The Global Arsenic Problem: challenges for safe water production

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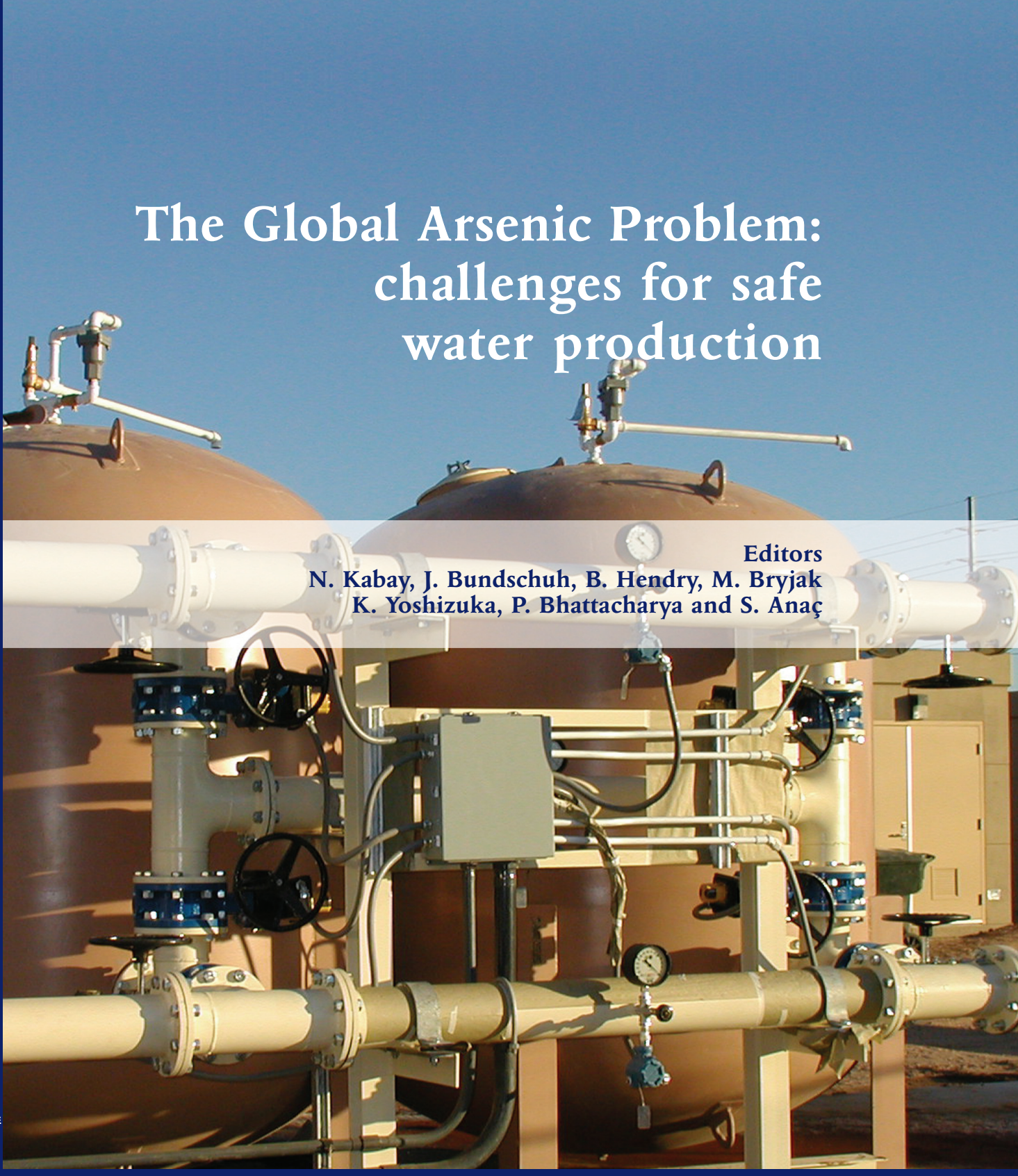

ARSENIC IN THE ENVIRONMENT VOLUME 2

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THE GLOBAL ARSENIC PROBLEM: CHALLENGES FOR SAFE WATER PRODUCTION

Arsenic in the Environment

Series Editors

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Cover photo

The photograph shows an arsenic removal plant, designed by Layne Christensen, that was installed at El Mirage, Arizona in 2007. The system is designed to treat a water flow of up to 425 gallons (1610 liters) per minute and consists of two 7 foot (2.13 meter) diameter vessels in a lead-lag configuration, each containing 225 cubic feet (1870 liters) of ArsenX^{np} adsorption media. The system typically treats between 300,000 and 400,000 gallons (1140–1510 m^3) of water per day and lowers the arsenic content of the finished water to below the limit of 10 µg/L. The photo is courtesy of Dr. Paul Sylvester, Layne Christensen, Northborough, Massachusetts, USA.

