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WATER POISONING WITH ARSENIC AND ITS DEVASTATING EFFECTS ON THE ENVIRONMENT AND HUMAN HEALTH

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ABSTRACT
Water contamination is a pressing global concern, with profound repercussions for both the environment and human well-being. Among the various contaminants, arsenic stands out due to its ubiquitous presence, toxic nature, and far-reaching consequences. Arsenic, a naturally occurring element, can infiltrate water sources through geological processes or anthropogenic activities, thereby elevating its concentration beyond safe levels. This contamination carries devastating effects that span ecosystems and human health. Arsenic, a naturally occurring element, can infiltrate water sources through geological processes or human activities, leading to elevated levels that have dire consequences. This review examines the extensive and devastating effects of arsenic-contaminated water on both ecosystems and human populations. By acknowledging the devastating effects on both the environment and human well-being, society can forge a path towards holistic solutions that safeguard water resources for present and future generations.

Keywords: Contamination, Water poisoning, Environmental impact, Human health, Exposure.

I. OVERVIEW

The majority of the country's potable water comes from groundwater rather than surface water since there is less surface water accessible. According to Prakash (2017), industrialization and changes in lifestyle have led to the introduction of a large number of unneeded chemicals into ground water. These compounds exhibit toxicity and destroy the normally occurring functioning of biological components. Urbanization, home sewage, and a large rise in population all contribute to the enormous difficulty of obtaining safe drinking water in developing nations like India. Urbanization is the primary cause. According to Maharajan et al. (2005), the contamination of ground water with arsenic is a worldwide concern, and the possibility of contracting arsenicosis exists for millions of individuals. Many nations throughout the globe have previously documented the tragedy of arsenic poisoning, which is produced by arsenic polluted water. This catastrophe was caused by arsenic tainted water.

According to Upadhyay et al. (2019), arsenic is a pervasive and hazardous element that is classified in the metalloid group of the periodic table. Arsenic may be found naturally in the lithosphere, hydrosphere, and atmosphere, in addition to the biosphere as a whole. Arsenic may be found in nature in both its organic and inorganic forms (most often in the form of complexes); several transit pathways in the environment have been established, and fairly high concentrations of arsenic have been observed in different places around the planet (Meduni et al., 2020).

The World Health Organization (WHO) suggested that the regulating limit for the content of arsenic in drinking water be set at 10 micrograms per liter. This level was then enforced by the corresponding laws. This is also the maximum that the European Commission, the United States Environmental Protection Agency, and several other inter-national and national bodies have set for the amount of

arsenic that may be found in drinking water. As a result of arsenic's high level of toxicity, water, particularly groundwater, that has been contaminated by arsenic is seen as a serious public health concern in many parts of the globe. According to the findings of relevant research, prolonged exposure to high concentrations of arsenic poses a risk to human health and may lead to a range of health conditions, such as skin lesions (such as keratosis and pigmentation) as well as a number of different types of cancer, both internal and external.
The reductive breakdown of the iron oxyhydroxides results in the release of the arsenic. Because its chemical characteristics are midway between those of normal metals and non-metals, it is categorized as a metalloid, sometimes known as a semi-metallic substance. Arsenic may thus combine with other metals to create alloys, but it also easily forms covalent connections with carbon, hydrogen, and oxygen (Prakash and Verma, 2020a). It is a common environmental pollutant that enters the environment as a byproduct of geological processes as well as manmade activity such as the synthesis of chemicals and metals. It is known to be a trace element that is hazardous, and there is the potential for ecological problems to occur if considerable levels of arsenic were to be released into the environment as a consequence of operations in the industrial and agricultural sectors. There have been reports of increased arsenic concentrations in the ground water of a number of different nations, including India.

II. EFFECT OF ARSENIC ON ENVIRONMENTAL FACTORS

The environmental effects of arsenic contamination can be profound and have far-reaching consequences for ecosystems, biodiversity, and overall environmental health. Arsenic is a naturally occurring element, but human activities, such as mining, industrial processes, and agricultural practices, can contribute to elevated levels of arsenic in the environment. Here are some of the key environmental effects of arsenic contamination (Zhao H et al., 2019b):

Aquatic Ecosystems:

Toxicity to Aquatic Life: Elevated levels of arsenic in water bodies can be toxic to aquatic organisms such as fish, invertebrates, and algae. It can impair their growth, reproduction, and overall health.
Bioaccumulation: Arsenic can bioaccumulate in aquatic organisms over time. Predators at higher trophic levels, including humans, can be exposed to elevated levels of arsenic through the consumption of contaminated aquatic species.

