estimated Use of Water in the United States in 2015, Circular 1441. Reston, VA: US Geological Survey.

U.S. Government Accountability Office. (2009). *Chemical Regulation: Observations on Improving the Toxic Substances Control Act*. GAO-10-292T. Washington, DC: US Government Accountability Office. Retrieved from http://www.gao.gov/new.items/d10292t.pdf.

U.S. Office of Management and Budget. (2014). *Metropolitan Area Designations by OMB: History, 2010 Standards, and Uses.* Congressional Research Service Report, CRS-14-R42005. Retrieved from https://www.everycrsreport.com/files/20140606_R42005_cc88d5c754b797d095e0880142d7c28aa739d871.pdf.

VanDerslience, J. (2011). Drinking water infrastructure and environmental disparities: Evidence and methodological considerations. *American Journal of Public Health*, S101:109-114.

Vanderwarker, A. (2012). Water and environmental justice. In *A Twenty-First Century U.S. Water Policy* Edited by Christian-smith J. & Gleick, P. H. (2012) 52-89. New York: Oxford University Press.

Walker, J. T., & Madden, S. (2012). *Statistics in criminology and criminal justice: Analysis and interpretation*, 4th edition. Sudbury, MA: Jones and Bartlett.

White, H. (2003). Syndrome behavior and the politics of environmental justice. In *Our Backyard: A Quest for Environmental Justice*. Edited by Visgilio, G., & Whitelaw. D, 107-124. Oxford, UK: Rowman & Littlefield.

White, R. (2003). Environmental issues and the criminological imagination. *Theoretical Criminology*, 7(4):483-506.

White, R. (2008). *Crimes against Nature: Environmental Criminology and Ecological Justice*. Cullompton, UK: Willan.

White, R. (2009). *Environmental Crime: A Reader.* Cullompton, UK: Willan.

White, R. (2010). A green criminology perspective. In *the SAGE Handbook of Criminological Theory*, edited by E. McLaughlin & T. Newburn, 410-426. Beverly Hills, CA: Sage.

Wilson, S., Hutson, M., & Mujahid, M. (2008). How planning and zoning contribute to inequitable development, neighborhood health, and environmental injustice. *Environmental Justice,* 1(4): 211-216.

Wilson, S. M, Heaney, C. D., & Wilson O. (2010). Governance structures and the lack of basic amenities: Can community engagement be effectively used to address environmental injustice in underserved Black communities?. *Environmental Justice* 3(4): 124-133.

Wisconsin Council Report (2020). *Wisconsin Groundwater Coordinating Council Report to the Legislature*. Wisconsin Department of Health Services. Retrieved from https://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/Nitrate.pdf.

Zahran, S., Hastings, D. W., & Brody, S. (2008). Rationality, inequity, and civic vitality: The distribution of treatment, storage, and disposal facilities in the Southeast. *Society and Natural Resources*, 21(3): 179-196.

Zukin, C., Keeter, S., Andolina, M., Jenkins, K., & Carpini, D. (2006). *A New Engagement? Political Participation, Civic Life, and the Changing American Citizen.* Oxford, UK: Oxford University Press.

APPENDICES

Appendix A: Descriptive Summary of SDWA Noncompliance Model

Table A1. Descriptive Summary: SDWA Noncompliance Model (n=1,861).

Variable	Mean	SD	Min	Max
Length of noncompliance	308.58	235.66	1.00	1185
Length of noncompliance(lg)	2.2328	.4961	.30	3.02
Proportion of Black	8.3370	12.3256	.00	81.50
Proportion of Hispanic	12.9770	17.3416	.10	99.00
Average of voting rate (2012&2016)	55.3947	8.8906	27.90	79.90
Proportion of nonprofit organization	4.0250	2.0832	.70	28.00
Ownership: private	.1006	.3074	.00	1.00
Ownership: public	.8940	.3074	.00	1.00
Utility size: small	.6005	.4898	.00	1.00
Utility size: medium	.2238	.4168	.00	1.00
Utility size: large	.1757	.3802	.00	1.00
Water source: surface	.5500	.4975	.00	1.00
Water source: ground	.4500	.4975	.00	1.00
County typology: farming	.09	.290	.00	1.00
County typology: mining	.11	.312	.00	1.00
Proportion of rural residents	48.0879	29.8252	.00	100
Metro status (1=metro)	.50	.500	.00	1.00
Population density	253.7194	816.1019	.3000	34127.00
League of Conservation Voters	30.76	25.541	.00	97
Midwest	.264	.441	.00	1.00
West	.166	.372	.00	1.00
South	.476	.499	.00	1.00
Northeast	.093	.291	.00	1.00

Appendix B: Multicollinearity Diagnostics

Table B1. Multicollinearity Diagnostics: SDWA Violation Model.

