



The Impact of Arsenic Exposure on Human Health: A Comprehensive Review of Health Risks and Prevention Strategies

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Abstract

Water is one of the most important compounds or substances on Earth. Water is present in almost every form: solid, liquid, or gas. Water exists as a liquid that is used for drinking, washing individuals' bodies, keeping our houses clean, and keeping plants and animals alive. Water exists in the form of a solid, like glaciers and mountain snowfall. Water exists in the form of a gas, like evaporated water molecules (steam), etc. All animals, plants, and human beings need water to survive. The question arises: if there were no water on Earth, then there would be no survival of life on Earth. A critical content analysis method was used, which was qualitative in nature, and all previously published research papers were reviewed. The results revealed that, over that past few decades, drinking water has been continuously contaminated. The use of chemicals and inappropriate systems of sewerage and waste disposal contaminate drinking water. Due to the improper cleaning of drinking water, arsenic, a very dangerous chemical compound, is present in water. The paper recommended that boiling is effective for eliminating this compound, and the most dangerous compound can be removed from the water. It damages lives in many ways. Mostly, it is present in every kind of water, especially drinking water.

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Introduction

Arsenic is a chemical element. It is denoted by As, and its atomic number is 33. Arsenic occurs in many forms. It is a metalloid and sometimes occurs in various allotropes; it also occurs in many minerals (Marambio-Jones & Hoek, 2010). Rudimentary Arsenic is insoluble in water. Arsenic salts contain a high sort of pH value, and their compounds are found in the form of crystalline, powder, translucent, and amorphous forms. It ordinarily occurs in trace amounts in soil, water, rock, and air. However, the concentrations may vary from place to place. It may be high or low in certain areas as a result of variations in the environment (Mudgal et al., 2010). Weathering and anthropogenic actions that include metal excavating, combustion of fossil fuels, and insecticide use are all reasons for high and low levels of arsenic in various areas. Many arsenic compounds exist in the environment. Arsenic is used in alloys of lead. It is generally used in automobiles, vehicles, and batteries. Arsenic and arsenic compounds are particularly used in semiconductor electronic devices, and Arsenic trioxide is used in the manufacturing of pesticides, herbicides, insecticides, and in the production of wood products.

Long-term consumption of Arsenic water can cause cancer in the lungs, kidneys, bladder, and skin. It causes skin changes like hyperkeratosis and pigmentation variations. Arsenic-contaminated drinking water increases the risk of lung and bladder cancer and skin pigmentation (Vieira et al., 2011). Some detrimental findings indicate that arsenic becomes

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the cause of destruction in different types of cells with diverse endpoints among individuals and cancer patients. The results about arsenic are mainly negative. Inorganic arsenic that is soluble in water is intensely toxic, and assimilation of huge quantities of arsenic leads to gastrointestinal symptoms, disorder in the nervous system, and disturbance in cardiovascular functions, which can cause ultimate death. In survivors, melanosis, encephalopathy, hepatomegaly, bone marrow depression, hemolysis, and polyneuropathy are mainly observed (Jomova et al., 2011).

All these effects are discussed in many studies by using different methods and techniques related to study design. The article discusses the overall damage of arsenic on human health. On the other hand, in this article, we mention the reports of water samples from Lahore. This study is based on drinking water samples from Pakistan. Pakistan's population is very high (Abdul et al., 2015; Nazirullah et al., 2023). Due to the high population of Pakistan, the water use is also very high. Similarly, in the walled city of Lahore, the water is present at a very low surface level. In this way, the chances are very high that this low surface water contains more arsenic in it. Therefore, it is necessary to make people aware of the bad effects of arsenic on human health. It is one of the biggest cancer-causing sources in Pakistan and other Asian countries.