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About the book series

Although arsenic has been known as a 'silent toxin' since ancient times, and the contamination of drinking water resources by geogenic arsenic was described in different locations around the world long ago—e.g. in Argentina in 1917—it was only two decades ago that it received overwhelming worldwide public attention. As a consequence of the biggest arsenic calamity in the world, which was detected more than twenty years back in West Bengal, India and other parts of Southeast Asia, there has been an exponential rise in scientific interest that has triggered high quality research. Since then, arsenic contamination (predominantly of geogenic origin) of drinking water resources, soils, plants and air, the propagation of arsenic in the food chain, the chronic affects of arsenic ingestion by humans, and their toxicological and related public health consequences, have been described in many parts of the world, and every year, even more new countries or regions are discovered to have arsenic problems.

Arsenic is found as a drinking water contaminant, in many regions all around the world, in both developing as well as industrialized countries. However, addressing the problem requires different approaches which take into account, the differential economic and social conditions in both country groups. It has been estimated that 200 million people worldwide are at risk from drinking water containing high concentrations of arsenic, a number which is expected to further increase due to the recent lowering of the limits of arsenic concentration in drinking water to 10 $\mu g\ L^{-1}$, which has already been adopted by many countries, and some authorities are even considering decreasing this value further.

The book series "Arsenic in the Environment" is an inter- and multidisciplinary source of information, making an effort to link the occurrence of geogenic arsenic in different environments and the potential contamination of ground- and surface water, soil and air and their effect on the human society. The series fulfills the growing interest in the worldwide arsenic issue, which is being accompanied by stronger regulations on the permissible Maximum Contaminant Levels (MCL) of arsenic in drinking water and food, which are being adopted not only by the industrialized countries, but increasingly by developing countries.

The book series covers all fields of research concerning arsenic in the environment and aims to present an integrated approach from its occurrence in rocks and mobilization into the ground- and surface water, soil and air, its transport therein, and the pathways of arsenic introduction into the food chain including uptake by humans. Human arsenic exposure, arsenic bioavailability, metabolism and toxicology are treated together with related public health effects and risk assessments in order to better manage the contaminated land and aquatic environments and to reduce human arsenic exposure. Arsenic removal technologies and other methodologies to mitigate the arsenic problem are addressed not only from the technological perspective, but also from an economic and social point of view. Only such inter- and multidisciplinary approaches, will allow case-specific selection of optimal mitigation measures for each specific arsenic problem and provide the local population with arsenic safe drinking water, food, and air.

We have an ambition to make this book series an international, multi- and interdisciplinary source of knowledge and a platform for arsenic research oriented to the direct solution of problems with considerable social impact and relevance rather than simply focusing on cutting edge and breakthrough research in physical, chemical, toxicological and medical sciences. The book series will also form a consolidated source of information on the worldwide occurrences of arsenic, which otherwise is dispersed and often hard to access. It will also have role in increasing

the awareness and knowledge of the arsenic problem among administrators, policy makers and company executives and improving international and bilateral cooperation on arsenic contamination and its effects.

Consequently, we see this book series as a comprehensive information base, which includes authored or edited books from world-leading scientists on their specific field of arsenic research, but also contains volumes with selected papers from international or regional congresses or other scientific events. Further, the abstracts presented during the homonymous biannual international congress series, which we organize in different parts of the world is being compiled in a stand-alone book series "Arsenic in the Environment—Proceedings" that would give short and crisp state of the art periodic updates of the contemporary trends in arsenic-related research. Both the series will be open for any person, scientific association, society or scientific network, for the submission of new book projects. Supported by a strong multi-disciplinary editorial board, book proposals and manuscripts are peer reviewed and evaluated.

