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Recommendations for Strengthening Local Infrastructures for Clean Water in the United States

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Abstract

Several households in the Unites States face issues of poor water quality. While water is essential for healthy human development and is one of the most plentiful nature resources on earth, existing research suggests that many Americans live in communities where water systems are outdated and violate Clean Water Act standards. The current report provides a summary of violations in states and territories in the United States, identifies infrastructure vulnerabilities that could be contributing to these violations, and offers recommendations on how to strengthen these weaknesses that have contributed to a nationwide environmental injustice.

Keywords: Water; local infrastructure; clean water; United States

Introduction and Overview

Water is one of the most essential resources for human survival, wellness, and ecosystem health. The quality of water is crucial not only for ensuring public health, but also for sustaining the environment and supporting economic growth. The United States has a vast and diverse range of water resources – including rivers, lakes, groundwater, and oceans – that are integral to various aspects of human life and community industry.

The Clean Water Act (CWA) was enacted in 1972 to restore and maintain the integrity of the nation's waters. The act focuses on the following goals: 1) pollution control; 2) water quality standards; 3) reducing the number of impairments on public water systems (PWSs); and 4) funding for efforts to improve water quality and wastewater treatment facilities. Another related objective of the CWA is citizen participation, which empowers individuals and groups to hold polluters accountable and to seek legal remedies if water quality standards are violated. Overall, the CWA has been instrumental in improving the quality of U.S. waters, though challenges remain in addressing the emergence of several contaminants on PWSs and ensuring compliance across all 56 states and territories.

One of the reasons why safe drinking water is critical to human development is because of the direct relationship between water quality and public health outcomes. Contaminated water can be a breeding ground for various pathogens, including bacteria, viruses, and parasites, which can lead to waterborne diseases. Common pathogens such as Escherichia coli (E. coli), Salmonella, and Norovirus can cause gastrointestinal illnesses. These illnesses can lead to dehydration and, in severe cases, can be life-threatening, particularly for vulnerable populations such as young children, pregnant women, older adults, and those with compromised immune systems.

In addition to microbial contaminants, chemical pollutants in drinking water can present significant health risks. Heavy metals such as lead, arsenic, and mercury, often resulting from industrial activities or natural processes, can contaminate water supplies and pose serious physical and mental health problems. Perhaps the most lethal, lead exposure is particularly concerning as it can cause developmental delays and cognitive impairments in children. Arsenic, which can occur naturally or through industrial contamination (often called 'the silent killer'), is associated with an increased risk of many different types of cancers and skin lesions. Mercury, often released from industrial processes or local mining, has been found to be associated with neurological impairment, particularly in fetuses and young children (Rice et al., 2014).

The presence of chemical contaminants, including pesticides, herbicides, and industrial chemicals, can further exacerbate the physical and mental health risks associated with poor water quality. Pesticides used in agriculture can run off into water bodies. These have been shown to be associated with potential health issues, such as cancers and endocrine disruption (Bassil et al., 2007). Industrial chemicals, including solvents and byproducts from manufacturing processes, can contaminate water and lead to long-term health conditions. Emerging contaminants, such as pharmaceuticals and personal care products, represent a new challenge in local water quality management. For example, these substances, which enter water supplies through wastewater and runoff, are not often fully regulated. The presence of antibiotics and other drugs in water can contribute to antibiotic resistance, posing a serious public health threat. The potential health impacts of other emerging contaminants, such as microplastics and synthetic chemicals, are also areas of concern.

To manage these health risks, the United States has established regulatory frameworks and monitoring systems. The Safe Drinking Water Act (SDWA) mandates the Environmental Protection Agency (EPA) to set standards for drinking water quality, requiring public water systems to regularly test and treat water to remove contaminants. The SDWA also ensures that consumers are informed about their water quality through annual Consumer Confidence Reports (CCRs), which report any detected contaminants and the measures taken to monitor and address them. To assess whether PWSs are meeting these standards, the industry has created a water quality index (WQI), which is currently the most popular model for assessing surface water quality (Uddin et al., 2021). Water quality monitoring extends beyond drinking water to include recreational waters and wastewater. Public health agencies – such as the EPA – monitor recreational waters, such as local lakes and beaches, to ensure they are free from harmful levels of contaminants that could pose health risks. Along these lines, wastewater treatment facilities are essential in managing and treating sewage and industrial waste, ensuring that pollutants are removed before discharge into natural water bodies that are eventually used for drinking.

