Environmental Arsenic in a Changing World

As 2018

Editors

Yongguan Zhu, Huaming Guo, Prosun Bhattacharya, Arslan Ahmad, Jochen Bundschuh & Ravi Naidu

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Arsenic in the Environment – Proceedings

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Environmental Arsenic in a Changing World

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Cover photo

The cover photo shows the paddy field in mountainous Fujian province, Southeast China. Fujian (means "Happy Establishment")[1] is one of the country's smaller provinces, on the southeastern coast of China. The province is also known historically as Min, for the "seven Min tribes" that inhabited the area during the Zhou dynasty (1046–256 BCE). It was, however, during the Song dynasty (960–1279 CE) that the name Fujian was given to a superprefecture created in the area and the basic geographical boundaries of the province were established. Covering an area of approximately 123,100 square km, the Fujian province is bordered by the provinces of Zhejiang to the north, Jiangxi to the west, and Guangdong to the southwest; the East China Sea lies to the northeast, the Taiwan Strait (between the mainland and Taiwan) to the east, and the South China Sea to the southeast. The Fujian province is traversed by several ranges of moderate elevation that constitute a part of a system of ancient blocks of mountains trending from southwest to northeast, parallel to the coast although some narrow coastal plains are prevailing towards the soth-eastern part of the province. Rivers are of great importance in Fujian, and have been the only means of transport for centuries. Most of the rivers flow into estuaries that form natural harbours, and provide water supplies for domestic consumption and irrigation of the myriad rice fields in the alluvial plains. The area is also characterized by several mineral deposites which have been mined over centuries for mining of lead, zinc and copper deposits.

One of the most picturesque region in Asia, Fujian province is endowed with wooded hills and winding streams, orchards, tea gardens, and terraced rice fields on the gentler slopes. Its major crops are sugarcane, peanuts (groundnuts), citrus fruit, rice, and tea. Two crops of rice are harvested each year, the first in June, the second in September. After centuries of rice cultivation, soils in the valley plains have been greatly modified. Well-developed gray-brown forest soils are widely distributed in the forest areas of the interior mountains, whereas mature red soils are common in the low hills and on high terraces. Rice is the staple food in China, and it has been estimated that rice ingestion contributes to about 60% of arsenic exposure from food in China[2].

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[2] Li, G., Sun, G.X., Williams, P.N., Nunes, L. & Zhu, Y.G., 2011. Inorganic arsenic in Chinese food and its cancer risk. Environ. Int. 37(7): 1219–1225

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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 1914—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 elevated levels of arsenic in environmental matrices.

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 As, a number which is expected to further increase due to the recent lowering of the limits of arsenic concentration in drinking water to 10 μg/L, 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 – Proceedings" 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.

Consequently, we see the book series *Arsenic in the Environment-Proceedings* with the outcomes of the International Congress Series – Arsenic in the Environment, which we organize biannually in different parts of the world, as a regular update on the latest developments of arsenic research. It is further a platform to present the results from other from international or regional congresses or other scientific events. This Proceedings series acts as an ideal complement to the books of the series *Arsenic in the Environment*, which includes authored or edited books from world-leading scientists on their specific field of arsenic research, giving a comprehensive information base. Supported by a strong multi-disciplinary editorial board, book proposals and manuscripts are peer reviewed and evaluated. Both of the two series will be open for any person, scientific association, society or scientific network, for the submission of new book projects.

We have an ambition to establish 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. It shall 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.

Both of the book series cover 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 a 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

Jochen Bundschuh
Prosun Bhattacharya
(Series Editors)

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Dedication

Dipankar Chakraborti, Ph.D.
'Arsenic Legend of India'
Analytical Chemist who made legendary contributions to arsenic research in India and Bangladesh
Former Director (Research), School of Environmental Studies, Jadavpur University, Kolkata, India
* 29 October 1943 †28 February 2018

We dedicate the 7th International Congress on Arsenic in the Environment (As 2018) and the Volume of Proceedings of the International Congress of Arsenic in the Environment – *Environmental Arsenic in a Changing World (As 2018)* to the memory of Professor Dr. Dipankar Chakraborti (popularly known as Dip), who passed away on the 28th of February 2018 at the age of 74.