Jochen Bundschuh
Prosun Bhattacharya
(*Series Editors*)

Editorial board

Dedications

We dedicate this book to Ege University, the primier academic institutions in Izmir, Turkey upon the completion of 55th year in 2010. Ege University is committed to excellence in research and development as well as to teaching and education with its more than 3000 competent academic staff in order to contribute to the improvement of the quality of life at regional and national levels. The university has a pledge to produce new knowledge at global scale and to raise competent, capable and innovative students who are up-to-date in knowledge, well-equipped and also having an awareness of the national and global issues.

We also dedicate this book to the people of the beautiful ancient city of Izmir who have a great sensitivity for safe water production. The 8000-year old city of Izmir acquired its name from the Amazon Queen "Smyrna", which has witnessed a history dated back neolithic age, and remained a host to many civilizations during history; owns historical traces of great civilizations and one of the seven wonders of the world (Artemision-Ephesus) and Agora from Roman times.

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Foreword

Water is a significant natural resource and a key component of our environment. The quality of water resources has deteriorated as a result of the rapid population growth, unplanned urbanization and environmental pollution that resulted from global industrialization. The increasing demands for irrigation and for domestic and industrial purposes, are negatively affecting the quality of water supplies and placing greater stress on water resources, the capacity of which is already limited. Nowadays, the decrease in availability of high quality water resources has already reached serious dimensions including major threats and impacts on sensitive ecosystems. Therefore, problems pertaining to water consumption and supply need to be solved on a global scale. In addition to these, global warming and climate change have begun to threaten the resources of water.

Considering the current development level, none of the available means are sufficient to combat the growing complexity of regional and global water problems. That is why there is a need for a visionary, predictive and proactive approach. The traditional approaches to managing water quality, supply and demand, including restrictive regulations, are no longer likely to be sufficient or satisfactory since changes in ecosystems are unpredictable and irreversible and most of them may occur after a long period of time. In some cases quality recommendations and standards may determine that previously acceptable water becomes unfit for particular uses due to only one or two low concentration problem substances being present in variable amounts in otherwise fresh water supplies. A significant example is arsenic (As) species in groundwater and other resources in many parts of the world and especially in developing regions.

In this context, an "International Congress on Production of Safe Water" was organized in Izmir city in Turkey from January 21 to 23, 2009 in cooperation with Izmir Metropolitan Municipality and Ege University in order to create an international platform where the most recent researches, experiences and applications on production of safe water were exchanged and presented, with particular emphasis on arsenic in the groundwater supplies to the city of Izmir.

I would like to congratulate the great efforts of the editorial team of this volume. I hope that this book will serve the people to acquire the scientific information and experiences required for safe water production.

Prof. Dr. Candeğer Yılmaz
Rector
Ege University
December, 2009

Editors' preface

Water constitutes an important component of the environment and its availability is indispensable to the efficient functioning of the ecosystem. Water is an important element of the existence of humans, animals and plants. Water is also of vital importance to all socio-economic sectors—human, and economic development simply is not possible without a safe water supply. Total volume of water on the Earth is approximately 1.3×10^9 km^3, but only 4 million km^3, i.e., 0.3% of the total water volume is actually usable for humans. The sources of this portion are mainly rivers, lakes and groundwaters. The water resources are subject to increasing stress both in terms of quantity as well as quality. In recent decades, surface water resources have become highly contaminated with domestic and industrial wastes, as well as due to the human influence. Thus, safe water resources must be seen in the overall context of global sustainable development.

The water consumption was estimated as 86 cubic kilometers during the later half of the 17th century (1680), in 1900, this amount had risen to 522 km^3, but in 1980 to 2120 and in 2000 to 2700 km^3 per year. The forecast that human water consumption could triple once more in the next 30 years is alarming. At least 40% of the world's population will live in countries that suffer from a chronic shortage of water. Today more than 50 countries suffer from a shortage of water but by 2025, the United Nations estimates that two-thirds of world population will not have enough drinking water.

Increased water demand from population and economic growth, environmental needs, changes in rainfall, flood, and contamination are the major factors that will continue to create water shortage problems. It was estimated that, about 70% of the water is used for agricultural activities. The problem with agricultural activities is not only consumption of large volume of water for irrigation but also the use of large amount of fertilizers, pesticides and other chemicals. Industry uses only 20% of water available for use. The remaining 10% is consumed for daily usage although this much depends on the regions of the world.