Arsenic a problem in different Countries

Some species of bacteria use arsenic compounds as respiratory metabolites. Rats, goats, chickens, humans, as well as various other species use arsenic quantities as an essential dietary element. However, its poisoning effects are also found in many species. Millions of individuals around the world are affected by the problem of Arsenic detoxification in groundwater. The lives of 150 million people around the world are threatened by arsenic contamination in drinking water. Almost 110 million of these people belong to countries in South-East Asia. Nepal, Bangladesh, India, Pakistan, China, Cambodia, Vietnam, Laos, Taiwan, and Myanmar (Singh et al., 2015). The lives of people are affected by the direct or indirect consumption of arsenic-polluted drinking water and arsenic-contaminated food that is dangerous for health. The high or low concentration of As in drinking water and contaminated food varies from place to place. It is necessary to deal with this issue in order to control the diseases and health threats that are caused by arsenic-contaminated drinking water and soil. Treating arsenic-contaminated water and soil is the only option to control these diseases. In light of the above-mentioned factors, it is essential to update all individuals about arsenic and its effects on human health. This paper is based on the properties, occurrence, and sources of Arsenic in the environment; the dangerous effects on human health (cancer-causing effect) and other health-related factors; and the use of several conventional and modern technologies for the elimination of As from water and soil.

Measurement of Arsenic Level

There is a diversity of instrumental techniques used for the measurement of arsenic levels. Some of the techniques are used for the determination of Arsenic. These include atomic absorption spectrometry (AAS), atomic fluorescence spectrometry (AFS), inductively coupled plasma atomic emission spectrometry (ICP-AES), inductively coupled plasma mass spectrometry (ICP-MS), and voltammetry. Among these, ICP-MS could be used as an arsenic-specific detector. "Hyphenated" approaches are used for defining specific arsenic types. Hydride generation procedures are often used to increase the sensitivity of a formal range of arsenic compounds (Carlin et al., 2016). In Bangladesh, a color reaction testing equipment for arsine-containing bromide is used for groundwater testing, and it has a detection limit of 50–100 µg/liter in underground settings.

Sources of Arsenic in the Environment

There are two sources of every matter. Primary source and secondary source. Primary sources of arsenic are present in the environment and all around the earth in the form of gases, liquids, and solids. There are different protection layers that exist all around the Earth.

Hydrosphere, Pedosphere, Biosphere, Atmosphere

Hydrosphere: is all the water that occurs on the Earth's surface in lakes, seas, oceans, ponds, rivers, streams, and in clouds. Hydrosphere is the liquid form of the water component. Arsenic exists in the hydrosphere, and the hydrosphere covers almost 70% of the Earth's surface. Water is an essential element for all plants and animals (Mertz, 2012). The hydrosphere, like the atmosphere, is always in motion. The water motion is in the form of streams, lakes, and clouds.

Pedosphere: The outermost layer of the earth is the Pedosphere. It is made up of soil and soil processes. The pedosphere is the collection of soil, water, air, and all the organisms on the Earth. It is considered the covering of the Earth. It protects the Earth from the dynamic interactions happening between the atmosphere and other layers like the biosphere and lithosphere. The atmosphere contains air, soil, and organisms above the soil (Sun et al., 2012).

