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Water Pollution's Global Threat to Public Health : A Mini-Review

Dr. Amit Krishan[1], Dr. Shweta Yadav[2], Ankita Srivastava*[3]

[1]LEA Associates South Asia Pvt. Ltd., New Delhi, Delhi, India

[2]Department of Environmental Science, Integral University, Lucknow, Uttar Pradesh, India

*[3]Aarush Welfare Society, Lucknow, Uttar Pradesh, India

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ABSTRACT

Water resources are essential for a region's development, serving as a primary source of drinking water, agriculture, and industry. However, water contamination from natural and human activities is a global public health threat. This review consolidates data from various studies and reports to comprehensively examine water pollution's impact on public health. Over 80% of untreated sewage is released into water bodies, causing environmental pollution and contributing to over 50 diseases. Poor water quality is responsible for 80% of diseases and 50% of child deaths worldwide. The impact of water pollution varies regionally and by age and gender. This paper aims to clarify the link between water pollution and public health, including the association of water pollution with diarrhea, skin diseases, cancer, and impact on child health. Diarrhea is the most common waterborne illness, primarily transmitted by aquatic enteroviruses. Exposure to heavily polluted water increases the risk of skin diseases. Water pollution can affect human health through the source, treatment, and distribution of water. Prominent waterborne carcinogens include arsenic, nitrate, chromium, and trihalomethanes. To mitigate these risks, governments must strengthen water management, implement measures to improve water quality and reduce the adverse impact of water pollution on human health.

Keywords: Cancer, Child health, Diarrhea, Public health, Water pollution, Water quality, Skin diseases

I. INTRODUCTION

Water is a vital resource crucial for human existence [1]. The 2021 World Water Development Report, as published by UNESCO, reveals a remarkable six-fold surge in global freshwater utilization over the past century, with a consistent annual growth rate of approximately 1% since the 1980s. This escalating demand for water resources presents a significant and pressing challenge to the quality of water [2].

Industrialization, agricultural activities, and urbanization have collectively given rise to environmental deterioration and pollution, negatively impacting the vital water sources essential for sustaining life. This, in turn, has far-reaching consequences for human well-being and the prospects of sustainable social progress [3-5]. On a worldwide scale, approximately 80% of industrial and municipal wastewater is released into the environment without any preliminary treatment, leading to detrimental repercussions for both human health and ecosystems. This percentage is notably greater in the least developed countries, where there is a significant deficiency in sanitation and wastewater treatment infrastructure [2].

Widespread apprehensions about water pollution persist, given its detrimental impact on human health and overall well-being. Enhancing public health, preventing waterborne diseases, and ensuring access to clean, safe water are imperative for sustaining life. Nonetheless, the quality of water can be compromised by various contaminants, making it unsuitable for everyday use and consumption [6, 7].

Both human and natural actions hold the potential to pollute water sources. Natural sources of contamination arise from microbial processes, geological formations, and the presence of naturally occurring pollutants within water reservoirs. Conversely, anthropogenic sources result from human activities like industrial processes, agricultural methods, improper waste management, and inadequate sewage systems. These activities introduce contaminants into water supplies, endangering their integrity and purity [8, 9].

Water pollutants encompass a range of elements, including microbiological pathogens, chemical substances, heavy metals, pesticides, pharmaceuticals, and emerging contaminants. Chemical pollutants from sources like household chemicals, agricultural runoff, and industrial effluents can contaminate water sources, posing risks to human health. The impact of these contaminants on human well-being is an ongoing subject of research, and the emergence of new pesticides, pharmaceuticals, and evolving pollutants adds to the complexities of the issue [1].