Dr. Chakraborti had established himself as a legendary scientist in the field of arsenic research across the globe for a period of more than three decades through his contributions towards raising a global awareness about the growing arsenic crisis in the Bengal delta. Born in Ujirpur in the district of Barisal in Bangladesh, Dip was raised in Madaripur in Faridpur district where he had spent his childhood before moving to West Bengal, India around 1949.

Following the Bachelor and Master of Science degrees in Chemistry, he received his Ph.D. in Analytical Chemistry from Jadavpur University, Kolkata, India in 1973. His carreer in academics commenced as early as in 1967, when he joined as an Assistant Professor (lecturer) at Jadavpur University. Later in 1977, he moved abroad, to join University of Prague of Czech Republic as UNESCO Fellow. In 1978, he moved to Universitaire Instelling Antwerpen, Wilrijk in Belgium, where he worked with Prof. Freddy Adams. He joined Texas A & M University at College Station, Texas, USA in 1981 and worked with Professor K. J. Irgolic until 1983. He was once again invited as a Visiting Scientist to work at Universitaire Instellig Antwerpen, Wilrijk, Belgium during the period between 1984 and 1986. After an illustrative carreer as a scientist abroad, he returned back to to India to join Jadavpur University in Kolkata in 1987. He became the Director of School of Environmental Studies (SOES) at the Jadavpur University and continued until his formal retirement.

It did not take a long time for Dr. Chakraborti to form the internationally recognized Arsenic Research Team at SOES and he started working on arsenic toxicity since 1988, in collaboration with Dr. K.C. Saha (School of Tropical Medicine, Kolkata), Dr. D.N. Guha Mazumder (Institute of Post Graduate Medical Education and Research, Kolkata) and Dr. Allan H. Smith (School of Public Health, University of California-Berkeley, USA) over an extended period of time to highlight the epidemiological impact of arsenic-laden groundwater in West Bengal, India. Since then, along with his team he had not only been engaged in research on groundwater arsenic in the Ganga-Meghna-Brahmaputra (GMB) Plain, but also worked on fluoride one of the most widespread geogenic contaminant in groundwaters of India. He and his co-workers have played a pivotal role in documenting the magnitude of the arsenic calamity in the Bengal delta, both in India and Bangladesh.

Chakraborti's work on arsenic contamination in the environment brought him international recognition. He was the key proponent of the hypothesis on the arsenic mobilization mechanism in groundwater of Bengal delta, known as the *pyrite oxidation theory*. He was the person who raised an alarm on a possible widespread groundwater arsenic contamination in Bangladesh and also discovered the contamination in Bihar state of India. Dissemination of science among a broader public was certainly one of Chakraborti's aims and his research outputs helped Governments of both Bangladesh and West Bengal to take the necessary steps to mitigate the well neglected arsenic calamity. To the end of his life, though he continued to fight for clean water he became increasingly tolerant to failures of drinking water supply mitigation schemes across both countries.