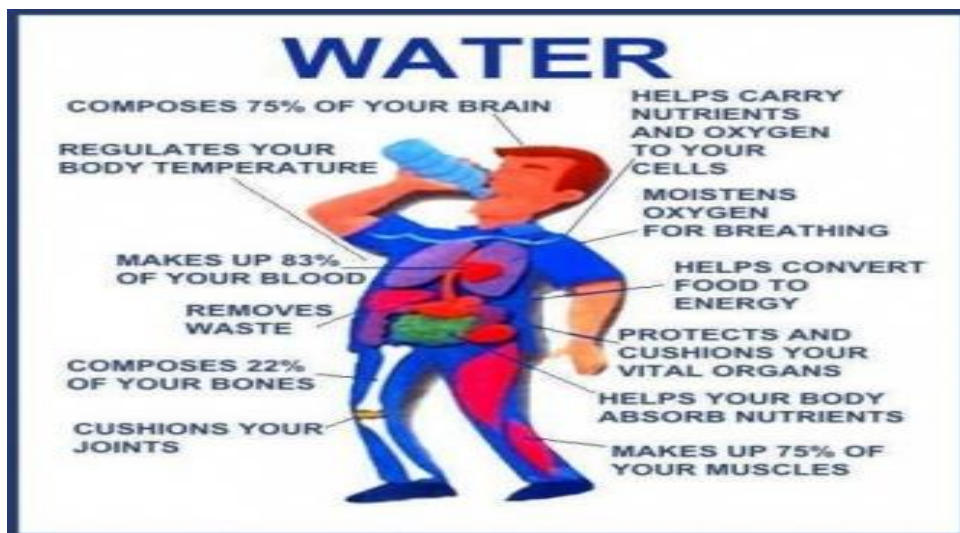
Biosphere: The biosphere contains only living organisms. On the other hand, the hydrosphere contains all the water on Earth that exists above the soil, below the soil, and in the air. The biosphere is the area on Earth that is occupied by living organisms, whether it is in the atmosphere or on the surface of the Earth. This region extends up to 10 kilometers beyond sea level; in this region, some birds usually fly, and 8 kilometers below the sea, where marine life exists. The layer of the biosphere in which life exists is thin and contains a small amount of oxygen in the atmosphere.

The atmosphere consists of a layer of gases surrounding all around the Earth and other material bodies. It is the outer covering of gases surrounding the planet, including Earth. This layers of the Earth mostly consist of different gases like nitrogen (approximately) 78%, oxygen (approximately 21%, other gases (like), argon 0.9% along with carbon dioxide and some other gases in very rare amounts. Oxygen is used for the respiration of living organisms (Tyler & Allan, 2014). Nitrogen is used by nitrogen-fixing bacteria, and lightning helps produce ammonia; nitrogen is also used in the formation of nucleotides and amino acids. On the other hand, carbon dioxide is used by plants, algae, and other cyanobacteria for photosynthesis. In this way, the atmosphere helps living organisms survive on Earth and protects against ultraviolet solar radiation that nowadays comes directly towards Earth due to damage to the ozone layer and ozone depletion. Ozone depletion is now a day's also huge issue that damages living organisms on Earth. These are all the primary sources of arsenic. Arsenic exists in water as well as on the soil surface in the form of As-enriched minerals.

The secondary sources of arsenic include the use of insecticides and herbicides, mining and smelting, semiconductor industries, phosphate fertilizers, coal combustion, industrial processes, and timber preservatives. These are the secondary sources of arsenic in the environment. Secondary sources contain soil and food enriched with arsenic compounds. When individuals eat such food and material, it ultimately becomes a case of serious infection in their bodies. And after cooking or heating such type of food, it becomes more dangerous for health. All of these become the source of cancer for the human body. There are detailed descriptions of all aspects of arsenic on the individual body. This article highlights all arsenic effects on the living body and the reasons for cancer by arsenic.

Use of Water in the Human Body

Water is a very essential need for all living organisms. If there is no water on Earth, then there will be no life on Earth. When a person drinks water, the body absorbs water in different ways. All the cells of the body require water for their proper functioning. This image clearly shows the absorption of water in the human body (See Figure 1).



Arsenic and human health effects (Source: National Kidney Foundation (2017))

Effect of Arsenic on Human Body Parts

Chronic exposure to inorganic arsenic can damage multiple organ systems, including the skin, nervous system, cardiovascular system, liver, kidneys, and endocrine system, leading to disorders such as skin lesions, peripheral neuropathy, cardiovascular disease, diabetes, and liver dysfunction (Hughes, 2002; World Health Organization [WHO], 2022). Long-term ingestion of arsenic-contaminated drinking water is also associated with an increased risk of cancers of the skin, bladder, lung, and kidney, as well as adverse effects on cognitive development and overall human health (WHO, 2022). These widespread health effects make arsenic contamination a major global public health concern, particularly in regions where groundwater is the primary source of drinking water (WHO, 2022).