In addition to public health concerns, water quality issues have significant economic implications. Contaminated water can lead to increased healthcare costs due to the treatment of waterborne diseases and chronic conditions caused by pollutants. The economic burden of managing and treating these health issues can be substantial for individuals, state healthcare systems, and government agencies. For example, outbreaks of waterborne illnesses can lead to increased medical expenses, loss of productivity, and strain on the healthcare system. With regards to economic growth, property values may also be influenced by water quality. Areas with polluted water sources, or impaired water bodies, may experience a decrease in property values and reduction in investments. Concerns about local water quality can deter potential buyers and investors, leading to economic losses for communities that need expansion. Additionally, property owners may face increased costs for water treatment and remediation efforts if their properties are affected by toxins or pollutant contamination. Furthermore, industries that rely on clean water, such as agriculture, fishing, and tourism, can be affected by poor water quality. With respect to agriculture, poor water quality can impact yearly crop yields and irrigation practices. Contaminated water can affect the safety of crops and livestock, leading to economic losses for farmers. The fishing industry can also suffer by experiencing declining fish populations due to water pollution that affects both commercial and recreational fishing. Tourism, particularly in areas known for water-based recreational activities, can be affected by water quality issues. Polluted or unsafe water can deter tourists and impact local businesses, leading to economic losses for communities. Thus, investing in local water quality management and infrastructure can provide significant economic benefits. Effective water treatment, such as advanced filtration and purification systems, help improve water quality and reduce the long-term costs associated with contamination, such as poor health and economic losses. Sustainable water management practices, including conservation efforts, efficient use of water resources, and adequate amount of qualified system operators at utility plants, can ensure that water remains available and of high quality for residents of communities in the United States.

Problem Statement

Despite advancements in water quality management, several challenges continue to persist. To date, there are more than 148,000 PWSs providing drinking water to Americans. The EPA sets legal limits for drinking water to not have more than 90 contaminants. Every year, it is estimated that between 3-10% of these PWSs in the United States exceed this legal limit. Recently contaminants, such as pharmaceuticals, personal care products, and microplastics, have introduced new risks. These substances can enter water supplies through wastewater and runoff, and their effects on health and the environment are not always fully understood. Addressing these emerging contaminants will require future innovative research, advanced treatment technologies, and updated regulatory frameworks.

Regulatory frameworks such as the SDWA and CWA play crucial roles in addressing water quality challenges. The SDWA establishes standards for drinking water quality, while the CWA regulates pollutant discharges and supports water quality improvements for surface waters. The EPA and state agencies work to enforce these regulations, conduct research, and support initiatives aimed at improving water quality. Public awareness and community engagement are essential for effective water quality management. Educating the public about water conservation, pollution prevention, and the importance of water quality fosters greater community involvement and support for water protection efforts. Public participation in water quality monitoring, conservation initiatives, and policy advocacy can lead to positive change and contribute to improved water management.

The current report provides a summary of violations in states and territories in the United States. The report discusses possible infrastructure vulnerabilities that may contribute to reported violations and offers recommendations for how to strengthen these weaknesses to improve water quality. Annual data from 2020 to 2023 on water violations across states and territories of the United States from the Environmental Protection Agency (EPA) are analyzed to summarize trends in the number of violations and percentage of public water system (PSW) violations. To date, this is the first report to analyze EPA data on water violations for 2023 and situate them within the larger context of violations since 2020. It is the hope that evaluating this data will help to identify geographic hotspots of vulnerability, which can be the target of intervention.

Topic Discussion

Through ongoing investment in water quality management, conservation efforts, and technological advancements, the United States can safeguard its water resources and ensure their availability for everyone. Prioritizing water quality is not only a responsibility, but also a critical investment in the future sustainability and resilience of the nation (Vasistha & Ganguly, 2020). By fostering a comprehensive approach to water quality management, we can protect public health, preserve ecosystems, and support economic development, ensuring that water remains a vital and sustainable resource. This holistic approach, encompassing regulatory measures and technological innovations will be crucial in navigating the evolving challenges and ensuring the long-term sustainability of our nation's water resources. By working together and remaining vigilant, we can address water quality issues and secure a healthier and more sustainable future.

Without question, access to clean and safe water is essential for public health, environmental integrity, and economic stability. In the United States, substantial progress has been made in addressing water quality issues, yet persistent and emerging challenges continue to impact communities, ecosystems, and industries. The following section delves into the various dimensions of the clean water problem, examining sources of contamination, regulatory and infrastructure challenges, as well as implications for public health.

