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Arsenic Remediation of Food and Water

Technological Interventions and Perspectives from Developing Countries

Springer

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Foreword

Arsenic is naturally present in the groundwater. It is highly toxic in its inorganic form and exposure to high levels of arsenic poses a serious threat to the public health. Arsenic-contaminated water used for drinking purposes, food preparation and irrigation of crops are the major sources of exposure. Arsenic contamination of groundwater is widespread and there are a number of developing countries in which the arsenic contamination of drinking water is above the WHO provisional limit of 10 μg/L.

The signs and symptoms caused by long-term elevated exposure to arsenic differ between individuals, population groups and geographical areas. They are usually observed on the skin and may include hyperpigmentation, skin lesions and hard patches on the palms and soles of the feet (hyperkeratosis), and these may be a precursor to skin cancer. In addition, long-term exposure to arsenic may also cause cancers of the bladder and lungs. Other adverse health effects include developmental effects, diabetes, pulmonary and cardiovascular diseases. Exposure to arsenic in utero and early childhood has been linked to increases in mortality in young adults due to multiple cancers, lung disease, heart attacks and kidney failure. Also, numerous studies have demonstrated the negative impacts of arsenic exposure on cognitive development, intelligence and memory.

The most important action in the affected communities is the prevention of further exposure to arsenic by the provision of a safe supply of water for drinking, food preparation and irrigation of food crops. There are a number of options to reduce levels of arsenic in the drinking water: (a) substituting high-arsenic sources, such as groundwater, with low-arsenic safe sources such as rainwater and treated surface water, (b) discriminating between high-arsenic and low-arsenic sources, (c) mixing low-arsenic water with higher-arsenic water to achieve an acceptable arsenic concentration level, and (d) installing arsenic removal systems. Technologies for arsenic removal include oxidation, coagulation-precipitation, absorption, ion exchange and membrane techniques.

Awareness, education, and community engagement are the key factors for ensuring successful interventions for arsenic remediation. There is a need for the affected community to understand the risks of high arsenic exposure and its sources.

The United Nations' Sustainable Development Goals on good health and well-being (SDG 3), and safe and clean water and sanitation for all (SDG 6) cannot be achieved without monitoring and remediating arsenic-polluted groundwater. This book is a timely and useful contribution to arsenic remediation of food and water through technological interventions. It is hoped that such publications will contribute significantly in the dissemination of knowledge on the subject and will help in achieving these goals in a timely manner.

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Preface

Arsenic is one of the ten chemicals of major public health concern. Arsenic contamination of groundwater from natural geogenic sources has long been regarded as a global problem by the World Health Organisation (WHO). A research team based at the Swiss Federal Institute (Podgorski and Berg, Science, 2020) has estimated by using a machine learning tool that 94 to 220 million people in the world that includes more than 94% in Asia, are exposed to unsafe levels of arsenic following the WHO provisional guideline value of 10 micro-grams per litre (μg/l). While the population affected in Africa is under 10 million, one may get little comfort from such data due to a relaxed drinking water standard (50 μg/l) for arsenic in countries such as Angola, Benin, Congo, Madagascar, Malawi, South Sudan and Gambia. Unfortunately, countries like Bangladesh, Myanmar, Nepal, Afghanistan, Cambodia and Pakistan have also set the same standard for drinking water risking the unabated occurrence of arsenicosis and cancer particularly amongst the rural population.

Environmentalists and health professionals working in the science and policy interface have been clamouring for a long time to tighten the current arsenic standard, where it exceeds 10 μg/l. At the same time, agronomists and soil scientists have been arguing against exploiting arsenic-contaminated groundwater for irrigation use to improve crop safety. There is a general reluctance among the affected nations to acknowledge the intensity of arsenic pollution and its effect on the population. While the arsenic problem is global and widespread in the Americas, it is the Global South that is bearing the brunt of the arsenic crisis due to poor infrastructure, lack of investment and enthusiasm from the local governments. The arsenic crisis emanating from the reckless use of contaminated groundwater for drinking and irrigation purposes in Asia, notably in the Ganga-Meghna-Brahmaputra delta in South Asia have far-reaching consequences for the population in the region and beyond. A maximum of 0.3 microgram of arsenic per kg bodyweight per day is often taken as the upper limit of exposure for an adult by international regulatory agencies, which may be imputed to 2 litres of water containing 10 micrograms of arsenic per litre. Such simple statistics would insinuate historicity of any claim on the safe limit of daily exposure from arsenic.

Accumulation of arsenic in soil in high concentrations due to contaminated groundwater use has resulted in translocation of arsenic from soil to the crop, predominantly turning rice into a toxic staple. This occurrence is global for arsenic-contaminated rice fields and is getting bad press for both importing and exporting nations. A recent example is the US rice export to Haiti, containing unsafe levels of arsenic (Reuters, 24 April 2024).

If we leave geopolitics aside, millions of people living in poverty and having little access to safe food and water, face a grim prospect of arsenic related cancer. It is unthinkable that the population living on the margins in scores of the affected countries could access safe food and water without help and support. Such responsibilities bestowed on 193 nations that have signed up for the UN Development Agenda.

In this context, we are delighted to present an edited book titled *Arsenic Remediation of Food and Water—Technological Interventions and Perspectives from Developing Countries* with general readers, policymakers, scientists and engineers in mind. It includes wide-ranging topics on arsenic-source identification, distribution, technologies for treating water for safe use, contamination of food and water and its impact on health. The book broadly covers the arsenic related issues in the Global South. It also includes two technical papers focusing on arsenic distribution in soil emanating from smelter waste in Mexico.

