

To What Extent Are the Long-Term Effects of Polyfluoroalkyl Substances and Microplastics in Freshwater Used in American Cities?

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Abstract

Polyfluoroalkyl substances (PFAS) and microplastics have become widespread contaminants in freshwater systems across the United States, raising major concerns about public health, water infrastructure, environmental sustainability, and economic resilience. To examine the long-term impacts of these persistent pollutants on freshwater resources used by American cities, this literature review combines findings from government reports, reviewed studies, and scientific review articles. The review explores how PFAS and microplastics enter freshwater systems via wastewater, landfills, industrial discharges, and other human-made sources. These molecules' resistance to degradation allows them to bioaccumulate and affect human populations primarily through drinking water. Current evidence connects long-term PFAS exposure with immune dysfunction, endocrine disruption, thyroid diseases, kidney disease, developmental effects, and certain cancers, although the underlying biological mechanisms remain an active area of investigation. Beyond human health, the review analyzes how these contaminants disrupt freshwater ecosystems, move through aquatic food webs, and reduce biodiversity, which creates long-lasting ecological consequences. It also analyzes the socioeconomic challenges associated with contamination, including the need for expensive advanced water technologies, increased healthcare expenses, declining property values, aging infrastructure upgrades, and financial pressures on local governments. Finally, the review analyzes PFAS and microplastic contamination through a public policy and economic perspective, explaining how cleanup costs are often shifted from polluting industries to local governments and taxpayers. Altogether, the evidence shows that PFAS and microplastic contamination is a complex interdisciplinary challenge requiring continued scientific research, stronger regulatory policies, improved environmental monitoring, and sustainable management strategies to protect freshwater resources and public well-being.

Keywords: Long-term effects, polyfluoroalkyl substances, microplastics, freshwater

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Introduction

Every glass of tap water most Americans drink today carries an invisible intrusion: synthetic chemicals that have never fully broken down since they were first manufactured decades ago. Polyfluoroalkyl substances are an umbrella term for the thousands of synthetic chemicals that resist natural decay. These substances, also known as “forever chemicals,” have one of the strongest bonds in organic chemistry, carbon and fluorine bonds, allowing the chemicals to persist within their environments. In parallel with the pervasive growth and nondegradable nature of Polyfluoroalkyl substances, microplastics are permeating our environments as well. Microplastics are plastic particles smaller than 5 millimeters (National Center for Biotechnology Information, 2024). Both of these emerging pollutants have transformed into an environmental threat to freshwater ecosystems across the United States. This is an issue for every American, as freshwater bodies sustain ecological systems.. Not only is our drinking water derived from these freshwater bodies, but water is also used for global agriculture, disaster regulation, and the balance of ecosystems.

What started as a century of remarkable technological advances unfortunately resulted in an ongoing health disaster. The mass incorporation of durable plastics and non-stick polymers into various household appliances and food packaging has unfortunately resulted in an ongoing health disaster. It is the very nature of these synthetic materials, specifically their stability and heat resistance, that makes them extremely harmful to the environment and the people using these products daily. Most Americans use a wide range of these chemical compounds without realizing the dangers they pose. The clean tap water that enters our homes contains a mixture of microscopic synthetic chemicals that natural processes cannot degrade. The proportion of people affected by these chemicals is tremendous. The research data shows that perfluorooctanoic acid (PFOA), one of the most common perfluorinated chemicals and a type of polyfluoroalkyl substance, is found in the blood serum of about 99.7 percent of the US population (McNamara et al., 2018)

The driving factor for this extensive exposure is the pollution of public and private drinking water sources. An important report published in 2016 by the National Library of Medicine demonstrated the presence of PFAS in drinking water systems used by the residents of 33 different U.S. states (Hu et al., 2016). Additionally, an analysis conducted by the Environmental Working Group of national water quality monitoring results indicated that around 110 million Americans consume drinking water contaminated with dangerous amounts of per- and polyfluoroalkyl substances.