A few of the common sources of contamination for water in the United States include microbial and chemical contaminants. Microbial contaminants include pathogenic bacteria, which are pathogens such as Escherichia coli (E. coli), Salmonella, and Vibrio cholerae. These have been shown to be related to gastrointestinal illnesses and, in severe cases, serious health complications. Microbial contamination often originates from animal waste, sewage spills, and agricultural runoff. One common source of microbial contamination includes inadequate wastewater treatment. This often occurs when many wastewater treatment facilities are outdated or insufficiently maintained, leading to the release of untreated or partially treated sewage into water bodies. Another source is agricultural runoff. This is typically runoff from farms carrying manure and fertilizers that can introduce pathogens into rivers, lakes, and groundwater, impacting both recreational and drinking water sources. Another source is urban runoff, which can be storm water runoff that can carry pathogens from streets, pet waste, and other sources into water supplies, increasing the risk of contamination.

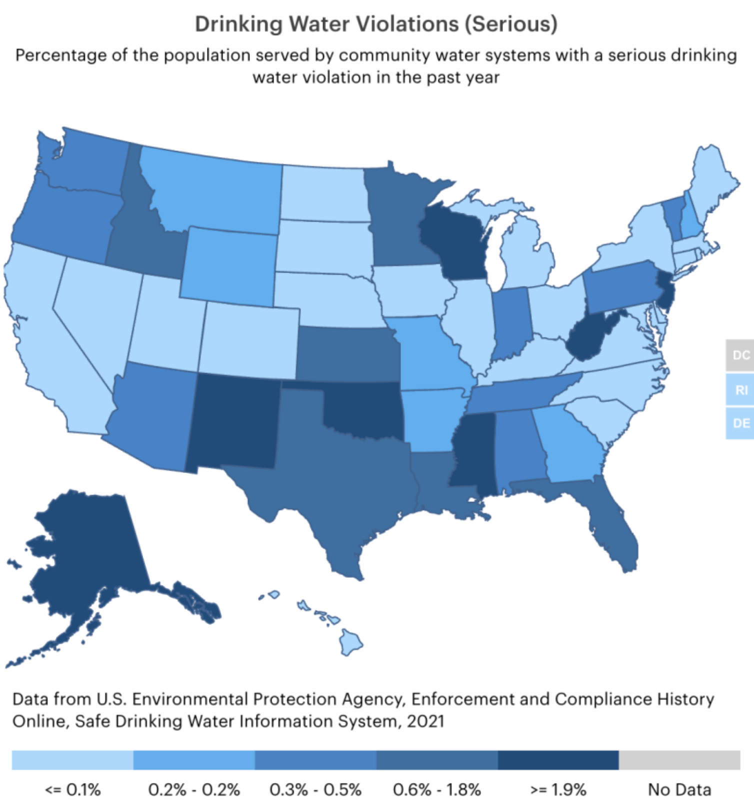
There are also chemical contaminants. These include heavy metals, pesticides and herbicides, and industrial chemicals. Metals such as lead, arsenic, and mercury can contaminate water sources and pose significant health risks. Lead, for instance, often leaches to water from old pipes and plumbing systems, affecting children's developmental and cognitive functions (Shih et al., 2007). Arsenic, commonly found in groundwater, is associated with various cancers and skin lesions (Tapio & Grosche, 2006). Mercury, which can accumulate in aquatic organisms, can increase the risk of neurological disorder (Cariccio et al., 2019). Agricultural chemicals, including pesticides and herbicides, can contaminate water bodies through runoff. These chemicals have been linked to health issues, such as endocrine disruption, reproductive harm, and cancer (Zahm et al., 1997). Their persistence in the environment poses long-term risks. Chemicals used in industrial processes, such as solvents and byproducts, can contaminate water through discharges and spills. Persistent organic pollutants (POPs) and other industrial chemicals may also have severe long-term health and environmental impacts on humans. The sources of these chemicals generally include: 1) industrial discharges from factories and manufacturing plants that can release chemicals into water bodies through direct discharges or accidental spills, 2) agricultural practices that use pesticides, herbicides, and fertilizers that lead to chemical runoff into nearby water stream sources and 3) household products, such as cleaning instruments and pharmaceuticals, which can contribute to water pollution when disposed of improperly or through wastewater.