Nervous System

The mind is a significant target structure of arsenic toxicity, affecting cognition and attention because of its ability to pass the blood-brain barrier easily. Arsenic is distributed throughout all parts of the brain. However, studies show that arsenic accumulates most in the hypophysis, also called the pituitary gland. Neurological difficulties developed due to severe and long-term exposure to arsenic, and these difficulties were reported in a quick and regular manner by sensorimotor neuropathy.

Sensory nerves are usually more sensitive to arsenic than motor nerves, and neurons with extended axons are affected more than neurons with short axons. Because of decreased neuronal function due to arsenic accumulation, very severe clinical symptoms of different diseases like paresthesia, pain, and detachment in the soles of the feet occur; in this way, neurons also fail to purify reactive oxygen species (ROS) and produce glutathione (Kim et al., 2013). However, one of the most harmful effects due to huge accumulation of arsenic is neurotoxicity and disorder in the cytoskeletal framework. This causes changes in the composition of proteins in the cytoskeleton and hyperphosphorylation of proteins.

One of the key sources of arsenic-induced neurotoxicity is oxidative stress. Under normal conditions, arsenic's effects on the nervous system may lead to the inactivation of essential enzymes that are helpful for proper cell functioning. Different studies show different damage due to arsenic on the nervous system. For example, neuronal apoptosis, loss of memory, verbal learning deficiencies in expertise, cognitive impairment, and behavioral

disorders are all reasons for arsenic accumulation in the nervous system. Arsenic affects both central and peripheral neuropathies (Mertz, 2012).

Respiratory system

Arsenic exposure causes serious complications in the respiratory system of human beings over time. This arsenic exposure takes place by drinking arsenic-contaminated water or the direct combustion of arsenic metals in industries and factories. These sources of arsenic exposure led to ultimate damage in the respiratory system and cause environmental pollution. Arsenic exposure by drinking arsenic-contaminated water is most frequently found in Bangladesh. The high mortality rate due to arsenic toxicity is found in the Bangladeshi population, which leads to common causes of cancer among the people. All of these can cause many respiratory diseases. Arsenic dust particles that are found in air or soil, fume inhalation, and during the refining of arsenic material produce respiratory diseases such as chronic cough, bronchitis, laryngitis, and rhinitis (Sun et al., 2014). Parvez (2010) conducted a study in a cohort that highlights the symptoms of arsenic causing respiratory diseases such as chronic cough, difficulties in breathing, chest sounds, blood in saliva, and other breathing problems. However, there is also an inverse relationship between urinary arsenic levels and lung function. On the other hand, this cohort study explores arsenic exposure at low to moderate levels and becomes the reason for decreased proper lung functioning and tuberculosis (See Figure 2).