This contamination does not remain confined to pipes and reservoirs; it has escalated to people's health. Research has shown that this circulation of polyfluoroalkyl substances is detrimental in its physiological effects caused by the continuous exposure of individuals to these artificial substances, creating a threat to people's well-being. The International Agency for Research on Cancer (IARC) classified polyfluoroalkyl substances into the Group 2B carcinogen category. Exposure was discovered to be linked to kidney and testicular cancer (McNamara et al., 2018).

The diffusion extends beyond exposure in daily life; these artificial particles can cross and contaminate biological barriers once thought impermeable. Environmental biomonitoring has increasingly demonstrated transplacental transfer, revealing that newborns are now entering



the world with microplastics and synthetic fluorinated particles already embedded in their cord blood and biological tissues from birth (Zhu et al., 2024).

Given the prevalent presence of microplastics and fluorinated compounds in freshwater systems, there is a need for structural intervention in the field of environmental engineering and municipal management. Conventional water treatment infrastructure systems have been engineered to remove suspended solids from water and eliminate pathogenic organisms in the process. However, they do not possess the necessary filtration technology to isolate and break down chemicals that are linked by carbon-fluorine covalent bonds, which require higher energy levels to be broken down. The scope of this contamination raises questions that extend well beyond chemistry alone: the health consequences of long-term exposure, the environmental toll on freshwater ecosystems already under strain, and the economic burden of retrofitting water infrastructure built for a bygone era of pollutants.

Health Lens

PFAS, also known as Per- and Polyfluoroalkyl Substances, are a vast group of synthetic chemicals that have been widely used around the world since the 1940s in consumer products and industrial processes because of their resistance to water, heat, oil, and stains. Environmental chemist Elsie M. Sunderland and colleagues from Harvard T.H. Chan School of Public Health explain that the same strong carbon-fluorine bonds that make PFAS useful also make them extremely resistant to breaking down, allowing them to persist in the environment and the human body for many years. This persistence has led to PFAS being commonly referred to as “forever chemicals” (Sunderland et al., 2019). As PFAS are released from manufacturing facilities, landfills, wastewater, firefighting foams, and other industrial and consumer sources, they can contaminate water bodies like rivers, lakes, groundwater, and other freshwater systems that supply drinking water to many American communities. Since traditional water treatment processes do not always completely remove PFAS, these chemicals can remain in freshwater and enter city drinking water supplies, which creates an ongoing source of human exposure (Sunderland et al., 2019). Food, consumer goods, household dust, and drinking water are some of the ways that people are exposed to PFAS; however, in areas where freshwater sources are affected, drinking water contamination is the most prominent factor. Unlike many environmental contaminants, PFAS are eliminated from the body very slowly, meaning repeated exposure to them through drinking water can gradually increase the amount of chemicals spread in the body over time (Sunderland et al., 2019). This accumulation provides the basis for understanding the long-term health concerns associated with PFAS exposure. The following section first analyzes how the bioaccumulation of PFAS contributes to prolonged exposure before evaluating current evidence linking long-term exposure to immune and developmental effects, cancer risk, thyroid dysfunction, and the potential implications of their continued persistence in freshwater systems.

Bioaccumulation

The ability to bioaccumulate within the human body is one of the defining characteristics of PFAS. Bioaccumulation is the net result of competing rates of chemical uptake into and elimination from an organism, causing chemicals to accumulate when uptake exceeds the