There are also a few emerging contaminants to consider such as microplastics. These are tiny plastic particles from consumer products and plastic waste that can contaminate local water bodies. Microplastics can have harmful effects on aquatic organisms and may accumulate in the environment. In a similar vein, per- and polyfluoroalkyl substances (PFAS) are potential toxic agents. PFAS are a group of synthetic chemicals used for various industrial reasons and found in consumer products. They are highly persistent in the environment and can contaminate water supplies, leading to health risks, such as cancer and liver damage (Messmer et al., 2022).

Based on the numerous contaminants that may degrade water resources for local communities in the United States, it is important to the understand the current water infrastructure responsible for maintaining water quality. Unfortunately, the United Sates currently faces several challenges related to its aging water infrastructure. These primarily include – but are not limited to – pipe leaks and breaks as well as inadequate treatment facilities. To illustrate, many water and sewer systems are old and prone to leaks, which can lead to contamination and loss of clean water. The aging infrastructure of many water systems in the United States also contributes to water main breaks, which can disrupt service and require costly repairs (Greer, 2020). In addition to the deterioration of infrastructures across the United States, there is currently a high level of inadequate treatment facilities serving local communities (Wu et al., 2021). Many wastewater treatment plants are outdated and may not be equipped to handle contaminant infiltration, emerging contaminants, or increased loads of contaminants from growing populations. Upgrading these facilities is essential, but often faces financial and logistical hurdles such as local or state budget allocations to repairs. There is also the possibility of inconsistent monitoring and enforcement due to budgetary restrictions and/or lack of qualified personnel. Comprehensive monitoring of water quality is necessary to identify and address contaminants, but resources for monitoring may be limited. Inadequate data can hinder the ability to manage and respond to water quality issues effectively.

One data resource that provides the most inclusive information on drinking water violations every year in the United States is the EPA. Figure 1 presents percentage estimates on

Figure 1.



Adopted from the United Health Foundation Report on Drinking Water Violations (Serious) (United Health Foundation, 2024) serious drinking water violations for every state in 2021 based on the population served by community water systems. As can be seen, it appears that most states (with the exceptions of Alaska, Mississippi, New Jersey, New Mexico, Oklahoma, West Virginia, and Wisconsin) reported less than 2% of the population that was served by a community water system had a serious drinking water violation in 2021. However, it is important to put these findings into context with trends in states over time for total drinking water violations and the percentage of violations for failure to comply to industry standards as these can be indicators of overall infrastructure operational effectiveness. One would expect that violations and the percentage of compliance failures will decrease over time if infrastructures for public water systems (PSWs) are being strengthened. Table 1 presents the number of PWS violations, number of compliance violations, and trends for violations by state from 2020 to 2023. The last column of the table also presents the percentage of PWS with violations for 2023 to provide an up-to-date estimate of state rankings for water system violations. As shown, there was much variation in the trend of violations from 2020-2023. Based on the total amount of violations across all states and territories in the United States, the amount of violations increased from 37,936 in 2020 to 40,368 in 2023 (+6.41%) and the amount of violations for compliance status increased from 14,727 in 2020 to 16,396 in 2023 (+11.33%). The national prevalence rate of PWSs with compliance violations for 2023 was 27.5%. While there were several states that exceeded this percentage in 2023, the five states with the highest rates were Mariana Islands (81.4%), District of Columbia (80.0%), West Virginia (74.8%), Virgin Islands (65.4%), and Oklahoma (56.1%). A pattern among these states is the relatively small size of the territory (i.e., Mariana Islands, District of Columbia, and Virgin Islands) and high poverty levels (i.e., West Virginia and Oklahoma),