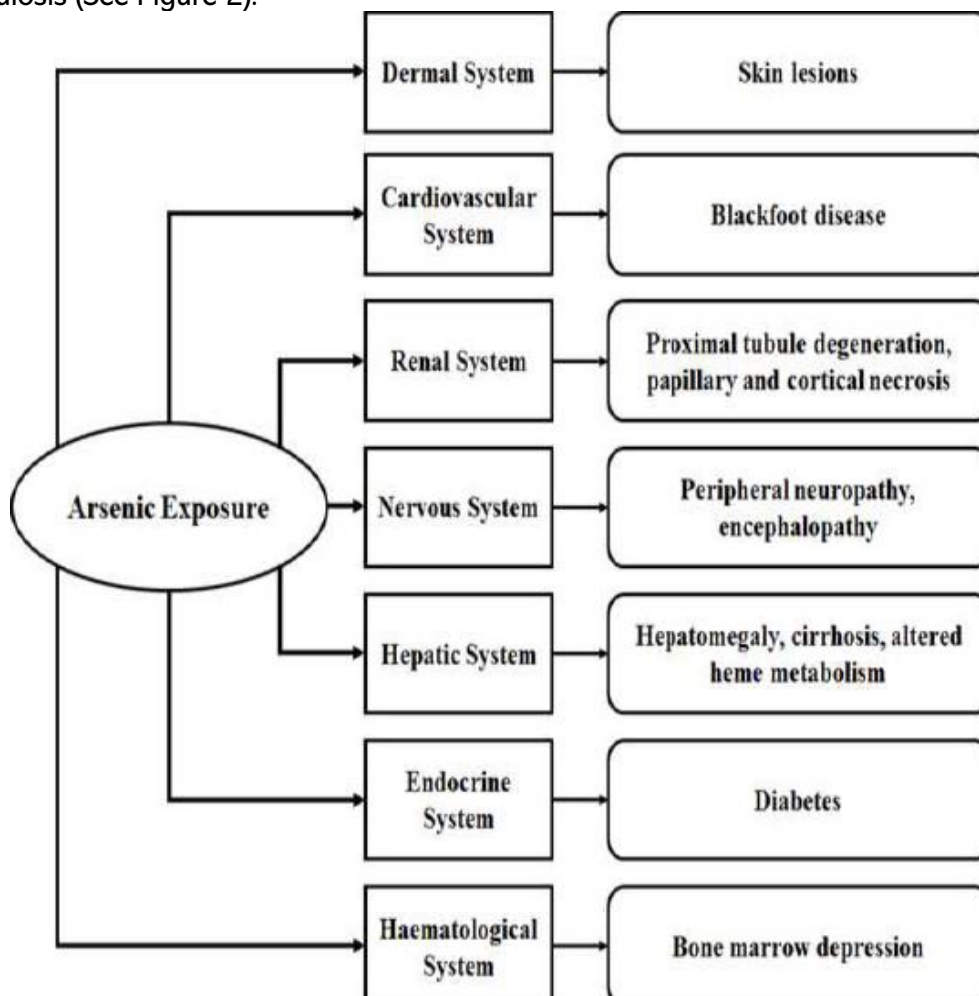


Figure 2: Major health effects of chronic arsenic exposure on different organ systems (Source: Hughes (2002))

Immune System

The immune system is made up of cells, tissues, and organs that work together to protect the body from foreign attacks by bacteria, fungi, and other microorganisms. Different types of damage are found in the human body due to arsenic exposure in drinking water.

DNA, oxidative processes, and cross-linking proteins are all affected by arsenic. These are all responsible for increasing the level of susceptibility in the body of healthy persons. Therefore, to avoid all these problems, and should be aware of the severity of arsenic-contaminated drinking water and foods (Nazirullah & Ullah 2025).

Skin Infection

Skin cancer and skin infection development are also due to arsenic exposure in drinking water. It has become a source of chronic arsenic skin poisoning. Skin poisoning and infectious cases are mostly reported in coastal areas of Taiwan. People are now suffering from hyperpigmentation and keratosis, and their ratios are different among the different areas of the people. These skin infections are also found due to arsenic-contaminated drinking water, also found in China, Pakistan, India, and Bangladesh (See Figure 3). Ultraviolet light and arsenic cause two types of non-melanoma skin cancer, basal cell carcinoma and squamous cell carcinoma. These are all the causes of skin cancers among individuals (Tyler & Allan, 2014).