body's ability to remove them (Arnot et al., 2023). This persistence is one of the main reasons why they are called the "forever chemicals" and why researchers are particularly concerned about the long-term consequences of repeated exposure. According to Sunderland et al. (2019), researchers in the Harvard Department of Environmental Health, many PFAS compounds have "long biological half-lives," meaning they are removed from the human body very slowly after exposure. The review explains that the strong carbon-fluorine bonds found in PFAS make these chemicals highly resistant to degradation, allowing them to persist not only in the environment but also within the human body. However, drinking water represents one of the most significant exposure routes in communities where freshwater sources have become contaminated (Sunderland et al., 2019). Unlike exposure from an individual product that may be used occasionally, drinking contaminated water can introduce small amounts of PFAS into the body on a regular, continual basis. As this process repeats over months and years, new PFAS compounds may be absorbed before the previous compounds have been fully eliminated, gradually increasing an individual's overall PFAS body burden (Sunderland et al., 2019). Even though each individual exposure may appear minimal, the cumulative behavior of this compound becomes more important. The review also emphasizes that the persistence of PFAS results in continuous internal exposure, even if a person's contact with contaminated sources is reduced. As body concentrations increase through repeated exposure, organs and biological systems may remain exposed to PFAS for extended periods of time, creating greater opportunities for these chemicals to interact with normal physiological processes (Sunderland et al., 2019). The bioaccumulation itself is not the direct cause of the disease; rather, it provides the biological foundation for understanding why long-term PFAS exposure has been associated with a variety of health conditions.

Cancer and Thyroid Effects

Since PFAS remains in the body for years through bioaccumulation, researchers have investigated how prolonged exposure may affect multiple biological systems. Current research examines the associations between long-term PFAS exposure and a range of chronic health conditions rather than identifying a single disease caused by PFAS. A comprehensive review of current public health studies found consistent associations between PFAS exposure and kidney disease, kidney cancer, thyroid dysfunction, immune effects, and adverse reproductive and developmental outcomes, while emphasizing that additional research is needed in order to better understand the biological mechanisms responsible for these relationships (Fenton et al., 2021). This interpretation reflects the current general agreement by recognizing that PFAS are linked with increased health risks without concluding that they directly cause each disease.

The endocrine system is one of the biological systems most consistently associated with PFAS exposure; this system regulates hormones responsible for metabolism, growth, reproduction, and normal organ function. Current evidence suggests that thyroid dysfunction is among the most consistently reported health outcomes associated with PFAS exposure and that these chemicals may interfere with normal hormonal signaling and endocrine regulation (Fenton et al., 2021). As hormones coordinate the function of multiple organs, even relatively small disruptions may have widespread physiological consequences. This helps explain why



researchers continue to investigate endocrine disruption as one of the primary mechanisms through which PFAS may contribute to long-term health problems.

Scientists have also explored the relationship between PFAS exposure and cancer, specifically kidney cancer. Several epidemiological studies summarized in the review observed associations between long-term PFAS exposure and kidney cancer, although the strength of these associations varies and the underlying biological mechanisms remain under investigation. The available evidence suggests that prolonged exposure may interfere with normal cellular processes that regulate cell growth and function, rather than concluding that PFAS directly causes cancer. This cautious interpretation strengthens the credibility of current research by acknowledging both the consistency of the observed associations and the remaining scientific uncertainties (Fenton et al., 2021).

Immune System and Developmental Effects

Beyond cancer risk and endocrine disruption, growing attention has focused on the immune system because of its sensitivity to environmental contaminants. Research summarized in the review indicates that PFAS exposure has been associated with altered immune function, including reduced immune responses following routine childhood vaccinations. These findings suggest that prolonged PFAS exposure may reduce the body's ability to develop an effective protective immune response. Since immune cells rely on complex chemical signaling to function properly, persistent exposure to PFAS may interfere with these processes and contribute to immune suppression over time (Fenton et al., 2021).

There's also evidence linking PFAS exposure to reproductive and developmental concerns, specifically during pregnancy. The review reports associations between prenatal PFAS exposure and adverse developmental outcomes, including lower birth weight and altered fetal development. Since organ systems are rapidly developing and depend on carefully regulated hormonal and cellular processes, pregnancy and early childhood represent especially vulnerable stages. As a result, exposure during these critical periods may have lasting effects that continue well beyond birth. Although researchers continue to investigate the mechanisms responsible for these outcomes, the available evidence suggests that prenatal and early-life exposure may increase susceptibility to developmental health concerns later in life (Fenton et al., 2021).