Table 1. Number of Public Water System (PWS) Violations by State from 2020-2023

State or Territory	2020		2021		2022		2023			Trend for	% of PWS
	Number of Violations	Violation of Compliance Status	Number of Violations	Violation of Compliance Status	Number of Violations	Violation of Compliance Status	Number of Violations	Violation of Compliance Status	Trend for Violations	Violation of Compliance Status	with Violations for 2023
Alabama	92	12	116	22	202	21	130	37	↗	↗	22.8%
Alaska	642	177	642	167	638	148	598	140	→	↘	43.6%
American Samoa	18	2	16	1	18	2	17	7	↗	↗	17.9%
Arizona	709	220	769	227	729	245	794	258	→	→	51.9%
Arkansas	359	202	307	170	330	201	323	204	→	→	31.5%
California	988	356	1091	407	1079	373	837	389	→	→	11.3%
Colorado	770	289	793	313	828	290	821	314	↗	→	38.4%
Connecticut	1065	729	1048	718	1066	630	1013	571	→	↘	42.0%
Delaware	79	57	85	56	84	55	75	61	→	→	15.8%
District of Columbia	4	3	4	3	3	3	4	1	→	→	80.0%
Florida	1437	653	1382	720	1587	760	1885	737	→	→	36.1%
Georgia	424	235	608	301	699	344	730	387	↗	↗	30.2%
Guam	3	1	2	1	1	0	1	0	→	→	12.5%
Hawaii	5	0	1	0	4	2	2	2	→	→	1.4%
Idaho	844	481	856	503	910	527	952	525	↗	↗	46.5%
Illinois	1130	212	1252	350	1386	400	1393	678	↗	↗	26.2%
Indiana	1587	323	1550	310	1520	336	1419	407	↘	→	35.0%
Iowa	356	96	376	135	419	134	401	161	↗	↗	21.8%
Kansas	479	250	373	204	447	204	337	143	→	→	34.6%
Kentucky	99	23	97	45	100	17	78	8	→	↘	18.0%
Louisiana	535	316	571	346	589	317	548	324	↗	→	42.3%
Maine	676	322	879	545	876	462	863	460	↗	↗	44.5%
Mariana Islands	43	13	29	13	46	14	57	5	↗	↘	81.4%
Maryland	232	61	255	70	319	76	317	71	↗	↗	9.6%
Massachusetts	244	182	273	198	288	201	334	234	↗	↗	19.0%
Michigan	2171	190	2207	300	2272	339	2213	352	↗	↗	17.7%
Minnesota	152	15	321	130	209	71	192	47	→	↘	2.9%
Mississippi	201	83	217	84	272	128	255	136	→	→	21.4%
Missouri	879	325	818	288	864	282	867	295	→	→	30.5%
Montana	790	306	749	255	813	283	718	230	→	↘	31.7%
Nebraska	68	9	64	6	78	6	98	15	↗	↗	7.2%
Nevada	154	21	141	18	156	30	169	60	→	↗	27.3%
New Hampshire	488	108	135	120	417	120	441	113	→	→	17.6%
New Jersey	1072	504	1261	438	1153	506	1197	623	→	→	33.5%
New Mexico	687	332	638	256	478	295	484	195	↘	↘	44.6%
New York	1586	401	1602	445	2141	479	2306	513	↗	↗	26.6%
North Carolina	1223	525	1119	531	1232	562	1328	647	↗	↗	25.3%
North Dakota	102	55	100	64	124	58	108	59	→	→	25.8%
Ohio	1461	1119	1568	1195	1622	1303	1642	1284	↗	↗	37.6%
Oklahoma	748	195	741	227	798	242	757	229	→	→	56.1%
Oregon	898	230	816	250	1161	297	1326	376	↗	↗	49.9%
Pennsylvania	3348	1009	3467	1155	3957	1267	3660	1323	↗	↗	45.3%
Puerto Rico	373	180	373	94	256	43	214	41	↘	↘	46.0%
Rhode Island	127	26	89	19	105	22	111	20	↘	→	23.3%
South Carolina	124	83	132	84	160	85	144	91	→	→	9.8%
South Dakota	139	56	126	63	114	26	104	40	↘	↘	15.7%
Tennessee	234	148	298	197	301	206	302	213	↗	↗	38.5%
Texas	3152	1765	3244	1722	3192	1731	2989	1613	↘	↘	41.0%
Utah	559	200	383	111	345	68	321	115	↘	↘	29.6%
Vermont	330	178	424	225	424	223	459	217	↗	↗	32.7%
Virgin Islands	174	111	174	165	174	170	174	173	→	→	65.4%
Virginia	503	69	508	82	550	83	617	134	↗	↗	21.5%
Washington	1052	171	1005	192	1255	147	1028	179	→	→	22.5%
West Virginia	653	317	652	308	677	222	622	174	→	↘	74.8%
Wisconsin	1426	650	1307	580	1257	587	1296	630	↘	→	11.5%
Wyoming	242	131	266	132	267	128	297	135	↗	→	38.0%
Total	37936	14727	38320	15561	40992	15771	40368	16396	↗	↗	27.6%

which may represent a weak infrastructure for monitoring and maintaining safe levels of drinking water. In sum, over a quarter of PWSs in the United States and territories in 2023 received a violation for lack of compliance to safe water drinking standards.