	VIF	1/VIF
Proportion of Black	2.29	.4369
Proportion of Hispanic	2.03	.4928
Proportion of Poverty	2.61	.3825
Average of voting rate (2012&2016)	1.90	.5285
Proportion of nonprofit organization	1.68	.5968
Ownership: private	1.10	.9129
Utility size: medium	1.15	.8691
Utility size: large	1.37	.7287
Water source: ground	1.20	.8333
County typology: farming	1.41	.7103
County typology: mining	1.15	.8712
Proportion of rural residents	3.33	.3003
Metro status (1=metro)	1.99	.5021
Population density	1.56	.6419
League of Conservation Voters (LCV)	2.03	.4919
Northeast	2.11	.4749
Midwest	1.83	.5474
West	1.79	.5601
Mean VIF	1.80	

Table B2. Multicollinearity Diagnostics: Noncompliance Model.

	VIF	1/VIF
Proportion of Black	1.72	.5816
Proportion of Hispanic	1.93	.5177
Proportion of Poverty	2.19	.4565
Average of voting rate (2012&2016)	1.79	.5589
Proportion of nonprofit organization	1.44	.6928
Ownership: private	1.11	.9012
Utility size: medium	1.28	.8562
Utility size: large	1.17	.7789
Water source: ground	1.26	.7942
County typology: farming	1.31	.7625
County typology: mining	1.14	.8806
Proportion of rural residents	3.52	.2884
Metro status (1=metro)	1.82	.5479
Population density	1.67	.5999
League of Conservation Voters (LCV)	2.10	.4761
Northeast	1.82	.5488
Midwest	1.48	.6738
West	1.45	.6902
Mean VIF	1.68	

Appendix C: Inflated (Binary) Portion of SDWA Violation, 2016-2018

Table C1. Inflated (binary) Portion of SDWA Violation, 2016-2018

	SDWA violation	
	b	SE
% Black	.012**	.004
% Hispanic	-.003	.003
% Poverty	-.045***	.011
% Nonprofit org.	-.115***	.027
% Voter turnout	-.003	.006
Size (Small omitted)		
Medium	.095	.095
Large	.085	.117
Ground water (Surface omitted)	1.064***	.096
Private (Public omitted)	.116	.111
Farm-dependent county	-.119	.154
Mining-dependent county	-.262†	.144
Density	.001***	.000
% Rural residents	.005*	.002
Rural county	.019	.165
Metro	.035	.099
LCV score	.014***	.002
Region (South omitted)		
Northeast	-.609*	.206
Midwest	.156	.119
West	.128	.136
Spatial lag: Weighted county-level violation	-.029***	.004

†<0.10 * p<.05 ** p<.01 *** p<.001

Appendix D. Kernel Density Estimate

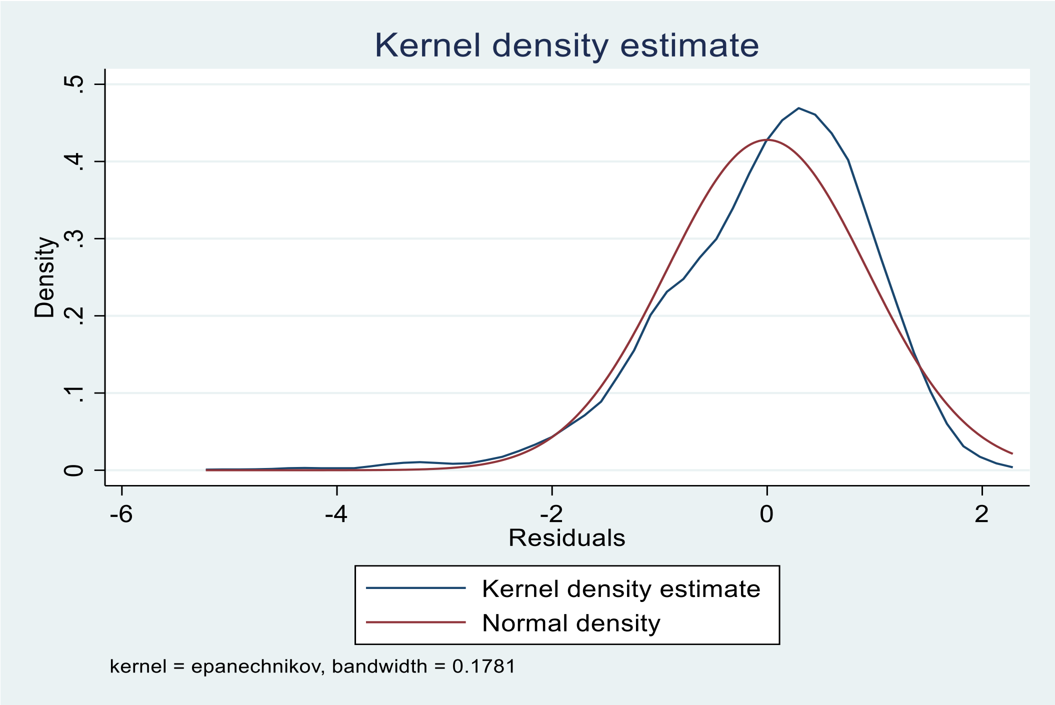

Figure D1. Kernel Density Estimate