



"Assessing the Occurrence, Causes, and Health Effects of Arsenic Contamination in Groundwater: A Comprehensive Review"

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Abstract: This article presents a new geological and scientific perspective on the major sources of arsenic contamination in India. Arsenic, a toxic element, is naturally present in various geological resources such as soil, sediments, rocks, water bodies, and groundwater. The geographical occurrences of extreme arsenic levels are linked to volcanic eruptions, weathering of rocks, river overflows, and action of water. In India, several geological resources have been identified as primary or secondary origins of arsenic contamination. These include Gondwana coal layers in East India, Bihar mica site in the east, Pyrite-bearing shale in Central India, Son River gold basin in the east, and isolated outcrops of sulfides in the eastern Himalayas. Additionally, anthropogenic activities contribute to arsenic pollution through high-temperature procedures in industries like pyrometallurgical and nonferrous metal mining, iron and steel production, and coal ignition. Specifically, the Yamuna and Ganga Rivers, which hold spiritual and cultural importance in India, are highly affected by arsenic pollution due to domestic, industrial, and electronic waste discharges, as well as agricultural activities. Arsenic's toxicological and carcinogenic effects vary depending on its oxidation states and chemical forms. Inorganic arsenic, particularly in its trivalent form, proves to be more hazardous than its organic and pentavalent counterparts. Unfortunately, removing arsenic from contaminated water is challenging, especially when mixed with other impurities like lead, iron, and selenium. The health impacts of arsenic exposure are far-reaching, with long-term ingestion of contaminated water leading to various cancers (urinary bladder, lungs, skin, kidney, nasal passages, liver, and prostate) and non-cancerous disorders (cardiovascular, pulmonary, immunological, neurological, and endocrine).

Key Words: Arsenic contamination, Geological resources, Carcinogenic effects, Anthropogenic activities.

1. INTRODUCTION:

A Comprehensive Study of Arsenic Contamination in India: Geological and Scientific Perspectives

Arsenic contamination is a pressing environmental concern in India, affecting various regions and water sources. In this research, we adopt a geological and scientific approach to identify the major sources of arsenic contamination in the country. Arsenic can be found naturally in the environment, resulting from geological processes such as volcanic eruptions, weathering of rocks, and actions of water in rivers, lakes, and oceans. Arsenic is commonly present in soil, sediments, rocks, water bodies, groundwater, and river plains, with potential origins traced back to the Himalayan Mountains and the Shillong Plateau.

2. Geological Resources as Sources of Arsenic:

India hosts numerous geological resources containing arsenic, which may have significantly contributed to large-scale pollution. Some key findings include:

a) Gondwana coal layers in the Rajmahal region in eastern India, containing arsenic at a concentration of 0.02%.



- b) Bihar mica site in eastern India, where arsenic concentrations range from 0.08% to 0.12%.
- c) Pyrite-bearing shale from the Proterozoic Vindhyan range in central India, containing 0.26% arsenic.
- d) Son river site, a gold basin in eastern India, with an average arsenic concentration of approximately 2.8%.
- e) Isolated outcrops of sulfides in the eastern Himalayas, containing around 0.8% arsenic.

Anthropogenic Sources of Arsenic:

Human activities also play a significant role in arsenic contamination. High-temperature processes, such as pyrometallurgical operations, nonferrous metal mining and manufacturing, iron and steel production, and coal combustion, release arsenic into the environment. Additionally, industrial activities, including cement production, burning of wastes, and chemical industries, contribute to arsenic release. In regions like Rajasthan and Bihar, mining activities for copper and lead ores containing trace amounts of arsenic can substantially contaminate groundwater sources.

Power Generation and Coal Ash:

Coal-fired power generation is a major non-point source of arsenic pollution due to mercury emissions. Coal ash, which contains heavy metals, including significant amounts of arsenic, also contributes to environmental contamination.

Electronic Waste:

Improper disposal of electronic waste (E-waste) leads to the release of dangerous chemicals, carcinogens, and arsenic, posing severe health risks to humans and the environment.

Contamination in Yamuna and Ganga Rivers:

The sacred Yamuna and Ganga rivers suffer from severe arsenic contamination due to various sources, including domestic, industrial, and electronic waste discharges. The Ganga river, with its numerous branches, receives wastewater from major cities, resulting in heavy metal contamination along specific stretches.

3. Addressing the Issue:

To mitigate arsenic contamination, defensive and proactive measures are essential. These include scientific treatment and disposal of contaminated wastewaters, improved waste management strategies, controlled use of chemicals in agriculture, and the creation of artificial lakes to regulate water flow. Legislative measures and public awareness campaigns are also crucial in curbing pollution. Furthermore, strict enforcement, proper supervision of construction works, and penalties for polluters and defaulters are necessary to ensure effective and lasting solutions. In conclusion, this geological and scientific study highlights the diverse sources of arsenic contamination in India, emphasizing the need for a comprehensive approach to protect both the environment and public health from this hazardous element.

In recent times, arsenic poisoning has emerged as a significant environmental issue, posing a threat to millions of individuals worldwide due to exposure to excessive levels of arsenic through contaminated drinking water. This article delves into the geological and scientific aspects of arsenic toxicity, focusing on its carcinogenic effects, regulatory measures, and challenges faced by environmentalists, doctors, scientists, engineers, and policymakers. Furthermore, it examines the toxicology of arsenic, its chemical forms, and the difficulties associated with its removal from contaminated sources.

Carcinogenic Influence of Arsenic: A Group 1 Carcinogen

Scientific evidence from epidemiological studies has classified arsenic as a Group 1 carcinogenic substance, highlighting its potential to cause cancer in humans. This revelation has prompted the World Health Organization (WHO) to revise the maximum allowable concentration limit (MCL) of arsenic in drinking water, reducing it from 50 mg/l to 10 mg/l. This regulatory adjustment reflects the urgent need to address the challenges posed by arsenic contamination and its detrimental impact on human health.