In addition to the numerous healthcare implications associated with weak local and state infrastructures for maintaining clean water, there are several economic and environmental burdens related to poor water quality that may be emerging problems in the United States. These include infrastructure and remediation costs, which entail engaging in environmental remediation efforts and addressing contamination sources that require significant financial investment. These costs can impact local and federal budgets and divert resources from other priorities for public safety. Also included in this category is the property market. Water quality issues can lead to decreased property values and affect industries reliant on clean water, such as agriculture, fishing, and tourism. Reduced property values and economic losses can therefore have broader economic implications for communities beyond public health. With respect to environmental impact, failed water system infrastructures can lead to contaminants, such as excess nutrients, heavy metals, and chemicals that disrupting aquatic ecosystems, leading to problems like harmful algal blooms and aquatic dead zones. These issues can result in fish kills, loss of biodiversity, and habitat degradation. Contaminants entering water bodies can affect soil quality and plant health as well. Excess nutrients and chemicals can lead to soil degradation and reduced agricultural productivity, affecting food security and environmental sustainability.

Based on EPA data from 2020 to 2023, it is clear that many state and territory infrastructures are struggling to protect local water sources from contaminants to provide safe drinking water to community members. The clean water problem in the United States is multifaceted to say the least. It involves a range of contaminants, regulatory and infrastructure challenges, and significant public health and environmental impacts. Addressing these issues will require a comprehensive approach that includes a range of initiatives including 1) updating regulations, 2) investing in technology and infrastructure, 3) engaging communities, and 4) doing our best to foster collaborative efforts across industries and communities. By tackling these challenges, the nation can work towards ensuring safe and clean water for all. Yet, this will require supporting public health, environmental sustainability, and economic development. The commitment to improving water quality across the country in urban, suburban, and rural areas is essential for securing a healthier and more sustainable future for current and future generations of Americans.

Way Forward

Ensuring access to clean and safe water is essential for maintaining public health, protecting environmental ecosystems, and supporting economic stability in any society. Although significant progress has been made in improving water quality with local infrastructures, ongoing and emerging challenges require a comprehensive approach to creating more clean water in the United States. This section outlines key recommendations for moving forward to strengthen infrastructures for water quality. These include a focus on: 1) infrastructure improvements, 2) employing advanced technologies, 3) increasing regulatory enhancements, and 4) addressing new issues surrounding contaminant management, conservation efforts, and community engagement.

1. Upgrade and Modernize Water Infrastructures

A. Replace Aging Infrastructure: Develop a prioritized plan for replacing and rehabilitating old and deteriorating water and sewer pipes, especially in areas with frequent leaks or contamination issues. Focus on regions with known infrastructure problems and high risks of contamination. These may include rural or urban areas that are in close proximity to runoffs or factory plants. In Texas specifically, there are more than 7,000 water systems and many have not been updated since the 1960s or 1970s. This may increase risk of transporting poor water and pipe fractures. Colonia, Texas - a small predominately Latino community along the Texas-Mexico border – are currently without a basic infrastructure for water and sewage. As a result, close to a third of residents do not have access to safe drinking water according to recent data from the Rural Community Assistance Program. Dedicating local or state financial resources to update these systems can help improve clean water for many small rural towns in Texas and across the United States.

B. Infrastructure Material Upgrades: Use modern materials such as high-density polyethylene (HDPE) for new pipes to improve durability and reduce leakage (Whelton & Dietrich, 2009). It might also be recommended that industry professionals implement trenchless technologies where feasible to minimize disruption and reduce costs associated with traditional excavation methods (Wu et al., 2021).

C. Modernize Water Treatment Facilities: Invest in upgrading water and wastewater treatment facilities to incorporate advanced treatment technologies. These upgrades might include improved filtration systems, disinfection methods, and sludge management techniques. Additionally, expand the capacity of treatment facilities to accommodate growing populations and demands. Be sure that facilities are equipped to handle both conventional contaminants and emerging pollutants in local areas.

D. Expand Infrastructure Investment: Local, state, and national utility leaders should advocate for increased federal and state funding to strengthen water infrastructure projects. Specifically, they should assess whether additional funding sources, such as infrastructure banks, green bonds, and climate adaptation funds are available to them. For example, the Drinking Water State Revolving Fund (DWSRF) in Texas is an implemented program that provides low-interest loans to PWSs for infrastructure improvements. This helps communities replace old pipes, improve treatment facilities, and enhance water quality in general.

E. Implement Maintenance and Resilience Strategies: Industry leaders and workers should establish regular maintenance schedules for existing water infrastructure systems to prevent failures. It is recommended that predictive maintenance technologies be implemented when possible to identify and address issues before they lead to significant problems down the road. In addition, design and implement infrastructure upgrades that enhance resilience to climate change impacts, such as flooding and extreme weather events. This can be done by incorporating climate adaptation measures into infrastructure planning and design.

