Water Science and Technology Library

Akhilesh Kumar Yadav
Saba Shirin *Editors*

Emerging and Innovative Arsenic Removal Technologies for a Sustainable Future

Springer

Contents

1 **Arsenic in Water: Understanding the Silent Threat** 1
Yusra Sharf and Rushda Sharf

2 **Challenge of Arsenic Contamination in Crop Lands and Food Chains in India and Need for Cost-Effective Solutions** 19
Dhanya Punnoli and Kunnampally Jayarajan

3 **Smart Sensor Technologies for Arsenic Monitoring** 29
Ramireddy Venkata Sai Reddy, Navaneeth K. Nampoothiri, and Sourav Maity

4 **Emerging Innovations in Arsenic Detection and Removal** 47
Rishagni Chetia, Kevizali Neikha, and Amrit Puzari

5 **Removal of Arsenic from Water Using Adsorption and Phytoremediation Techniques** 67
Archana Kushwaha, Zeenat Arif, and Bineeta Singh

6 **Role of Adsorption on Arsenic Contamination in Groundwater** 85
Rijin M. D. Tom, Thomas J. Kallupurakel, Neethu Shajan, and Vishnu Manirethan

7 **Electrochemical Processes for Arsenic Mitigation** 107
Ram Raj Meena, Hemangini Rathva, and Pramod Soni

8 **Arsenic Removal from the Environment Using Biological Methods** 129
Laxmi Kant Bhardwaj, Prangya Rath, Divya Upadhyay, and Vartika Singh

9 **Arsenic Biological Treatment Using Microorganisms in the Environment** 143
Rushda Sharf, Ambrina Sardar Khan, and Yusra Sharf

10 Bioremediation of Arsenic-Poisoned Environments Using Bacteria and Fungi 163
Sri Keerthana Gopalakrishnan, Shiva Krithika Srinivasan, S. Rahul, and A. Arumugam

11 Ex-Situ and In-Situ Arsenic Removal from Contaminated Environments 183
Subhajit Dutta, Manik Chandra Kundu, Animesh Chowdhury, Biswajit Pramanik, Umalaxmi Thingujam, and Sandip Debnath

12 Biological Treatment of Arsenic Contaminated Soil and Water by Using Phytoremediation and Microbial Bioremediation 203
Swati Sonker and Abhay B. Fulke

13 Integration of Nanotechnologies for Sustainable Remediation of Arsenic Removal 221
Shivanshu Kushwaha and Zeenat Arif

14 Harnessing Nanoparticles for Sustainable Arsenic Remediation in Food Crops: A Comprehensive Study 239
Debadrita Das, Archita Dey, Swetanjana Ghosh, Urvashi Lama, Sharmistha Majumder, Monojit Mondal, and Tarit Roychowdhury

15 Challenges and Opportunities in Implementing Arsenic Technologies 263
S. C. Vetrivel, V. Sabareeshwari, K. C. Sowmiya, and V. P. Arun

16 Current Research and Future Directions in Affordable Arsenic Removal Technologies 285
Praveen Kumar, Ashish Kapoor, and Muthukumar Raghunathan

Chapter 1
Arsenic in Water: Understanding the Silent Threat

Yusra Sharf and Rushda Sharf

Abstract In Minnesota, arsenic is found naturally in soil and rocks. Volcanoes, the weathering of minerals and ores that contain arsenic, and commercial or industrial processes all release arsenic into the atmosphere. Groundwater that could be used for drinking water may absorb trace amounts. Compared to organic and inorganic arsenic, inorganic arsenic is typically too toxic. In certain nations, inorganic arsenic can be found in private well water, copper-chromated arsenate-treated lumber, and industrial settings. For the vast majority, drinking water contaminated with naturally occurring inorganic arsenic is the source of contact. The biggest risk to public health is drinking water polluted with arsenic, which can increase the risk of cancer and other serious health consequences. The most common ways that arsenic exposure results in disease are through ingestion and inhalation. The symptoms of arsine gas poisoning differ significantly from those of other types of arsenic poisoning. Arsine rapidly linked itself to red blood cells after inhalation, causing irreversible destruction of the cell membrane. Neurological, respiratory, hematologic, cardiovascular, gastrointestinal, and other systems can all be adversely affected by arsenic. Arsenic causes cancer in several of organ systems. Skin, lung, prostate, bladder and liver angiosarcoma, are the most prevalent forms of cancer. The central nervous system, cell respiration, inhibition of the pyruvate dehydrogenase enzyme complex, and overt gastrointestinal disturbances may be caused by acute or subacute exposure to As (more than a few mg of inorganic arsenic/day). Chronic arsenic hyperpigmentation can affect mucous membranes in addition to the trunk, where it manifests itself as a thinly dappled “raindrop” manner. Arsenic is a teratogen and a reproductive toxin. The concentrations in the cord blood and maternal blood are comparable, and it is transferred across the placenta. The chapter focuses on causal inference, which is also known as hazard identification and clinical prevention in the terminology of risk assessment.