Collectively, these findings demonstrate that the potential health effects associated with PFAS exposure extend far beyond a single disease or organ system. Instead, current evidence links prolonged PFAS exposure with endocrine disruption, kidney cancer, immune dysfunction, and adverse developmental outcomes while continuing to investigate the biological mechanisms that connect these associations (Fenton et al., 2021). Because PFAS remains in the body for years while exposure continues through contaminated freshwater and other environmental sources, understanding these long-term health effects remains an important area of ongoing research.



Future Long-Term Concerns

Even though considerable progress has been made in understanding the health effects of several well-studied PFAS compounds, important uncertainties remain regarding the long-term impacts of the broader PFAS family. Reinikainen et al. (2024) explain that more than 12000 PFAS compounds have been identified, yet only a relatively small number have been extensively studied for their environmental behavior and potential health effects. This results in current scientific knowledge that is largely based on a limited group of PFAS, while the health implications of many other compounds remain uncertain. This underlines the need for continued research as scientists work to better understand the potential risks associated with the full range of PFAS chemicals.

The continued persistence of PFAS in the environment is another important consideration. The review notes that releases of legacy PFAS from contaminated sites, landfills, and wastewater treatment plants are expected to continue for a long time, while other PFAS compounds remain in production and use in various applications. Therefore, the spread of PFAS through both point and diffuse sources is expected to continue even as regulatory restrictions expand (Reinikainen et al., 2024). Opportunities for human exposure through drinking water are likely to persist since these chemicals remain in freshwater systems and other environmental media long after their release.

Overall, the available data suggests that long-term exposure to PFAS through freshwater used in American cities presents a significant public health concern because these chemicals persist in both the environment and the human body, allowing repeated exposure to accumulate over time. Existing research has associated prolonged exposure with a range of health outcomes, rather than identifying a single disease caused by PFAS. These health outcomes include endocrine disruption, kidney cancer, immune dysfunction, and adverse developmental effects. Although many PFAS compounds remain insufficiently studied, the persistence of these chemicals in freshwater systems and their continued presence in drinking water highlight the importance of ongoing scientific research. As scientific understanding of PFAS continues to evolve, future research will further clarify the long-term health implications of these persistent chemicals and strengthen the evidence used to evaluate their impacts on communities that rely on freshwater resources.

Environmental Lens

According to the United States Geological Survey (USGS), PFAS and microplastics have been found in many rivers, streams, and freshwater sources across the United States. The long-term presence of these pollutants can create serious environmental problems for freshwater systems used by American cities. Because these pollutants are very difficult to remove, they can stay in the environment for many years. As more pollution enters rivers, lakes, and streams, it becomes harder to keep water clean and protect aquatic habitats. This can also increase the cost of cleaning water and maintaining safe freshwater supplies for cities.

There are several ways to reduce these problems. Government leaders can create stricter laws to reduce pollution from factories and other sources. Cities can improve waste management programs to keep plastic waste out of waterways. They can also invest in better water



treatment systems to remove harmful pollutants from freshwater. Taking these steps can help protect ecosystems, improve water quality, and make sure future generations have access to clean freshwater resources.

In conclusion, Polyfluoroalkyl substances and microplastics affect freshwater in American cities to a huge extent, posing a real threat to the environment. Lakes, rivers, and other natural bodies of water continue to be polluted with substances such as Polyfluoroalkyl and other microplastics, globally causing a negative reaction to the environment. Research shows that PFAS (polyfluoroalkyl) are highly persistent chemicals that resist natural degradation, while microplastics can stay in aquatic environments for decades and can transport additional contaminants throughout ecosystems.

The conclusions made by these researchers really demonstrate the effect of microplastics on the natural environment and how different microplastics, along with different bodies of water (lakes, rivers, oceans), can vary with researchers' findings and affect results. For example, in more populated and diverse parts of the sea, such as lakes, aquatic life is affected more by the microplastics than anything. Over time, this may reduce biodiversity and disrupt ecological balance in freshwater habitats that support wildlife. Additionally, due to the effect the pollution has on the waters and organisms living in those waters, humans are also equally as affected, as some homes and towns rely on lakes and rivers for their water and food supply.