The degradation of water quality is an escalating concern driven by substantial environmental shifts and the expanding scope of human endeavors. Water quality is influenced by a multitude of factors, encompassing natural phenomena, human actions, and the impacts of climate change [3, 4]. These factors manifest their effects on water quality through elevated concentrations of pollutants and contaminants within aquatic systems. The existence of these pollutants and contaminants carries significant ramifications for both human well-being and the ecosystem. Consequently, it is imperative to vigilantly assess water quality and implement suitable measures to avert further degradation [10, 11]. The decline in water quality has been influenced by human-caused factors, including the inadequate disposal of pharmaceuticals, metabolic excretion, industrial utilization, and municipal wastewater discharge [12]. Extensive global research efforts have been undertaken to explore water quality and its associated health risks. This concerted research is driven by the recognition that consuming contaminated water can lead to severe adverse consequences for human health [13, 14]. These investigations have established connections between waterborne contaminants and a wide range of health concerns. These include, among others, obesity, diabetes, cancer, endocrine disruption, cardiovascular ailments, developmental challenges, and reproductive issues [15, 16]. The health consequences of water pollution are multifaceted and diverse. The impact of exposure to contaminated water can lead to both acute and chronic health issues, contingent on the nature of the contaminants, the extent and duration of exposure. Waterborne illnesses can result in gastrointestinal problems, dehydration, and in severe cases, life-threatening conditions, especially among vulnerable groups like children, the elderly, and individuals with compromised immune systems. Prolonged exposure to specific contaminants can result in organ damage,

developmental complications, reproductive issues, and an elevated risk of cancer [14, 17].

Annually, over two million people across the globe succumb to diarrheal diseases, and the primary cause of nearly 90% of these fatalities is attributed to inadequate sanitation and the consumption of unsafe drinking water. Regrettably, children are disproportionately affected by these circumstances [2]. More than 50 types of diseases are attributable to the poor quality of drinking water, and globally, 80% of diseases and 50% of child fatalities can be linked to inadequate drinking water quality. Water contamination can lead to a range of health issues, including diarrhea, skin ailments, malnutrition, and even more severe conditions like cancer. Consequently, it is essential to study the influence of water pollution on human health, particularly the diversity of diseases, and underscore the significance of clean drinking water, which holds critical theoretical and practical implications for achieving sustainable development goals. Regrettably, despite numerous studies focusing on water pollution and specific diseases, there remains a dearth of comprehensive research that systematically analyzes the impact of water pollution on human health and the varying nature of associated illnesses. This paper aims to address this gap by concentrating on the repercussions of water pollution on human health and the diverse spectrum of diseases it can trigger.

A. Causes and sources of water pollution

Water pollution primarily emanates from industrialization, agricultural practices, natural influences, and the inadequacy of water supply and wastewater treatment infrastructure. In particular, industries such as distilleries, tanneries, pulp and paper mills, textile factories, food processing facilities, iron and steel plants, and nuclear operations play a pivotal role in causing water pollution. These industrial processes can discharge a wide array of hazardous substances, including toxic chemicals, organic and inorganic compounds, noxious solvents, and volatile organic chemicals. When these waste materials are released into aquatic ecosystems without proper treatment, they become a significant source of water pollution [18]. Arsenic, cadmium, and chromium are notable contaminants released into wastewater, with the industrial sector being a major source of these hazardous pollutants [19]. As urbanization continues to advance, there has been a gradual rise in industrial wastewater resulting from increased industrial production [20]. Furthermore, the impact of industrialization on water pollution is significantly influenced by foreign direct investment. In less developed countries, there exists a positive correlation between industrial water pollution and foreign direct investment [21]. Agriculture plays a substantial role in the occurrence of water pollution. Pesticides, nitrogen-based fertilizers, and organic farm waste are prominent contributors to water pollution stemming from agricultural practices. Agricultural operations can lead to water contamination by introducing nitrates, phosphorus, pesticides, soil sediments, salts, and pathogens into the water [22].

Moreover, agriculture has inflicted significant damage upon all freshwater systems, altering their once-pristine conditions [23]. Untreated or inadequately treated wastewater is extensively utilized for irrigation in water-scarce regions of developing nations, such as China and India. The presence of pollutants in sewage presents substantial risks to both the environment and public health. This practice has led to severe pollution of agricultural lands and food products, including pesticide residues and heavy metal contamination, thereby posing a significant threat to food safety and human health [24]. Pesticides have a detrimental effect on health when introduced into the drinking water supply. A comparison of pesticide usage with data from the Health and Life Expectancy Longitudinal Survey revealed that a 10% increase in pesticide usage corresponded to a 1% rise in the medical disability index for individuals aged over 65 years [25]. The case of the Musi River in India highlights a greater prevalence of health issues in villages where

wastewater irrigation is practiced compared to households using clean water sources.