Soil Contamination:

Impact on Soil Health: Arsenic contamination can degrade soil quality and impact soil microorganisms and nutrient cycling. This can have cascading effects on plant health and ecosystem productivity.
Plant Uptake: Plants can take up arsenic from contaminated soil, leading to reduced crop yields and potential contamination of the food chain.

Biodiversity and Ecosystem Functioning:

Reduced Biodiversity: Arsenic contamination can lead to shifts in species composition and reduced biodiversity in affected ecosystems, as certain species are more tolerant to arsenic than others.
Ecosystem Imbalance: Changes in species composition can disrupt ecosystem dynamics and alter the interactions between organisms, potentially leading to imbalances in ecosystem functioning.

Groundwater Contamination:

Contaminated Drinking Water: Elevated levels of arsenic in groundwater sources can contaminate drinking water supplies, posing a significant risk to human health. Many rural communities around the world rely on groundwater for their water needs (Sheng D et al., 2021).

Airborne Contamination:

Volatilization: Arsenic compounds can be released into the air through processes such as volatilization from soil and water surfaces. This can lead to atmospheric dispersion and potential deposition onto soil and water bodies.

Long-Term Persistence:

Slow Natural Decay: Arsenic is relatively stable and can persist in the environment for a long time. This persistence can result in long-term exposure risks for both ecosystems and human populations.

Ecosystem Services:

Loss of Ecosystem Services: The disruption of ecosystems due to arsenic contamination can lead to a reduction in ecosystem services, such as water purification, carbon sequestration, and habitat provision.

Efforts to mitigate the environmental effects of arsenic contamination include implementing proper waste disposal and management practices, enforcing regulations on industrial emissions and mining activities, promoting responsible agricultural practices, and implementing remediation strategies for contaminated sites. Addressing arsenic contamination is crucial for maintaining healthy ecosystems, protecting biodiversity, and ensuring the well-being of both the environment and human populations.

III. ROUTE OF ARSENIC ENTRY IN HUMAN BODY:

In the majority of the globe, you may find arsenic in the form of oxyhydroxide, sulfide, or compounds of other metals in the soil, rocks, and sediments. Metal ores also include arsenic in their natural state. The majority of people in the human population are exposed to arsenic by ingestion, inhalation, and skin contact. The population may be acutely and chronically exposed to arsenic via a variety of different pathways, including the ingestion of arsenic-contaminated water, foods, medications, wines, cigarette smoke, and fossil fuels, among other things. Workers in businesses such as smelting and refining metals, making and utilizing arsenic-containing compounds, manufacturing glass, semiconductors, and other medicinal substances are subjected to occupational exposure to airborne arsenic. This kind of arsenic exposure is known as occupational exposure to airborne arsenic. Arsenic-containing medications are used in the medical treatment of a variety of conditions, including syphilis, asthma, rheumatism, cough, pruritus, itching, trypanosomiasis, and acute promyelocytic leukemia (Wang et al., 2003). These conditions may be exacerbated by exposure to arsenic. According to the ATSDR (2006), one of the most common causes of arsenic poisoning in humans is the consumption of seafood that contains high levels of organic arsenic.