We would like to take this opportunity to thank the Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre), New Delhi, and Springer Nature, Singapore for publishing this book. We hope this book serves the intended audience well and answers some critical questions on challenges for arsenic remediation of groundwater.

Edinburgh, UK — Bhaskar Sen Gupta, Ph.D.
San Luis Potosí, Mexico — Nadia Martínez-Villegas, Ph.D.

Introduction

Arsenic contamination of groundwater in many parts of the world is caused by the weathering of arsenic-bearing minerals, having high local concentration in the earth's crust.

In developing countries, groundwater provides a safe alternative source of drinking water to polluted surface water. However, the presence of arsenic in some groundwater sources has resulted in chronic arsenic poisoning around the world causing severe health hazards.

The problem became a serious health concern after mass poisoning of the population was detected due to arsenic contamination of groundwater in Bangladesh and West Bengal, India. Over the years, the same problem surfaced in many other parts of the world affecting the local populations. The World Health Organization (WHO) recommends limiting arsenic concentrations in water to 10 μg/L, although this is often an unattainable goal for many countries due to the difficult nature of removing arsenic from water sources, and the lack of appropriate, cost-effective and sustainable technologies for arsenic remediation of groundwater.

Considering the importance of the subject and to address the serious issue of arsenic contamination in developing countries, the Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre), New Delhi has brought out this book titled *Arsenic Remediation of Food and Water—Technological Interventions and Perspectives from Developing Countries*. The book highlights the current status of arsenic contamination of water, related health hazards and the state of sustainable and cost-effective technological solutions for removing arsenic from groundwater in developing countries.

The book comprising 22 chapters contributed by leading experts and professionals from 9 countries has been divided into 5 parts. Part I and II of the book provides an understanding of the sources of arsenic contamination of groundwater and the process development such as nano-adsorbents for removal of arsenic and other heavy metals. Part III deals with technological interventions for the removal of arsenic, for example by filtration using locally manufactured ceramic membranes. Additionally, two chapters have been included in the Part III, which highlights the emerging and innovative technology like Subterranean Arsenic Removal (SAR) that can remove arsenic and iron from groundwater without using any adsorption bed. Part IV of the book includes a few chapters on arsenic contamination in the food materials and the food chain systems. Arsenic has long been associated with a variety of health complications in the human body. In order to address this issue, a chapter on arsenic contamination and its impacts on human health has been included in the Part V of the book.

I would like to express my sincere gratitude to Professor Emeritus Mohd. Ali Hashim, Department of Chemical Engineering, Universiti Malaya, Kuala Lumpur, Malaysia for writing the "Foreword" of the Book.

The leading international research and academic publisher—Springer Nature, Singapore has published this Book. We are thankful to Dr. Loyola D'Silva, the Executive Editor of Springer Nature for his encouragement and kind support; and Ms. Kavitha Palanisamy, Production Editor, Springer Nature, Chennai, India and Mr. Gowtham Chakravarthy V, Production Supervisor, Straive, Chennai, India for handling all the technical and production matters related to publication of this book. I am confident that our association with "Springer" would lead to such valuable collaborative endeavours in future.

I would like to express my gratitude to the Editors, Prof. Bhaskar Sen Gupta, OBE (UK) and Prof. Nadia Martínez-Villegas (Mexico) for sparing their valuable time for technical editing of the papers published in this book.

The publication of this book has been made possible through a Project Grant titled "*Reducing Arsenic Exposure from Food and Water in Developing Countries—A Road Map for Technological Solutions for the Future*" (Grant No. G-77/PGTF Project No. INT/20/K01 Project Code: 124567) from the G-77 Secretariat and project support from the UN Office for South-South Cooperation (UNOSSC), United Nations, New York, USA. We are extremely grateful to Dr. Donaldo Lopez from UNOSSC for his kind support and guidance in execution of the above project.

I will take this moment to express my sincere gratitude to Mr. Madhusudan Bandyopadhyay, Senior Adviser, NAM S&T Centre for his kind advice and guidance in various stages of planning and execution of this book project. Further, I am also thankful to Ms. Jasmeet Kaur Baweja, Programme Officer, NAM S&T Centre for her significant contributions in coordinating this book project.

I also acknowledge the help and support received from the entire team of the NAM S&T Centre. I am especially thankful to Mr. Pankaj Buttan, Data Processing Manager; Mr. Rahul Kumra, Assistant Administrative Officer; Mr. Sunil Kumar, Accounts Manager and Mr. Jayakumaran, Public Relations Manager, NAM S&T Centre for their support in bringing out this publication.

I am sure that this book would be a valuable reference material for the scientific community in developing countries working on community water supply and treatment, food safety, public health and policy.

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The book provides information on the sources of arsenic contamination of groundwater and their impacts in the first part of the book consisting of 8 chapters. Process developments such as nano-adsorbents for removal of arsenic and other heavy metals are discussed in second part of the book that comprises of 4 chapters. The third part of the book includes 4 chapters on technological interventions for the removal of arsenic such as indigenous ceramic membranes and Subterranean Arsenic Removal (SAR). The fourth part of the book deals with arsenic contamination in food materials and food chain systems, and consists of 5 chapters. Arsenic has long been associated with a variety of health complications in the human body. In order to address this, a chapter on arsenic contamination and impacts on human health has been included in the fifth part of the book. The book would be a valuable reference material for the scientific community in developing countries working on community water supply and treatment, food safety, public health and policy.

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