2. Enhance Water Treatment Technologies

A. Adopt Advanced Treatment Methods: Incorporate membrane filtration technologies, such as reverse osmosis and ultrafiltration, to effectively remove contaminants, including microorganisms, heavy metals, and organic compounds in water (Acero et al., 2010). It would also be helpful if systems could use activated carbon filtration to address chemical contaminants, including pesticides, pharmaceuticals, and industrial chemicals.

B. Utilize UV and Ozone Treatment: Implement ultraviolet (UV) disinfection systems to address microbial contaminants and reduce the reliance on chemical disinfectants. UV systems can be effective against a broad range of pathogens, including those resistant to chlorine (Kheyrandish et al., 2017). Incorporate ozone treatment as well to address both microbial and chemical contaminants. Ozone is a powerful oxidant that can effectively remove organic compounds and disinfect water (Rodríguez et al., 2008).

C. Support Technological Research and Development: It will be important for federal and state governing bodies to provide grants and funding for research initiatives focused on developing new water treatment technologies and solutions. This will require encouraging collaboration between academic institutions, research organizations, and industry partners. To facilitate the transfer of innovative water treatment technologies from research laboratories to commercial applications there needs to be consistent support of pilot research projects and demonstrations to refine new methods.

D. Pilot Testing and Evaluation: Implement pilot programs to test and evaluate emerging water treatment technologies and practices. Use the data generated from these programs to inform the adoption and integration of methods into existing water treatment systems. After this, there should be performance monitoring systems implemented to assess the effectiveness of these new technologies and practices. Monitoring data will inform decisions about effective and efficient technology use.

3. Strengthen Regulatory Frameworks

A. Update and Expand Regulations: Update regulatory standards to address the issue of emerging contaminants, such as pharmaceuticals, microplastics, and per- and polyfluoroalkyl substances (PFAS). With this in mind, it will be important to establish enforceable limits and treatment requirements for these toxins. This will likely require revisions to health-based standards for existing contaminants based on recent research findings. Based on these findings, industry leaders and workers should use this knowledge to ensure that standards reflect a current understanding of health risks.

B. Improve Compliance and Enforcement: There should be an effort to strengthen enforcement mechanisms to ensure state and local compliance with water quality standards. Increase the amount of resources for inspections, monitoring, and enforcement. Also, enhance transparency and accountability in regulatory practices. A few examples of this could be the continuation of publishing water quality data, compliance reports, and enforcement actions to keep the public informed. One specific example in Texas Commission of Environmental Quality (TCEQ), which sets regulatory standards for drinking water quality, ensuring that public water systems comply with EPA regulations and are in line with health-based requirements.

C. Enhance Interagency Collaboration: Improve coordination between federal, state, and local agencies responsible for water quality management. This will entail developing policies and strategies that address water quality issues in a comprehensive way. For example, the sharing of resources, data, and expertise among agencies to enhance water quality management will be critical. It would also help if joint task forces or working groups are created to address specific water quality issues. In Texas, the Texas Water Development Board (TWDB) has been created to oversee water planning, funding, and development initiatives. The board works on projects focused on improving drinking water, wastewater management, and the protection of groundwater.

D. Engage Stakeholders in Policy Development: Engage stakeholders, including environmental organizations, industry representatives, and community groups, that are involved in the regulatory process. Use their input for policy changes and decision-making. In addition, provide educational resources and training to stakeholders to help them better understand and participate in water quality management practices. The Texas Clean Rivers Program is one example of a state initiative that focuses on monitoring and managing water quality across river basins in Texas. The program creates a way for local stakeholders to collaborate to assess water quality data and development strategies for improvement.

4. Address Emerging Contaminants

A. Increase Monitoring and Research: Comprehensive monitoring programs should be established with a focus on addressing emerging contaminants. Monitor both drinking water sources and wastewater. Implement real-time monitoring systems to detect and respond to contamination events more quickly. Use data from these systems and practices to create more informed treatment and management decisions.

B. Support Research Initiatives: Invest in research to better understand the sources, deleterious health effects, and treatment options for emerging contaminants. Collaboration with research institutions and industry experts will be critical to advance knowledge and create solutions on this topic. Furthermore, there should be studies conducted to assess the health impacts of emerging contaminants on different populations. These findings can be used to inform policy and treatment decisions.