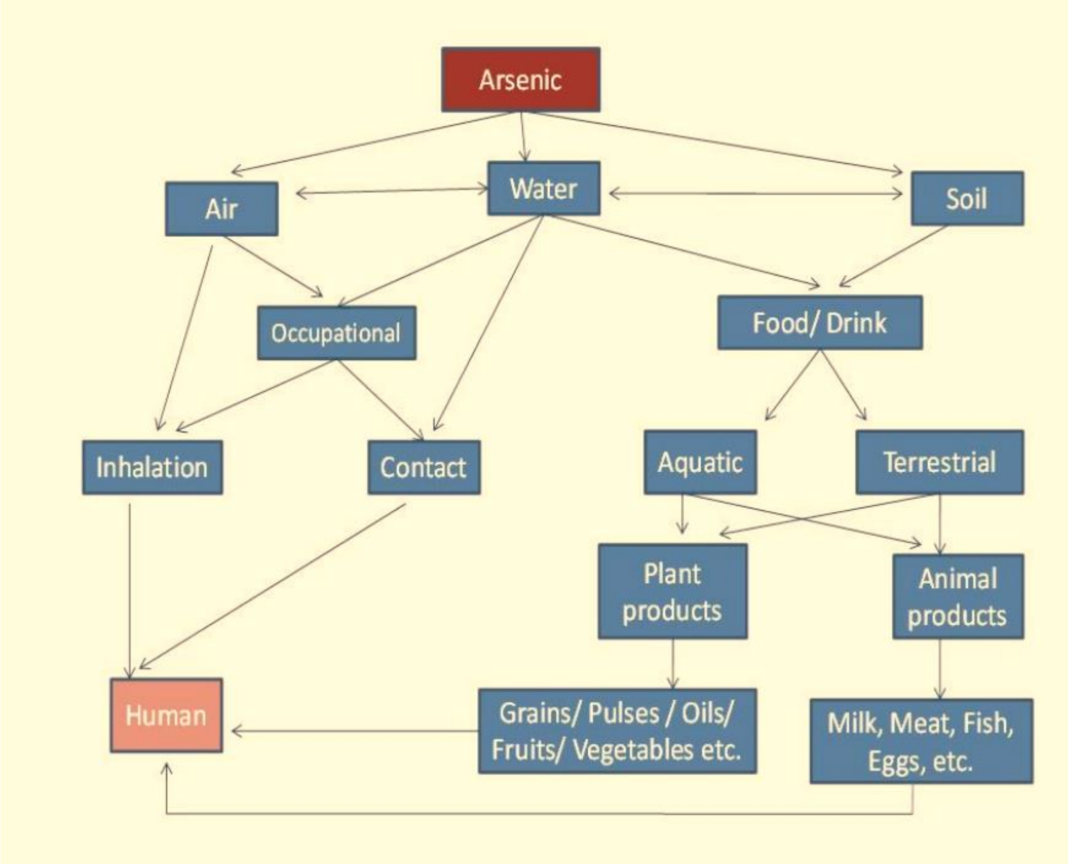

Figure 1: Various routes of exposure of Arsenic to Human

Symptoms of acute arsenic poisoning usually occur within half an hour of ingestion but may be delayed if arsenic is taken with the food. Early symptoms of arsenic intoxication may be muscular pain, abdominal pain with nausea, vomiting and diarrhea, flushing of skin. Chronic ingestion of inorganic arsenic causes multi system adverse health effects including cancer of skin, lung, liver, kidney and urinary bladder. Increased exposure of arsenic is also associated with non-insulin dependent diabetes mellitus. The children with high arsenic in their hairs have less height than the children with low arsenic (Siripitayakunkit et al., 2000b). Arsenic contaminated drinking water is also responsible for growth retardation, spontaneous abortion, stillbirth and infant mortality (Hopenhayn-Rich et al., 2000).

IV. MAIN EFFECTS OF ARSENIC CONTAMINATION ON HUMAN HEALTH

Arsenic is a chemical that is known to cause cancer and is regarded to be of the highest priority as a pollutant owing to its high level of toxicity. Arsenic ingestion by people has been proven all over the globe due to the consumption of polluted water and food. Arsenic may be found in the environment in both its organic and inorganic forms; however, the inorganic kind is the one that poses the greater health risk. The presence of inorganic as is more common in water sources and, as a consequence, in the edible fish items that include it. When it comes to plant life, being exposed to arsenic pollution (for example, via soil that is polluted) may result in the suppression of plant development, as well as the loss of or decrease in photosynthetic and reproductive functions.

The buildup of arsenic in the food chain has the potential to have both short-term and long-term consequences on human health. According to Zeng et al.'s research from 2020, the primary health effects of consuming an excessive amount of arsenic include experiencing nausea, gastrointestinal discomfort, diarrhea, numbness and tingling, muscular soreness and cramps, and in severe circumstances, even passing away.