He was member of WHO working group for "Environmental Health Criteria 224 for Arsenic and Arsenic compounds (2nd edition)", and IARC Monographs on the "Evaluation of Carcinogenic Risks to Humans – Some Drinking Water Disinfectants and Contaminants, including Arsenic, Volume 58". His ground-breaking research on arsenic field testing kits turned attention of UNICEF and led to the discontinuation of the use of improper test kits for arsenic measurement in Bangladesh and India.He authored more than 200 publications in highly acclaimed international peer-reviewed journals of high impact which include Environmental Health Perspectives (IF 9.78), International Journal of Epidemiology (IF 7.73), Science of the Total Environment (IF 4.9) and co-authored 20 chapters in books/monographs. The scholastic achievements of Dipankar's publications are demonstrated through more than 17000 citations, with 131 publications cited more than 10 times (i10 score) and a h-index of 53 till date. His citations peaked both in 2015 and 2016 with ca 1100 citations, which definitely is one of the highest among the community of scientists in India. He had organized five international conferences on the groundwater arsenic problem including International Conference on Arsenic Pollution of Groundwater in India (Kolkata, India, 1995) and the International Conference on Arsenic Pollution of Groundwater in Bangladesh – Causes, Effects and Remedies (Dhaka, Bangladesh, 1998), where he highlighted the interdisciplinary aspects of arsenic pollution in groundwater in Bangladesh and West Bengal, India and kindled global attention of multidisciplinary group of scientists on the environmental health calamity caused by arsenic in drinking water from groundwater sources affecting health of millions of exposed population.

He owed a great deal to his birth place, as later in his life he did spend more than 400 days in the remote villages of Bangladesh fighting for the victims of arsenic poisoning. He was married to Dr. Reena Chakraborty and one daughter, who have remained extremely supportive to his scientific acheivements. He has left behind his legacy through a number of his students who also made signifigant progress in the field of arsenic research in India and abroad. His pronouncements carried great authority, and he might ask his students to follow his life style including routine physical activities, healthy diet and yoga, himself being an addict to yoga. He was an extraordinarily determined person. He would never ask for funding to support his research and SOES was a self-funded and self-sustained unit and as per his principle, he did never accept any foreign grant.

Those who knew him as Dip, as he was so fondly called, would clearly appreciate the real human being, with an enormous zest for life, and tremendous determination, yet with normal human weaknesses, as well as his more obvious strengths. As a true environmentalist he cared deeply for Mother Nature and was the pioneer of arsenic research in India and Bangladesh. He was extremely regarded for his contributions to the understanding of the contamination of drinking water and the subsequent consequences to human suffering.

We deeply mourn the death of Dr. Dipankar Chakraborti. We lost a beloved colleague, friend, the kindest and most generous soul and a great personality, who devoted his entire life to the victims of arsenic poisoning. The arsenic community will always remember his contributions in the field of arsenic research and related problems and will miss his supportive, hard working and optimistic company.

M.M. Rahman
Debapriya Mandal
Prosun Bhattacharya

"Jodi tor daak shune keu na ashe tobe ekla cholore"

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Environmental Arsenic in a Changing World –
Zhu, Guo, Bhattacharya, Ahmad, Bundschuh & Naidu (Eds)
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Foreword (Director General, Institute of Urban Environment, Chinese Academy of Sciences)

Arsenic, as a global contaminant, is impacting the health of millions of people around the world, through water, food and potential also air pollution. It has recently been estimated that in China alone, there are about 19 million people may be drinking water above the World Health Organization guideline of 10 μg/L. Arsenic is also a cultural element, as it is a notorious poison. It has been suggested that a Qing Dynasty Emperor was poisoned by arsenic. With rapid industrialization and urbanization in modern China, arsenic pollution is a major environmental challenge. According to the recent China national soil pollution survey, about 3% of China's arable land exceeded the soil quality standards for arsenic.

The Institute of Urban Environment, Chinese Academy of Science (IUE-CAS) is very happy to host the 7th International Congress on Arsenic in the Environment together with China University of Geosciences (Beijing). The institute was established on 4 July 2006. It is located in the beautiful coastal city-Xiamen. IUE-CAS is a unique national research institute engaged in comprehensive studies on the world's urban environment and the impacts of urbanization on ecosystem and human health. IUE-CAS hosts over 200 staff scientists plus around 200 graduate students. There are number of scientists within the institute working on arsenic biogeochemistry, human health impacts. Over the last 10 years, IUE-CAS has published about 150 papers related to arsenic in international journals, covering topics ranging from environmental chemistry, ecotoxicology, risk assessment and microbial ecology and genomics etc. in terrestrial and aquatic environments.