The quality of drinking water is significantly influenced by the state of water supply and sewage treatment facilities, particularly in developing nations. An econometric model forecasts the influence of water purification equipment on water quality and its subsequent impact on human health. In scenarios where the proportion of household water treated with water purification equipment decreases from 100% to 90%, the anticipated health advantages diminish by as much as 96%. This reduction is even more pronounced when the initial water quality is of higher risk [26].

In summary, water pollution is the outcome of a complex interplay between human and natural elements. Numerous human activities, such as urbanization, population expansion, industrial manufacturing, climate change, and various other factors, exert direct influences on water quality and religious activities [27, 28]. Inadequate disposal of solid waste, as well as sand and gravel, stands as a contributing factor to the deterioration of water quality [29].

II. DISCUSSIONS

The primary objective of this paper is to elucidate the intricate relationship between water pollution and human health. This includes examining the link between water pollution and diarrhea, its underlying mechanisms, the association between water pollution and skin diseases, the pathogenic factors involved, the connection between water pollution and cancer, considering carcinogenic factors and cancer types, and the relationship between water pollution and child health, particularly its impact on prevalent childhood diseases.

A. Effects of water pollution on human health

Unsafe water poses profound risks to human health. According to the UNESCO 2021 World Water Development Report, approximately 829,000 individuals perish annually due to diarrhea resulting from the consumption of unsafe drinking water, inadequate sanitation, and poor hand hygiene. This includes almost 300,000 children under the age of five, accounting for 5.3% of all deaths within this age category.

Data from Palestine indicates that those who directly consume municipal water are more susceptible to diseases like diarrhea compared to individuals who rely on desalinated or household-filtered drinking water [30]. In a comparative analysis of tap water, purified water, and bottled water, tap water emerged as a significant source of gastrointestinal illnesses [31]. The absence of adequate water and sanitation services contributes to a heightened occurrence of diseases, including cholera, trachoma, schistosomiasis, and helminthiasis. Research findings from developing nations consistently highlight a strong connection between cholera and water contamination. Furthermore, implementing household water treatment and safe storage measures has been shown to effectively reduce the incidence of cholera [32]. In addition to causing diseases, unsafe drinking water and inadequate environmental hygiene can result in gastrointestinal illnesses, hindering nutrient absorption and contributing to malnutrition, with children being particularly vulnerable.

The quality of drinking water plays a pivotal role in human health, and poor water quality has given rise to waterborne diseases. As per the World Health Organization (WHO) survey, a staggering 80% of global diseases and 50% of child fatalities are linked to subpar drinking water quality, with over 50 diseases stemming from this issue. The state of drinking water quality in developing nations raises serious concerns. The adverse health effects of water pollution continue to be a leading cause of illness and mortality in these regions. This paper primarily delves into the impact of water pollution on human health, considering the diversity of associated diseases. It specifically focuses on areas like diarrhea, skin disorders, cancer, child

health, among others, and elucidate the principal consequences of water pollution on human well-being.

B. Diarrhea and water pollution

Diarrhea is a prevalent symptom of gastrointestinal ailments and stands as the most frequent illness stemming from water contamination. It is a primary contributor to illness and mortality among young children in low-income nations. Diarrheal diseases, in fact, represent a substantial 21% of the yearly deaths in children under the age of 5 in developing countries [33]. Numerous infectious agents linked to diarrhea are closely associated with water contamination [34]. Diseases can be contracted when human beings consume parasitic worms present in untreated drinking water [35]. The research findings indicated that water treated at water treatment facilities carried a reduced risk of causing diarrhea across all age groups when compared to untreated water [36]. As an illustration, in the southern region of Brazil, an investigation uncovered significant factors linked to a heightened risk of mortality due to diarrhea. These factors included the absence of piped water, the absence of flush toilets, substandard housing conditions, and overcrowded households. Households lacking access to piped water faced a 4.8-fold greater risk of infant mortality from diarrhea compared to households with piped water access [37].

Enteroviruses are present in the aquatic environment. Over 100 pathogenic viruses are discharged in human and animal waste and disseminate through various environmental pathways, including groundwater, estuarine and sea waters, rivers, sewage treatment facilities, inadequately treated water, drinking water sources, and private wells [38]. The primary culprits behind drinking water pollution are the improper disposal of sewage and solid waste, excessive application of pesticides and fertilizers, and the deteriorating pipeline networks. Coliform bacteria serve as the primary source of waterborne diseases, including gastroenteritis, dysentery, diarrhea, and viral hepatitis [39].