Additionally, nonstop pollution of clean water affects cities' financial situations as well, considering the cost it takes to clean and provide safe water for the general public. PFAS and microplastics are found to be incredibly hard to completely remove from water. If direct action to stop pollution isn't taken, it may result in a financial crisis for cities and cause huge problems in the future.

Future research should focus on developing new technologies that are affordable, effective, and environmentally friendly. Researchers should also continue studying better ways to remove PFAS and microplastics from freshwater without causing additional harm to the environment. Government leaders should also make stronger laws to reduce pollution, improve waste management, and invest in better ways to clean water.

Socioeconomic/Economic Lens

The true longevity of polyfluoroalkyl substances (PFAS) and microplastics is measured not just by their thousands of years in freshwater ecosystems, but by the generational debt American cities must inherit to filter them out. Most people think of water pollution in terms of its impact on the environment or people's health, but it is also widely an economic issue. As a growing problem, American cities face a silent crisis of polluted drinking water supplies due to two prevalent forms of contamination: polyfluoroalkyl substances, a large category of thousands of synthetic chemicals that are resistant to decomposition (Moore et al., 2019), as well as particles of plastic smaller than 5 millimeters in length (NCBI, 2024).

As a direct result of these contaminants and the current ineffective and insufficient regulation of this issue in the U.S., urban areas are at risk. Almost all drinking water supplies rely heavily on rivers, lakes, and groundwater aquifers in most American cities. (EPA, 2026). In economic terms, this contamination is a classic example of a negative externality, a hidden



cost imposed on innocent bystanders by a business, an economic theory popularized by English economist Arthur Pigou. For decades, private chemical and plastic corporations made immense profits manufacturing these materials. However, because corporations never had to pay for the environmental damage they caused, the crushing financial burden of cleaning up this widespread crisis has been completely passed down to city governments and everyday taxpayers.

Infrastructure Demands and the Economics of Water Filtration

For citizens in many American cities, the contamination of local waters by polyfluoroalkyl substances and microplastics represents a major economic challenge. Many city water systems were constructed years ago and built to be equipped to filter out dirt and pathogens, according to the Royal Society of Chemistry in 2020. However, few were equipped with advanced filtration systems capable of trapping microplastic fibers, let alone removing unseen chemical particles such as PFAS. Microplastics, hence the name, are too small to pass through standard screening and filtering in municipal wastewater treatment plants. To thoroughly get rid of these plastics in freshwater, the water would have to go through specifically targeted and advanced methods such as microfiltration. To filter these pervasive toxins from city water systems, governments must install extremely expensive and advanced filtering systems, typically either reverse osmosis technologies or granular activated carbon (GAC). These filtration units can cost hundreds of thousands of dollars to billions to install and require ongoing costs to maintain. These costs would be difficult for most American cities to bear, as it could force them to make harsh economic trade-offs.

These trade-offs can arise as an opportunity cost for city funding to decrease budgets for other services such as public education, healthcare, and roadways (Mayerle et al., 2023). This can force a city to cut funding from other services such as local schools or road repairs because their water budgets are strained. According to a national infrastructure model compiled by the American Water Works Association (AWWA), the largest organization of water supply professionals in the world, implementing target filtration for PFAS and microplastics demands an estimated \$37 billion in upfront capital expenditures and a minimum of \$650 million in recurring annual operational costs.

The empirical evidence provided by Keiser and Shapiro demonstrates that the size of clean water infrastructure is tremendous at the macroeconomic level since the USA spent around \$4.8 trillion from 1970 until the beginning of the 2000s. (Keiser et al., 2019) This means that, on average, 0.8 percent of the country's GDP was invested annually into preventing pollution of surface water and ensuring drinking water safety. From a structural point of view, modern filtration technologies are characterized by economies of scale since highly populated cities are able to spread the costs of these facilities among a huge number of people, which ultimately reduces individual economic burden. In the case of small cities, costs per resident to introduce such equipment are considerably higher, possibly leading to increased costs of water utilities to comply with regulations. Such financial consequences affect public health vulnerabilities as these persistent chemicals accumulate more quickly than they can be naturally eliminated.