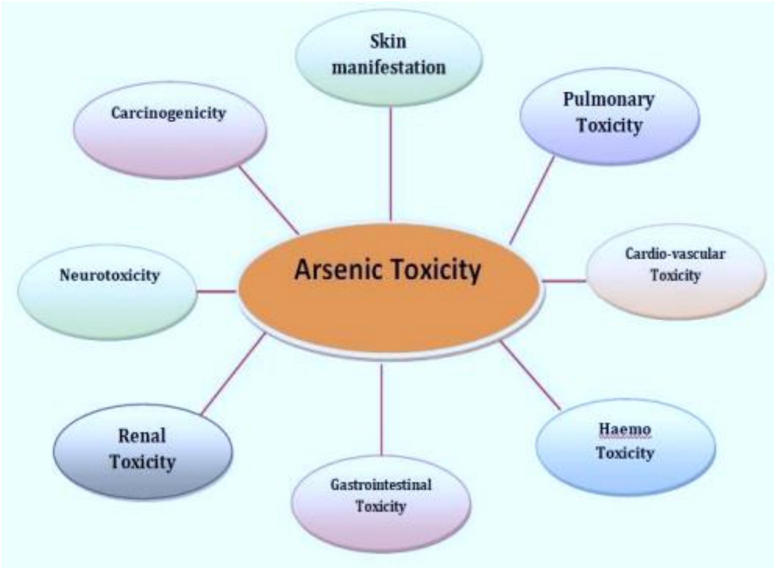

Figure 1: Different effects of arensic on human health

Higher concentrations of inorganic arsenic in the human body are thought to be responsible for the long-term consequences. The consequences are most easily seen in the skin and include pigmentation, the creation of lesions and patches, and possibly function as precursors to skin cancer. There is evidence that arsenicosis may also lead to the development of lung and bladder cancer. Other health problems, such as diabetes, lung illness, and heart disease, may also develop as a result of prolonged exposure to arsenic; for instance, Taiwan has seen gangrene as a result of black-foot disease, which has led to fatalities as a result of increased arsenic concentrations. There is evidence in the published literature to suggest that malnutrition also has a role in the severity of various illnesses. Additionally, infant mortality is seen in many different regions of the globe, particularly during pregnancy in many of these regions. Children who are exposed to arsenic are at a greater risk of having impaired cognitive development, intellect, and memory than other children. (Zhang et al., 2021).

V. ABIOTIC SOURCES OF ENVIRONMENTAL EXPOSURE TO ARSENICAL

Arsenic (As) is a hazardous metalloid element that is found in the earth's crust. It is abundantly present in the air, water, and soil in a variety of valence states, including As(0), As(III), and As(V), as well as arsine gas, which has an oxidation state of -3. Arsenic is a known carcinogen. Abiotic sources of arsenic in the environment include mining operations, industrial processes, agricultural activities, and so on (Nadiri et al., 2021). Geogenic sources of arsenic in the environment include subsurface water, minerals, and geothermal processes. Anthropogenic sources of arsenic in the environment include mining operations, agricultural activities, and so on. According to Dahlawi et al. (2018), a significant source of arsenic exposure in people is the consumption of plant-based food that was grown on arsenic-contaminated soil. This is because arsenic may be found in soil. Because of leaching and runoff that mixes with rivers, ponds, and other bodies of water, these polluted soils also add arsenic to groundwater and surface water resources. Unintentional human and industrial actions have the potential to spread the geological pollution much farther. Therefore, drinking contaminated groundwater and using it for other household activities contributes significantly to human exposure to the carcinogen arsenic.

(Chakraborti et al., 2018) It has been observed that there is a high amount of arsenic in groundwater that is equivalent to or more than 50 micrograms per liter. This is particularly concerning for society in Southeast Asia as well as areas of India and Bangladesh. (Shaji et al., 2021) Other research suggested that people living outside of Asia are also susceptible to arsenic poisoning as a result of drinking contaminated groundwater. It is interesting to note that Bharti et al. (2017) and Giri et al. (2020) both observed that water from high-altitude locations contains arsenic in addition to other heavy metals. Arsenic may also be found in the groundwater and river water thanks to another significant source: river silt. The findings of these research point to widespread arsenic poisoning in water supplies over a broad range of topographies, from mountainous regions to plains, regardless of the presence of industrialisation or other human-made causes. The World Health Organization (WHO) established a standard of 50 parts per billion (ppb) arsenic levels in drinking water throughout the exposure period in order to limit water arsenic levels sooner. However, in 1993, this standard was lowered to a lower level since it was regarded to represent an unacceptable risk of cancer mortality. The current WHO recommendation value is temporarily set at 10 ppb because to arsenic detection and removal limitations (Cheng et al., 2016). Despite the fact that this is still deemed an unacceptable level of health risk, the guideline value has been temporarily set at this amount. Therefore, each nation needs to choose its own acceptable amount of arsenic in drinking water; as of now, several nations have established standards ranging from 50 parts per billion to fewer than 10 parts per billion (Altowayti et al., 2021).