Hence, the foremost objective of water and sanitation health interventions is to impede the transmission of diarrheal pathogens from the environment to human beings [33]. Meta-analyses represent the predominant approach in water quality and diarrhea investigations. These analyses revealed that enhancing water supply and sanitation resulted in a notable 26% decrease in the overall incidence of diarrhea. Every intervention targeting water quality and sanitation exhibited significant reductions in the risk of diarrheal disease. In particular, water quality interventions proved to be even more effective than previously anticipated. It was also observed that combined interventions, encompassing water, sanitation, and hygiene measures, did not yield superior outcomes compared to single-focus interventions [40]. Water quality interventions lowered the risk of diarrhea in children and effectively minimized the risk of E. coli contamination in stored water [41]. Efforts to enhance water quality typically prove successful in averting diarrhea among children of various age groups, especially those under 5 years old. Nevertheless, certain trials exhibited notable variations, which could be attributed to differing research methodologies and environmental conditions [42].

C. Skin diseases and water pollution

Contrary to the conventional belief that swimming is beneficial for health, research dating back to the 1950s unveiled an unexpected pattern. It indicated that the overall disease incidence in the group that participated in swimming was notably higher than that in the non-swimming group. The data also revealed that the disease incidence among individuals under the age of 10 was roughly 100% higher than that of individuals over 10 years old. Skin diseases constituted a significant portion of these findings [43].

Through an examination of the connection between elevated arsenic levels in drinking water due to water pollution and skin diseases, primarily melanosis and keratosis, it was observed that individuals who consumed drinking water with high arsenic levels had

a significant increase in arsenic concentration in their hair compared to those consuming low-arsenic urban drinking water. The arsenic levels in drinking water had a direct impact on the health of local residents, with skin diseases being the most common clinical complication of arsenic poisoning. Notably, a correlation was detected between the arsenic concentrations in biological samples (hair and blood) of individuals with skin diseases and their consumption of arsenic-contaminated drinking water [44]. Moreover, water pollution stemming from industrial activities can also be a causative factor in the development of skin cancer [45].

Studies have indicated that exposure to contaminated marine recreational waters can result in adverse effects, including frequent skin discomfort such as rashes or itching. These skin ailments among swimmers may be attributed to an array of pathogenic microorganisms [46]. Individuals, both swimmers and non-swimmers, who were exposed to waters with bacterial levels exceeding certain thresholds, exhibited a heightened relative risk of developing skin diseases. The levels of bacteria in seawater demonstrated a strong correlation with the occurrence of skin symptoms.

Furthermore, studies have indicated that swimmers are 3.5 times more likely to report skin diseases compared to non-swimmers. This disparity might be influenced by a "risk perception bias" among swimmers, who are generally more aware of the potential health effects of such exposure and, therefore, more likely to recognize and report skin disorders. It's also plausible that swimmers may sometimes exaggerate their symptoms, reporting conditions that others might not classify as genuine skin disorders [47].

D. Cancer and water pollution

According to statistics from the World Health Organization (WHO), the year 2020 witnessed the diagnosis of 19.3 million cancer patients, with the number of cancer-related deaths surging to 10 million. Presently, one-fifth of the global population is projected to face cancer during their lifetime. The types and quantities of carcinogens found in drinking water can differ based on how they are introduced, whether through source water contamination, water treatment procedures, or during the distribution of water to consumers [48]. From the standpoint of water sources, substances such as arsenic, nitrate, chromium, and more are strongly linked to cancer. The consumption of arsenic-contaminated drinking water can lead to the development of skin cancer, as well as kidney and bladder cancer [49].

The risk of cancer in the population due to arsenic in the United States' water supply may be on par with the risks associated with tobacco smoke and radon exposure in residential settings. Nevertheless, it's important to acknowledge that individual susceptibility to the carcinogenic impacts of arsenic can vary significantly [50]. Additionally, research has indicated a synergistic effect of smoking and the consumption of arsenic-contaminated drinking water, contributing to the development of lung cancer [51]. Exposure to elevated levels of arsenic in drinking water was linked to an increased risk of liver cancer. However, this effect did not attain statistical significance at exposure levels below 0.64 mg/l [52].