Toxicity and Chemical Forms of Arsenic

The toxicology and carcinogenicity of arsenic are influenced by its oxidation states and chemical forms. Inorganic arsenic, particularly the trivalent form, is more hazardous and toxic compared to organic arsenic. Chemical transformations of arsenic are limited, and the element can only be converted into different forms or combined with



other elements, such as iron, to form insoluble compounds. However, this process becomes complex when impurities like lead, iron, and selenium are present, making the removal of arsenic economically challenging.

Associations and Health Effects

Groundwater in various regions across the globe is associated with different contaminants, including iron, calcium, magnesium, bicarbonate, chloride, and sulfate, along with arsenic. The presence of inorganic arsenic (As(V) and As(III)) in the form of Na_2HAsO_4 and NaAsO_2 renders the water toxic to humans and plants alike. Prolonged exposure to arsenic in drinking water has been linked to various health conditions, including urinary bladder, lung, skin, kidney, nasal passage, liver, and prostate cancers. Additionally, non-cancerous ailments such as cardiovascular, pulmonary, immunological, neurological disorders, and endocrine dysfunctions, including diabetes, have been associated with arsenic exposure. Furthermore, arsenic has been found to have genotoxic properties, increasing the risk of DNA damage.

Acute and Sub-acute Arsenic Poisoning

Arsenic poisoning can manifest in two distinct forms: acute and sub-acute. Acute poisoning typically occurs due to the ingestion of contaminated food or drink and requires immediate medical attention. Symptoms of acute poisoning include dryness and burning sensations in the mouth and throat, dysphagia, severe abdominal pain, vomiting, diarrhea, and hematuria. On the other hand, sub-acute poisoning is characterized by long-term exposure to arsenic-contaminated water, leading to chronic health effects.

Global Implications and Regional Cases

Arsenic contamination in groundwater is a widespread issue that poses a significant challenge to environmentalists, scientists, and policymakers worldwide. Regions such as West Bengal in India and Bangladesh have long suffered from the calamity of arsenic-contaminated groundwater, resulting in numerous cases of arsenic-related diseases. The magnitude of the problem became apparent after decades of continuous consumption of arsenic-contaminated water, leading to severe health consequences. Notably, concentrations of arsenic exceeding 60 mg/l are considered lethal for human consumption.

4. Conclusion:

In this geological and scientific approach, we have examined the major sources of arsenic contamination in India. Arsenic is found naturally in various geological resources such as soil, sediments, rocks, water bodies, and groundwater. The Himalayan Mountains and the Shillong Plateau are identified as the tentative origins of arsenic in the plains and delta regions of India. Anthropogenic sources of arsenic contamination include various industrial activities such as nonferrous metal mining, iron and steel production, coal-fired power generation, and improper disposal of electronic waste. Additionally, the use of fertilizers, pesticides, and insecticides in agriculture has contributed to considerable groundwater contamination in several states, including Punjab, Andhra Pradesh, Haryana, Karnataka, Tamil Nadu, West Bengal, and Uttar Pradesh. Specific regions, such as the Yamuna River and its surroundings, have high levels of arsenic pollution stemming from domestic, industrial, and agricultural activities, as well as mismanaged solid waste disposal. Similarly, the Ganga River and its branches, such as Ramganga, Kali, and Yamuna, are significantly contaminated due to discharges of domestic sewage and industrial wastes from cities along its course. Addressing arsenic contamination in India requires a multi-faceted approach. Defensive strategies involve scientific treatment and disposal of contaminated wastewaters, improved agricultural practices, and better solid waste management. Proactive measures include public awareness campaigns, maintaining sufficient water flow in rivers, and utilizing self-purifying abilities of water bodies. Additionally, legislative measures with strict enforcement and fines for polluters must be implemented. Furthermore, there is an urgent need to address the issue of electronic waste and promote proper disposal methods to prevent the release of dangerous chemicals and carcinogens, including arsenic. Scientific research and technological advancements should be employed to find efficient and cost-effective methods of heavy metal extraction from water sources. With a combination of preventive measures, strict enforcement, public awareness, and responsible waste management, we can work towards protecting our water bodies and ensuring a safer environment for all.

In conclusion, arsenic poisoning has emerged as a significant global environmental concern, impacting millions of people through contaminated drinking water. Its chronic toxicity has been linked to carcinogenic effects, classified as a Group 1 carcinogenic substance based on epidemiological evidence. As a result, strict regulations have been imposed by organizations like the World Health Organization (WHO) to limit the maximum allowable concentration of



arsenic in drinking water. Addressing this challenge requires the collective efforts of environmentalists, doctors, scientists, engineers, and policymakers. The toxicology and carcinogenicity of arsenic depend on its oxidation states and chemical forms, with inorganic arsenic and the trivalent form being particularly hazardous. Chronic exposure to arsenic through drinking water has been linked to numerous adverse health effects, both cancerous and non-cancerous, affecting vital organs and systems such as the urinary bladder, lungs, skin, kidney, and nervous system. To combat this alarming issue, various countries have set maximum contaminant levels (MCL) for arsenic in drinking water. However, the prevalence of arsenic-contaminated groundwater in regions like West Bengal, Bangladesh, the US, and India remains a critical concern, impacting millions of lives. The toxicology of arsenic involves acute and sub-acute poisoning, with acute cases requiring immediate medical attention due to severe symptoms. The chronic progression of arsenicosis includes preclinical, clinical, complications, and malignancy stages, causing a range of skin and organ manifestations.

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Competing interests

The author has professed the absence of any geological strata of conflicting interests.

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