Inhaling more than 10 to 25 parts per million of the gaseous form of arsenic (arsine) may be fatal in a period of less than an hour. This is the most poisonous form of arsenic. According to Zhao et al. 2019a, arsenic contamination in the air is being caused by activities related to mining as well as the burning of polluted charcoal. Arsenic does not produce tissue irritation and has no odor; as a result, exposure to this arsine does not result in any obvious symptoms. For this reason, there should be consistent monitoring of arsenic in a variety of abiotic sources in order to improve epidemiological research and control methods on arsenic toxicity and related health risks.

VI. NEW THERAPEUTIC AGENTS FOR CONTROLLING ARSENIC TOXICITY:

In recent years, the majority of in-vivo and in-vitro investigations have indicated that ROS production, oxidative stress, DNA damage, mutations, and cytotoxicity are the essential molecular alterations in arsenic toxicity (Firdaus et al., 2018). These findings were published in the journal Food and Chemical Toxicology. This indicates that arsenic promotes oxidative stressors and cytotoxicity in a variety of cell lines via ROS formation. This in turn stimulates NADPH oxidation, which ultimately results in unfavorable alterations to the cells. According to Rao et al. (2017), glutathione is an essential antioxidant that keeps the antioxidant / pro-oxidizing balance in check and plays a critical part in the process of shielding cells from the effects of oxidative stress. Therefore, regulating oxidative stress and increasing the body's antioxidant defenses is an essential method for managing arsenic poisoning and finding effective treatments for it.

As a result of the presence of a variety of flavonoids, alkaloids, trace minerals, and so on, plant extract has a high antioxidant content, and as a result, it has the potential to be effective as an antioxidant-based treatment agent in arsenic poisoning. Curcumin has been shown to have therapeutic benefits against arsenic-induced toxicity without causing any adverse consequences, according to Mohajeri et al. (2017). Another study on the extract of Ginkgo biloba (GBE), which was obtained from the leaves and contains ginkgo flavone glycosides, terpene lactones, and other active components, has shown that it has beneficial effects. These effects include modulating antioxidant functions, having anti-inflammatory effects, inhibiting platelet aggregation, and regulating the immune system. While the pathophysiology of arsenicosis causes an imbalance of pro-inflammatory and anti-inflammatory T cells, Xia and colleagues (2020) reported that GBE has repercussions for arsenicosis via the law of balance of pro-inflammatory and anti-inflammatory T cells. According to the findings of Yao et al. (2017), GBE may ameliorate lipid peroxidation in rats, which in turn reduces the buildup of arsenic in the liver as well as liver damage. Recent studies have shown that natural bioactive compounds have antioxidant characteristics and may effectively reduce the toxicity caused by arsenic by modifying the body's antioxidant defense mechanism. These findings were published in a number of studies. According to the findings of these investigations, antioxidant therapy is a relatively risk-free and cost-effective preventative medication for arsenic poisoning as well as other human illnesses and disorders. Table 1 provides a detailed evaluation as well as a summary of several research that have been conducted on various therapeutic materials to decrease arsenic toxicity.