Nitrates are a widespread contaminant that exhibits a closer association with various human cancers, particularly colorectal cancer. The carcinogenic risk associated with nitrates depends on their concentration. The risk escalates notably when drinking water levels surpass 3.87 mg/l, which is well below the existing drinking water standard of 50 mg/l. It's essential to note that even drinking water with nitrate concentrations lower than the current standards can still heighten the risk of developing colorectal cancer [53]. Consuming drinking water with elevated levels of chromium can significantly increase the carcinogenic risk, primarily due to hexavalent chromium exposure for residents. Experimental studies on the ingestion of hexavalent chromium have demonstrated its potential to induce respiratory cancer in humans [54].

A correlation has been established between the levels of trihalomethanes in drinking water and cancer mortality. Bladder and brain cancers in both men and women, as well as non-Hodgkin's lymphoma and kidney cancer in men, exhibited a positive association with trihalomethane levels. Notably, bladder cancer mortality displayed the most robust and consistent connection with the trihalomethane exposure index [55].

In terms of the water treatment process, the introduction of carcinogens can occur during chlorine treatment. The consumption of drinking water treated with chlorine has been associated with various types of cancers, including urinary and gastrointestinal cancers [56]. The byproducts resulting from the chlorination process used in water treatment have been linked to a heightened risk of bladder and rectal cancer. This association may contribute to approximately 5,000 cases of bladder cancer and 8,000 cases of rectal cancer occurring annually in the United States [48].

The relationship between drinking water pollutants and cancer is intricate. Epidemiological studies have revealed that drinking water contaminants, including chlorinated by-products, nitrates, arsenic, and radionuclides, are linked to cancer in humans [57]. Lead (Pb), uranium (U), fluoride (F^-), and nitrate (NO_3^-) are the primary groundwater pollutants and potential contributors to cancer [58]. Furthermore, numerous other water pollutants, such as herbicides, pesticides, and nitrates released from fertilizers, are also recognized as potential carcinogens [49]. The levels of three nitrogen compounds in well water exhibited significant positive correlations with esophageal cancer mortality [59].

Furthermore, because of the time-lag effect, the influence of watershed water pollution on cancer exhibits spatial heterogeneity. The mortality rate of esophageal cancer attributed to water pollution is notably higher downstream compared to other regions, primarily due to the historical impact of water pollution [60]. A study grounded in alterations in water quality within the watershed demonstrated that a significant drop to grade 6 in water quality led to a 9.3% surge in deaths attributed to digestive cancer [61].

E. Child health and water pollution

Diarrhea is a prevalent illness among children, and diarrheal diseases, including cholera, result in the deaths of 1.8 million people annually, with 90% of these being children under the age of five, primarily in developing countries. An overwhelming 88% of diarrheal diseases can be attributed to insufficient access to clean water, sanitation, and proper hygiene practices [62]. A significant portion of these cases is a consequence of exposure to water and food contaminated with harmful microorganisms. Diarrhea in infants and young children can result in malnutrition and a weakened immune system, thereby elevating the risk of extended and recurring episodes of diarrhea [63]. Exposure to pollution during critical developmental stages in childhood has been linked to reduced height in adulthood [64].

Diseases directly connected to water and sanitation, when coupled with malnutrition, can contribute to other causes of death like measles and pneumonia. Child malnutrition and stunting resulting from insufficient access to clean water and proper sanitation will persist, affecting more than one-third of the global population [65]. Research conducted in rural India indicated that children residing in households with access to tap water exhibited notably reduced disease prevalence and shorter durations of illnesses [66].

In summary, water pollution stands as a significant contributor to childhood diseases. The combined effects of air, water, and soil pollution resulted in the deaths of 940,000 children globally in 2016, with approximately two-thirds of these cases involving children under the age of 5. The vast majority of these fatalities occurred in low- and middle-income countries [67]. The severity of industrial organic water pollution exhibits a positive correlation with infant and child mortality rates in less developed countries. Industrial water pollution emerges as a significant factor contributing to infant and child mortality in

these regions [20]. Furthermore, arsenic in drinking water poses a potential carcinogenic risk to children. Nitrate contamination in drinking water may also lead to goiter in children [68].