The existence of arsenic in water is of global concern because it is a serious threat to human health and many of its compounds are especially potential poisons. Elemental arsenic and arsenic compounds are classified as toxic and dangerous for the environment in the European Union directive (67/548/EEC). Arsenic concentration in ground- and surface waters in western US ranged from 80 μg/L to as high as 15 mg/L, because of the abundance of geothermal activities in this region. In some countries such as China, Tibet, Mongolia, India, Bangladesh, Vietnam, Cambodia, Thailand, Taiwan, Argentine, Chile and Mexico, a large portion of water is contaminated with arsenic at levels from 100 to over 2000 μg/L. It has been estimated that a population of more than 100 million are exposed to drinking groundwater with arsenic concentrations above the 50 μg/L limit, which is still the maximum permissible concentration in many countries of South Asia. The WHO revised its recommended guideline value for arsenic in drinking water to 10 μg/L in 1993, which was later adopted by the US in 2001. The United States Environmental Protection Agency (US EPA) drinking water standard for As was 50 μg/L set by US EPA in 1975, based on a Public Health Service standard originally established in 1942. The US Safe Drinking Water Act provided the stringent framework for protecting public health on the basis of which US EPA has established a health based non-enforcable Maximum Contaminant Level Goal (MCLG) for zero

As and an enforcable Maximum Contaminant Level (MCL) of 10 μg As/L in drinking water in January 2001, that applies to both non-transient, non-community water systems as well as to the community water systems.

In 2001, EPA adopted a new standard, and public water systems must comply with the 10 μg/L as permissible level in 2003. In some of the new member states from Eastern Europe, such as Hungary, Romania, and Slovakia who have joined the European Union recently, the levels of arsenic in drinking waters are higher than the guideline values proposed in the European Union Drinking Water Directive (Council Directive 98/83/EC). In these countries, there is a need to develop cost-effective and alternative treatment technologies for the removal of arsenic in order to comply with the drinking water standards of the European Union.

An International Congress on "Production of Safe Water" was organized in Izmir, Turkey from January 21 to Januray 23, 2009 with a theme on arsenic in the environment and its elimination by various methods for the production of safe water. Following the congress, *The Izmir Declaration 2009* for safe water production for sustainable human development in Turkey was chartered based on the realization of the fact that natural water resources are essential elements for human development. The presence of elevated concentrations of geogenic arsenic exceeding the Turkish and the World Health Organisation (WHO) guideline values of 10 μg/L in groundwater as the main resources for drinking and irrigation water poses the principal environmental health risk of the 21st century in affecting the urban as well as the rural water supplies in Turkey and globally, the organizers, international scientific committee members and participants of the International Congress for Production of Safe Water, 21–23 January 2009 in Izmir, Turkey unanimously resolved that:

- It is necessary to investigate the presence, origin and mobilization of arsenic in water resources.
- Arsenic should be listed as an obligatory parameter for analysis of water used for drinking and irrigation purposes.
- It is necessary to create awareness of the presence and adverse health effects of arsenic in the water resources for human consumption amongst the population, the water and public health and the food and agriculture authorities as well as in the scientific community.
- It is necessary to identify and promote appropriate techniques for treatment of water resources with high arsenic concentrations and/or alternative water resources for public water supply and to address also the safe disposal of the residues from such processes.
- It is recommended to initiate and promote international cooperation on research with an interdisciplinary and multidisciplinary approach on arsenic and related elements in the environment of Turkey. This should involve the fields such as geosciences, hydrogeology, hydrogeochemistry, chemical engineering, agriculture, food and nutrition, toxicology, epidemiology, public health and medical sciences.

This monograph entitled "Global Arsenic Problem and Challenges for Safe Water Production" is presented as the second volume of the inter- and multi-disciplinary book series "Arsenic in the Environment" which comprises contributions from distinguished scientists from both academia and industry who participated in the congress as invited lecturers from four continents and also a number of others who have been actively working in this area. The sixteen chapters in the volume are grouped under four thematic sections that cover the major aspects of the global arsenic problem, human health effects and technologies for safe water production.

The main goal of the book is to focus attention of all affected parties worldwide on global arsenic problems and to present some challenges for safe water production in order to invoke appropriate actions in efficient innovative directions. We hope that this book will be useful

for environmental scientists and engineers in both academia and industries and for government and regulatory bodies dealing with water issues by providing an opportunity to acquire relevant scientific information and experiences in "Global Arsenic Problem and Challenges for Safe Water Production".

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