Table 1: Various Therapeutic Agent to Decrease Arsenic Toxicity

Therapeutic Agent	Mechanism of Action	Application and Use
Dimercaptosuccinic Acid (DMSA)	Chelation Therapy: Binds to arsenic and facilitates its excretion through urine.	Used for acute and chronic arsenic poisoning.
Dimercaptopropane Sulfonate (DMPS)	Chelation Therapy: Similar to DMSA, it forms complexes with arsenic for urinary elimination.	Used for arsenic poisoning and heavy metal toxicity.
Sodium Thiosulfate	Chelation and Antioxidant Effects: Enhances the elimination of arsenic and may counteract oxidative stress.	Administered in cases of acute arsenic poisoning.
British Anti-Lewisite (BAL)	Chelation Therapy: Forms stable complexes with arsenic for excretion.	Previously used, but limited by adverse effects and effectiveness.
Prussian Blue	Adsorption and Sequestration: Binds to certain forms of arsenic, reducing its absorption and promoting excretion.	Used for chronic arsenic exposure and certain heavy metal poisonings.
Penicillamine	Chelation and Binding: Forms complexes with arsenic for elimination.	Considered for arsenic and other heavy metal poisonings.
N-Acetylcysteine (NAC)	Antioxidant and Detoxification: Supports glutathione synthesis and detoxification pathways.	May be used to counteract oxidative stress from arsenic exposure.
Activated Charcoal	Adsorption: May help reduce absorption of arsenic from the gastrointestinal tract.	Used as a supportive measure in certain cases of poisoning.

Chelating therapy is also regarded an effective and well-known treatment for arsenic's toxicity; yet, it has exhibited various undesired consequences owing to the restricted safety of chelating agents. This is despite the fact that chelating therapy is considered an effective treatment. In addition, there is evidence that arsenic is taken up by the cells of mammals and other animals. Following this, it is possible for it to undergo biotransformation, and its metabolites are also known to have hazardous effects. Therefore, the suppression of arsenic's biotransformation ought to be regarded a primary mechanism for the bio-inactivation of arsenic and the lowering of arsenic's toxicity in the body. This is going to be a very important step in the creation of many different medicinal medicines in the future. In recent years, numerous biomedical applications have increasingly turned to the usage of nano metal oxides in order to find a solution to this worldwide issue. According to Edis et al. (2021), nanomaterials such as liposomes, polymeric micelles, and phospholipid complexes have emerged as a few viable therapeutic approaches for lowering arsenic toxicity. These materials have a variety of forms, as well as a big surface area, specificity for the particular substrates they are designed for, and surface area. In order to remove heavy metals from a variety of sources, several metal oxide nanoparticles (NPs) have been used as nano adsorbents. These nanoparticles include aluminum oxide, titanium dioxide, zinc oxides, copper oxide, and iron (hydro) oxides, among others. In the treatment of neurological and other biochemical disorders caused by arsenic, Naqvi et al. (2020) found that the protective impact of solid lipid nanoparticles loaded with monoisoamyl-2,3-dimercaptosuccinic acid (NanoMiADMSA) was superior to its volume of MiADMSA. According to the findings, the chelating characteristics of NanoMiADMSA with a size between 100 and 120 nm are superior to those of MiADMSA when it is in bulk form. These results provide encouragement for further research on the identification of effective nanomedicine in arsenic poisoning that has greater effectiveness and safety.

VII. CONCLUSION

In conclusion, the contamination of water sources with arsenic presents a critical and complex challenge that significantly impacts both the environment and human well-being. The devastating effects of arsenic-contaminated water on ecosystems and human health underscore the urgent need for comprehensive strategies to address this issue. The environment suffers profound consequences as aquatic ecosystems experience disruptions in biodiversity, impaired reproductive success of aquatic species, and altered nutrient cycling. The bioaccumulation of arsenic in food chains further magnifies these effects, with far-reaching implications for predator-prey relationships and the overall stability of ecosystems. Moreover, the persistence of arsenic in the environment exacerbates the long-term impacts on soil quality and plant health, disrupting crucial ecosystem functions and services.

Human health, too, bears the brunt of this crisis. Chronic exposure to arsenic-contaminated drinking water contributes to a spectrum of severe health problems. From skin lesions and cancer to cardiovascular and neurological disorders, the toll on public health is staggering. Particularly vulnerable are communities that rely on groundwater sources, often found in rural areas. The ripple effects of arsenic poisoning extend to economic and social dimensions, as affected populations struggle with the burden of healthcare costs and diminished quality of life.

The restoration of ecosystems and protection of human health necessitate sustained commitment across sectors. Research into innovative remediation strategies, improved water management practices, and sustainable land use planning can contribute to long-term solutions. By addressing the dual challenge of mitigating environmental degradation and safeguarding human well-being, we can pave the way for a healthier future in the face of arsenic-contaminated water's devastating effects.

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