Figure 3: Young Adult suffering with Hyperkeratosis (Source: Tyler and Allan (2014))

Lungs Cancer

In 2002, IARC recognized lung cancer that is caused by arsenic-contaminated drinking water. It is one of the other types of cancer. Khuzaiifa and Aasim (2025) have demonstrated that continuous consumption of arsenic-contaminated drinking water increases susceptibility to lung cancer. Tumorigenesis caused by arsenic exposure occurs in the lungs, which is one of the main targets of arsenic-induced tumorigenesis. In North America, a high death rate of patients has been reported due to lung cancer. It is also one of the significant causes of death in Asia and Africa (Joseph et al., 2015) Arsenic affects everyone in society. Although smoking is considered one of the main cause of lungs cancer but the arsenic contaminated drinking water effect both type of people either they are smoking and non-smoking people. The human could save ourselves from different types of cancer by proper cleaning of the water (Nazirullah et al., 2022).

Liver Cancer

The liver is considered one of the main target organs of the body that is affected by arsenic carcinogenesis. Arsenic-contaminated drinking water increases the cancer mortality rate of society. A contemporary study conducted in Taiwan indicates the arsenic effect on liver cancer. This study shows that there is a significant difference in the ratio of liver cancer-affected males and females. According to this study, 802 are males, and 301 are females in the 138 villages of the coastal areas of southwest. Liver cancer is most commonly found in

the age group of people who are between 0 and 19 years because of the high amount of arsenic in drinking water.

Prostate Cancer

It is one of the malignant types of cancer that develops with the passage of time. It depends on age. It develops with the passage of time. It is a proliferative disease. This type of cancer is most commonly found in males, and it is the cause of increased mortality rate among males. Some of the main risk factors that contribute to prostate cancer are age, family history, diet, diet, hormones, status, ethnicity, class, and exposure to heavy metals, hyperplasia, sexual activity, and sexually transmitted infections (Singh et al., 2015). Carcinogenesis is produced by the active and potential functioning of the prostate gland. This type of cancer itself involves many other types of cancers. Prostate carcinogenesis is one of the highest-risk cancers for death. This complex mechanism is usually responsible for the increase in different types of cancers as a result of chronic arsenic exposures.

Remediation strategies for Arsenic contamination

Arsenic is very dangerous for human health. It is necessary to eliminate the small quantities of arsenic from arsenic-contaminated drinking water and food. Remediation strategies include microfiltration, ultrafiltration, advanced hybrid technologies, and reverse osmosis. These are all called membrane technologies. However, oxidation and filtration, photochemical oxidation, photocatalytic oxidation, and biological oxidation. These are all processes of oxidation. Some more remediation's techniques include electrocoagulation and electrochemical arsenic remediation. All these strategies are applicable to eliminate arsenic compounds from drinking water because these are very harmful to health (Gohar, 2025).

Conclusion

Health impacts due to arsenic exposure are happening all over the world, but the variety of these impacts is found mostly in Africa and South Asia and some regions of North America. To control all these arsenic effects on human health, there is a diversity of methods and strategies that have to be applied for mitigation and to prepare people for the severity of different diseases and cancer factors. Health communities and individuals should encourage for achieving the direct co-benefits to cope with arsenic and its dangerous effects as a result of mitigation and adaptation. We should prepare the people of society for the treatment of cancer patients and provide emergency services for affected people (Molin et al., 2015) One of the most common adaptive strategies that many countries are now applying is raising awareness among people about the risk of arsenic exposure, contaminated drinking water, and the health risks associated with it. However, they are able to manage themselves according to that environment. They manage the water surfaces according to the level of contamination so that they remain safe from the harmful effects of arsenic exposure. Different techniques are used to control the increasing level of cancers in the human body. By understanding all these factors, we can plan to minimize arsenic exposure and health risks and survive the unavoidable effects of arsenic on human health.

Author Contributions:

The Conception and design: Muhammad Aasim. Collection and assembly of data and Qualitative Content Analysis and interpretation of the data: Muhammad Khuzaifa. Drafting and Critical revision of the article for important intellectual content by Muhammad Aasim and Corresponding Author Email: Khu81298zaifa@gamil.com

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