A comprehensive study has revealed that while various factors like country, region, age, and gender may yield different impacts, overall, water pollution significantly affects human health. Water pollution is a causal factor in numerous human diseases, most notably diarrhea, skin diseases, cancer, and various childhood ailments. The influence of water pollution on different diseases can be summarized as follows:

Firstly, diarrhea is the disease most easily induced by water pollution, with its primary transmission facilitated by enteroviruses present in aquatic environments. The transmission environments for enteroviruses encompass groundwater, rivers, seawater, sewage, drinking water, and more. Consequently, it is imperative to implement interventions aimed at preventing the transmission of enteroviruses from the environment to humans through drinking water.

Secondly, exposure to or use of heavily polluted water elevates the risk of skin diseases. Excessive bacterial contamination in seawater and the presence of heavy metals in drinking water are the primary pathogenic factors contributing to skin diseases.

Thirdly, water pollution can pose health hazards to humans through three key points: the water source, the water treatment process, and the water distribution. Major water source carcinogens include arsenic, nitrate, chromium, and trihalomethanes. The introduction of carcinogens during the chlorine treatment stage in water treatment also merits consideration.

Top of Form The effects of drinking water pollution on cancer are multifaceted, involving factors such as chlorinated by-products, heavy metals, radionuclides, herbicides, pesticides, and more. Ultimately, water pollution emerges as a significant contributor to children's diseases. Exposure to microbiologically contaminated water can trigger diarrheal diseases in children. Furthermore, malnutrition and compromised immunity resulting from diarrheal diseases can predispose children to additional health issues.

This study has conducted a comprehensive analysis of the impact of water pollution on human health and the diversity of diseases, offering an in-depth examination of the relationships, mechanisms, and influencing factors associated with water pollution and various illnesses. While this research primarily falls within the realm of environmental science and environmental management, there is an opportunity for future studies to delve into medical and pathological aspects.

In response to the findings of this research, countries, especially those in the developing world, should implement relevant water management policies to mitigate the health risks posed by water pollution. This includes a strong emphasis on improving water quality at the point of use, with interventions such as chlorination and safe water storage, and provision of treated and clean water [31, 38]. Secondly, to minimize the impact of water pollution on skin diseases, countries should conduct epidemiological research tailored to their specific circumstances, allowing for the establishment of bathing water quality standards that prioritize public health [69]. Thirdly, to mitigate the risk of cancer arising from water pollution, comprehensive oversight of water quality must be enhanced, encompassing the purity of water sources, the scientific soundness of water treatment processes, and the efficacy of drinking water monitoring.

Fourthly, every society should take proactive measures to prevent and control pollution at its source, addressing issues associated with production, consumption, and transportation [67]. Fifthly, widespread health education initiatives should be implemented. This should include the incorporation of environmental education to raise awareness about clean water and hygiene among residents through various media channels such as newspapers, magazines, television, and the Internet. Public health awareness should be enhanced through these efforts.

Additionally, farmers should receive training to reduce the overuse of agricultural chemicals that may lead to the contamination of drinking water sources.

III.CONCLUSION

Water contamination has emerged as a significant concern in the 21st century, yet it remains insufficiently acknowledged in many parts of the world, potentially due to a lack of awareness regarding the origins of water contamination and its detrimental health effects. Numerous studies have examined water contamination resulting from human activities, identifying major sources of contamination such as fertilizers, pesticides, industrial, and mining operations. These studies have documented the adverse impact of nitrates, harmful chemicals, and radioactive elements on both surface and groundwater quality. Vulnerable groups, particularly children and pregnant women, face elevated health risks when consuming water from such contaminated sources.

Geogenic sources of contamination indicate that water pollution can stem from geological factors responsible for enriching the water with various chemical substances. Chemical weathering, evaporation, and the breakdown of parent minerals (such as arsenopyrite and realgar) are implicated in the contamination of water with elements like arsenic, fluoride, manganese, uranium, sulfur dioxide, and several trace elements. Groundwater pollution with arsenic, for instance, has been linked to both cancer and non-cancer health issues in individuals. Notably, heavy metals, whether occurring naturally or as a consequence of human activities, can significantly pollute water. This includes metals like cobalt, cadmium, chromium, copper, mercury, nickel, zinc, and lead. While chromium and lead primarily present non-cancer concerns, cadmium poses the highest cancer risk.

In summary, various sources of pollutants can negatively impact human health and overall well-being. As research in this field continues to expand, the future of water contamination-related health hazards remains uncertain. This study provides a comprehensive overview of the myriad sources of water contamination and their potential repercussions on water quality and human health.

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