Financial Impacts on Health, Productivity, and Local Real Estate

In the United States, common diseases and chronic illnesses linked to such pollution include certain types of thyroid and immune system problems, as well as many cancers (International Agency for Research on Cancer, 2025). According to environmental economics researchers at Total Life Cycle Analytics (TLC Analytics), in an academic research study entitled “The Environmental Economic Cost per Cubic Meter of Untreated Sewage Discharges into Freshwater and Marine Environments,” leaving pollutants like microplastics and polyfluoroalkyl substances unchecked results in millions of dollars being wasted on treating preventable illness. Such studies highlight the massive hidden costs that accrue on public healthcare budgets when communities continue to accept untreated sewage discharges into their waters. Research shows these substances contribute to thousands of dollars per person for the cost of illness-related care, resulting not only in a health security crisis but also in a labor one, resulting in lost productivity in the workplace.

Health insecurity can quickly evolve into multi-faceted economic insecurities as chronic public exposure to bioaccumulative toxins creates localized labor supply shocks, directly diminishing human capital metrics, elevating workplace absenteeism, and depressing the overall Gross Municipal Product (GMP). Another important aspect of water pollution’s economic toll involves local real estate values. By applying methods commonly used in economics that measure value and preference, such as a ‘hedonic’ price model. This looks at how the prices of property respond to factors such as location, view, noise level, as well as pollution; researchers can ascertain just how much property is undervalued by its environmental surroundings, as discovered by economists Dennis Guignet and Anna Silva in 2026. If a particular neighborhood or an entire town is identified as a place that suffers from a high level of contaminants in the water, house prices in the area are going to decrease. For homeowners, this decline represents a severe contraction in household equity and net wealth, eroding the primary financial asset of the middle-class population (Michel et al., 2024).

Beyond individual household balance sheets, this asset devaluation triggers a critical macroeconomic domino effect on public finance. Since municipal governments rely heavily on property assessments to determine tax revenues, a systemic drop in neighborhood real estate values sharply contracts the city’s tax base. Consequently, local governments are forced into a structural deficit, leaving them with an unsustainable choice. Cities must either aggressively increase property tax rates on the remaining population to maintain baseline revenues, or drastically reduce public funding.

Market Failure and the Privatization of Profits

Essentially, the ubiquity of forever chemicals and microplastics in cities’ tap water is a massive market failure. When corporations produce highly persistent materials without full awareness of their environmental longevity, this imbalance represents a profound structural inefficiency within the unregulated market, wherein industrial entities maximize private returns while externalizing ecological and public remediation costs onto the public ledger. These companies lowered their production costs and inflated their share prices by essentially dumping their waste products into local rivers and landfills for decades. By doing so, corporations privatized all of the profits and socialized the long-term costs and externalities.



“Socializing the costs” is a way of saying that local citizens have to pay for the things that large, wealthy organizations do not. And, even if cities sue the corporations that caused them damage and win money through court settlements, they are rarely paid enough actually to address the damages they caused. It costs hundreds of billions of dollars and many decades of work to properly cleanse an underground water table or a major river system of these pollutants. By simply not providing enough money in legal settlements for corporations to clean up the messes they have left properly, taxpayers are forced to help clean up the toxic impacts. Public funds are thereby being used for cleanup operations that would be better suited for public services and public health improvements.

Policy Implications

The long-term impacts are severe, widespread, and inherently unfair to the public. Such impacts on the environment are critical to address because of the massive costs associated with them on all societal levels. Smaller to midsize cities are still looking at extremely steep costs for updating and treating water infrastructure. The economic impacts of this widespread pollution range beyond the cost of water filter replacement and actually involve reduced medical expenses and reduced productivity of America’s workforce. In addition to a workforce decline, home values can also decrease in the areas where these toxins have permeated freshwater, and there is a reduction of cities’ ability to fund essential services through taxes.