Y. Sharf (✉)
Department of Zoology, Aligarh Muslim University, Aligarh, India
e-mail: sharfyusra92@gmail.com

R. Sharf
Department of Environmental Science, Integral University, Lucknow, India

A. K. Yadav and S. Shirin (eds.), *Emerging and Innovative Arsenic Removal Technologies for a Sustainable Future*, Water Science and Technology Library 131,
https://doi.org/10.1007/978-3-032-01176-3_1

Keywords Arsenic exposure · Contaminated water · Carcinogenesis · Threats · Clinical prevention

1.1 Introduction

The concentration of arsenic (As) in the Earth's crust is 1.8 parts/million (ppm). It can be found as sulfides (As_2S_3) such as arsenopyrites (FeAsS) rather than in its elemental form. As is harmful in each form. Since it is a redox-sensitive element, pH and redox potential have an impact on its mobility in groundwater (Perkins, 2022). Worldwide, freshwater and marine environments contain arsenic, which poses a threat to aquatic life. This material occurs in both inorganic and organic forms. Variations in As toxicity have been present in monomet hylarsonate (MMA), arsenite, arsenate, and dimethyl arsenate (DMA). Deeper groundwater layers naturally occur at high As levels; this is referred to as "contamination." Globally, the Ganga–Brahmaputra region is the most polluted place on Earth and is a common element in groundwater. Arsenate (H_2AsO_4) and arsenite are the two predominant inorganic forms in water (H_2AsO_3). Arsenic is a critical environmental problem due to its bioaccumulation and movement through the aquatic food chain at different trophic levels. Arsenic bioaccumulates in aquatic organisms, such as fish, after prolonged exposure to low concentrations of the metal. When fish tainted with arsenic are consumed, humans may be exposed to the metal. The total amount of As that the gastrointestinal tract can easily absorb makes up N95% of the inorganic arsenic (iAs) in drinking water. However, up to 50–70% of the absorbed arsenic is removed by methylation in the kidneys, and this is subsequently eliminated through urine. When more As is consumed than eliminated, it tends to build up in tissues, including the hair, nails, and other body parts (Moulick et al., 2021). As is mostly present in the shallow groundwater zone, where clay and sulfite minerals combine to form in a reducing environment. During the summer session, groundwater levels rapidly decreased, leading to the oxidation of sulfides and their aeration into solution. The Worldwide problems associated with drinking contaminated water and groundwater contamination by As have been documented. Pigmentation, keratosis, and skin cancer are believed to be typical signs of chronic toxicity caused by long-term ingestion of tainted water. The most common type of As toxicity in humans is caused by interactions with various biological ligands that inactivate the enzyme system, and the symptoms of As exposure are keratosis in the soles and palms and hyperpigmentation, especially on the trunk. Some studies have reported that these skin lesions frequently appear 5–10 years after the first exposure (Adeloju et al., 2021). Arsenic is one of the most hazardous substances on Earth and is well known to cause cancer. Arsenicosis, is As-related health issues such as skin, bladder, kidney and lung cancer, probably diabetes, elevated blood pressure, and reproductive disorders, can be caused by excessive and prolonged (such as five to ten years) human ingestion of toxic food and drinking water (Fig. 1.1) As is currently thought to impact over 150 million people worldwide due to its progressively higher levels in drinking water (Shirin & Yadav, 2014; Stroud et al., 2011). Major river