C. Invest in Targeted Treatment Technologies: Develop and implement treatment technologies specifically designed to address emerging contaminants. This may include advanced oxidation processes, ion exchange, and adsorption methods (Miklos et al., 2018). Test new treatment technologies in pilot projects to evaluate their effectiveness and feasibility. Use pilot data to guide decisions about broader implementation.

D. Implement Source Control Measures: Implement measures to reduce the introduction of emerging contaminants into state and local water systems. This includes not only promoting proper disposal of pharmaceuticals and chemicals, but reducing the use of products that contribute to microplastic pollution specifically. One example of this could be enforcing regulatory controls on the production, use, and disposal of substances that contribute to this problem.

5. Promote Water Conservation and Efficiency in Communities

A. Public Education and Outreach: Create and launch public awareness campaigns to promote water conservation and efficient water use. Share information about water-saving practices and the importance of protecting water resources with local communities and stakeholders. This might include developing educational programs for schools, businesses, and nearby communities to teach them about approved water conservation techniques and the impact of water use on their local environment.

B. Incentive Programs for Water Efficiency: Offer incentives and rebates to local community members for the adoption of water-saving technologies, such as low-flow fixtures and water-efficient appliances. This may include encouraging residential and commercial customers to upgrade their water systems. Promoting the adoption of high-efficiency technologies through incentives and regulations could also be another viable strategy.

C. Develop Water Reuse Projects: Support the creation and implementation of water reuse projects that treat and recycle wastewater for various applications, including industrial processes and irrigation uses. In conjunction with this this, develop guidelines and best practices for safe water reuse to be distributed to local community members.

Furthermore, implementing pilot projects to offer evidence of feasibility and the benefits of water reuse would be helpful and possibly encourage participation.

6. Foster Community Engagement and Education

A. Community-Based Programs: Develop community-based water management programs that involve local residents in monitoring and protecting water resources. This will involve encouraging community participation in water quality initiatives and decision-making. It may also involve promoting opportunities for water quality monitoring, cleanup events, and conservation efforts. This will help foster local stewardship groups and community organizations that focus solely on water protection.

B. Public Engagement and Dialogue: Host public forums, workshops, and educational events to raise awareness about water quality issues and solutions. Facilitate discussions between water managers, policymakers, and community members. Implement feedback mechanisms to gather input from communities on water quality issues and proposed solutions. Use feedback to refine programs and policies.

C. Citizen Science Initiatives: Encourage citizen science projects that involve volunteers in water quality monitoring and data collection. Provide training and resources to support these projects and ensure data quality. Develop platforms for community members to report water quality issues and potential sources of contamination. Use reports to address local problems and inform broader water management efforts.

D. Advocacy and Policy Support: Support advocacy campaigns that promote stronger water quality regulations and policies. Collaborate with advocacy organizations to advance water protection and sustainability goals. Engage in policy development efforts to address emerging water quality challenges. Advocate for policies that support clean water access, state and local infrastructure improvements, and environmental protection.

In conclusion, addressing the clean water crisis in the United States requires a holistic and coordinated approach including infrastructure upgrades, advanced technologies, regulatory improvements, and community engagement. By implementing these recommendations, the United States can reduce the amount of unsafe drinking water and make significant strides toward ensuring a sustainable and resilient state and local water system. Enhancing water quality and availability will protect public health, improve environmental sustainability, and strengthen the economy. Through ongoing investment, innovation, and collaboration, the United States can achieve the goal of providing clean and safe water for all citizens.

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Biographical Note: Eric Connolly is an Associate Professor in the Department of Criminal Justice and Criminology at Sam Houston State University. His research uses a wide range of longitudinal research designs to mainly examine he following questions: 1) how are biological, psychological, and social factors related to stability and change in delinquency and crime; 2) are there bi-directional associations between health, victimization, and offending across the life span, and; 3) to what extent are there short- and long-term effects of different forms of early life adversity for delinquency and crime later in life. He has published over 80 peer-reviewed publications on these topics having used quasi-experimental research designs to better understand the extent to which modifiable biopsychosocial factors are related to individual changes in offending and victimization. His work has appeared in journals such as *Child Development*, *Child Maltreatment*, *Criminology*, *Journal of Adolescent Health*, *Journal of Quantitative Criminology*, and *Social Science & Medicine*. Recently, he has begun to focus pediatric traumatic brain injury, sleep disturbance, and delinquent behavior in previously adjudicated and community samples of youth.

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