All of this is ultimately rooted in a profound market failure that has become apparent over the past half century in the form of the widespread, pervasive environmental damages of “forever chemicals” and microplastics within the nation’s tap water supply and, in turn, cities. Federal regulations must finally force chemical and plastic companies to internalize the full life cycle cost of their products in order to be socially just and sustainable. Until that time, the costs will continue to be shouldered by American citizens.

Environmental cost (Body environmental lens)

Freshwater ecosystems across the United States are facing a growing environmental problem because of polyfluoroalkyl substances (PFAS) and microplastics. Unlike many other pollutants, these materials do not naturally break down over time.(Sunderland et al., 2019; U.S. Geological Survey [USGS], 2024). Instead, they remain in rivers, lakes, wetlands, reservoirs, and groundwater for many years. Because American cities depend on these freshwater sources for drinking water, agriculture, recreation, and wildlife, the long-term effects of PFAS and microplastics reach far beyond polluted water. They change how freshwater ecosystems function and make it much harder to protect these important natural resources.(Reinikainen et al., 2024; EPA, 2024).

One of the biggest environmental concerns about PFAS is that they are extremely stable. They contain very strong carbon-fluorine bonds, which are some of the strongest chemical bonds in nature. Because of this, sunlight, bacteria, and natural chemical reactions cannot easily break them down. Once PFAS enter rivers, lakes, or groundwater, they can remain there for decades. Even if factories stop releasing them, PFAS already stored in landfills, wastewater treatment



plants, and polluted soil can continue leaking into freshwater systems.(Sunderland et al., 2019; Reinikainen et al., 2024). This means pollution can continue long after the original source is gone.

Microplastics also remain in the environment for a very long time, but in a different way. Larger plastic products, such as bottles, bags, and food containers, slowly break apart because of sunlight, weather, and moving water.(National Center for Biotechnology Information [NCBI], 2024; Instead of disappearing, they become smaller and smaller plastic pieces called microplastics. These tiny particles can float in the water, sink to the bottom of lakes and rivers, or travel long distances through streams. As more plastic waste enters the environment, the amount of microplastics continues to increase instead of decreasing National Oceanic and Atmospheric Administration (NOAA, 2024).

Over time, both PFAS and microplastics collect in the mud and sediment at the bottom of rivers and lakes. These sediments act like storage areas for pollution. However, the pollution does not stay there forever (USGS, 2024; Reinikainen et al., 2024). Heavy rain, floods, strong currents, and construction projects can disturb the sediment and release the pollutants back into the water. As a result, rivers and lakes can become contaminated again even if pollution from factories has been reduced. This cycle makes freshwater much more difficult to clean because pollution that entered a river many years ago can continue affecting the ecosystem today

Another major environmental problem is that PFAS and microplastics build up in living organisms. Small fish, insects, shellfish, and other aquatic animals are exposed when they swim in contaminated water or eat polluted food. Many fish and other animals also mistake microplastics for food because the particles are so small. Once swallowed, the plastics can remain inside their bodies and make it harder for them to absorb nutrients. As larger animals eat smaller contaminated animals, the pollution moves through the food chain in a process called biomagnification (Sunderland et al., 2019; U.S. Environmental Protection Agency [EPA], 2024). Birds, larger fish, turtles, and other predators may end up with much higher levels of PFAS because they eat many contaminated animals throughout their lives. This shows that the pollution does not stay only in the water but spreads throughout the entire ecosystem

These pollutants can also affect how freshwater ecosystems function. Healthy rivers and lakes depend on many different plants, fish, insects, algae, and microorganisms working together. These living things help clean the water, recycle nutrients, produce oxygen, and support other wildlife. When pollution harms one group of organisms, it can affect many other parts of the ecosystem (EPA, 2024; NOAA, 2024). Research has shown that PFAS and microplastics may reduce the growth and reproduction of some freshwater species. Fish may produce fewer offspring, while small aquatic animals may grow more slowly or have trouble surviving. Over time, these changes can reduce biodiversity, which is the variety of living things in an ecosystem. When biodiversity decreases, freshwater ecosystems become weaker and are less able to recover from other environmental problems such as drought, invasive species, or climate change

Microplastics create another environmental problem because they can carry other harmful chemicals. Their surfaces can collect pesticides, heavy metals, pharmaceuticals, and other pollutants already found in rivers and lakes. When fish or other animals swallow



microplastics, they may also take in these harmful chemicals. This allows pollution to spread farther throughout freshwater ecosystems. Scientists have also discovered that bacteria and other microorganisms can grow on the surface of microplastics. These tiny plastic pieces can carry microorganisms through rivers and lakes, allowing them to spread farther than they normally would. Researchers are still studying how this may affect freshwater ecosystems, but it could change the balance of microorganisms that naturally live in the water (NOAA, 2024; NCBI, 2024).

Climate change is making these environmental problems even worse. Heavy rainfall and flooding wash more plastic waste and PFAS into rivers and lakes. Floods can also stir up polluted sediment and move contaminants farther downstream. During droughts, rivers carry less water, so pollutants become more concentrated (USGS, 2024; EPA, 2024). As weather becomes more extreme, PFAS and microplastics are likely to spread even farther through freshwater systems. Because rivers, lakes, wetlands, and groundwater are all connected, pollution in one location can eventually affect drinking water sources many miles away.

Many city water treatment plants were built to remove dirt, bacteria, and other common pollutants. However, they were not designed to remove PFAS or the smallest microplastics. Although newer technologies such as reverse osmosis and activated carbon filtration can remove many of these pollutants, they are expensive to build and maintain. As a result, preventing pollution before it enters rivers and lakes is often a better long-term solution than trying to remove it after contamination has already occurred. This highlights the importance of reducing pollution at its source through better waste management, stronger environmental regulations, and continued monitoring of freshwater systems (EPA, 2024; Sunderland et al., 2019).

Overall, the evidence shows that PFAS and microplastics have serious long-term effects on freshwater systems used by American cities. They remain in the environment for decades, collect in sediments, build up in wildlife, move through food chains, reduce biodiversity, and become even harder to control because of climate change. These environmental changes threaten the health of freshwater ecosystems that provide drinking water and support countless plant and animal species. Protecting these freshwater resources will require stronger pollution laws, improved waste management, better water treatment technology, and continued scientific research (Sunderland et al., 2019; Reinikainen et al., 2024; EPA, 2024). Taking these steps can help protect freshwater ecosystems and ensure that future generations continue to have safe and reliable water resources.

Conclusion

In conclusion, Polyfluoroalkyl substances and microplastics affect freshwater in American cities to a huge extent, posing a real threat to the environment. Lakes, rivers, and other natural bodies of water continue to be polluted with substances such as Polyfluoroalkyl and other microplastics, globally causing a negative reaction to the environment. Research shows that PFAS (polyfluoroalkyl) are highly persistent chemicals that resist natural degradation, while microplastics can stay in aquatic environments for decades and can transport additional contaminants throughout ecosystems.



The conclusions made by these researchers really demonstrate the effect of microplastics on the natural environment and how different microplastics, along with different bodies of water (lakes, rivers, oceans), can vary with researchers' findings and affect results. For example, in more populated and diverse parts of the sea, such as lakes, aquatic life is affected more by the microplastics than anything else. Over time, this may reduce biodiversity and disrupt ecological balance in freshwater habitats that support wildlife. Additionally, due to the effect the pollution has on the waters and organisms living in those waters, humans are also equally affected, as some homes and towns rely on lakes and rivers for their water and food supply.

Additionally, nonstop pollution of clean water affects cities' financial situations as well, considering the cost it takes to clean and provide safe water for the general public. PFAS and microplastics are found to be incredibly hard to completely remove from water. If direct action to stop pollution isn't taken, it may result in a financial crisis for cities and cause huge problems in the future.

Future research should focus on developing new technologies that are affordable, effective, and environmentally friendly. Researchers should also continue studying better ways to remove PFAS and microplastics from freshwater without causing additional harm to the environment. Government leaders should also make stronger laws to reduce pollution, improve waste management, and invest in better ways to clean water.



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