We cordially invite delegates from all corners of the globe to participate this important congress, and forge new friendship and collaborative linkages.

Professor Yong-Guan Zhu
Director-General
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Xiamen, P.R. China
May 2018

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Foreword (Vice President, China University of Geosciences, Beijing)

As a toxicant and carcinogen for humans, environmental arsenic is one of the biggest issues in the world. Hundreds of millions of people are suffering from chronical arsenic poisoning worldwide, including Bangladesh, India, China, Pakistan, Nepal, Cambodia, and Vietnam. China is a typical country facing ecologic poisoning of environment arsenic, where there were more than 5 million residents being at risk of chronic arsenic poisoning in both inland basins experiencing an arid/semiarid continental climate, and river deltas experiencing a humid tropical climate. Around forty million people were exposed to drinking water with arsenic concentration $>10\ \mu g/L$ (WHO drinking water guideline value).

As a major media hosting environment arsenic, high arsenic groundwater is closely related to human health due to the pathways for arsenic from water to human via ingestion of drinking water and digestion of the groundwater-irrigated foods. Hydrogeological and biogeochemical studies showed that redox milieu, the source of dissolved organic carbon, microbial diversity, sedimentation sequences and groundwater hydraulics are the major contributors for spatial and temporal variation in arsenic concentrations of groundwater from aquifers which do not contain abnormal arsenic contents. In addition, irrigation with high arsenic groundwater not only affects arsenic contents of food products but also deteriorates soil quality. Soil pollution was correlated with arsenic concentration of irrigation water extracted from groundwater aquifers, which led to arsenic accumulation from soil to food chains. Via drinking arsenic-contaminated groundwater or the food chain, arsenic is entering and accumulating in the human body since only approximately one-third of the uptaken-arsenic can be excreted daily, which causes chronic poisoning arsenicosis (such as keratosis, hyperpigmentation, diarrhoe, respiratory disorders, hypertension and malignancy). Elimination of drinking groundwater arsenic is an effective method to alleviate arsenic exposure to human body via drinking water pathway. Many new materials and filter systems have recently been developed to fix arsenic from aqueous solutions, some of which are available for practical applications in both the house-hold unit and the water supply plant scale. Although geochemical, health and mitigation investigations on environmental arsenic have made promising advances, interdisciplinary scientific exchanges among physicians, chemists, biologists and geologists and among different countries are quite limited. The coming 7th International Congress on Arsenic in the Environment, with a theme of Environmental Arsenic in a Changing World, is therefore quite necessary to strengthen and highlight the scientific exchanges among scientists from different disciplines and from different countries.

China University of Geosciences (Beijing) co-hosts the 7th International Congress on Arsenic in the Environment with The Institute of Urban Environment, Chinese Academy of Science. China University of Geosciences (Beijing), being founded in 1952, has become one of the national key universities and the advanced education center for geoscience studies in China. The university has 14,000 full-time enrolled students, 1400 teaching and research staff members. Good moral, sound background, wide knowledge, and high profession are the mutual goals of our students and staffs. Aiming at the first-class international university in the field of geosciences, the university values international and interdisciplinary cooperation and exchange. There are several groups working on arsenic geochemistry, biogeochemistry, remediation techniques and mechanisms in our university.

I am proud to write this forward to the Proceeding Series Volume of Arsenic in the Environment, which contains over 240 extended abstracts to be presented in the coming 7th International Congress on Arsenic in the Environment. This volume would be the state of the art of contributions to the arsenic research society around the world, which is related to geological arsenic in aquifers, geochemical and biogeological processes for arsenic mobilization, microbe-mineral-plant interactions, arsenic toxication, and mitigation techniques for arsenic fixation.

I deeply thank the Local Organizersf rom China University of Geosciences (Beijing) and the Institute of Urban Environment, and the Intemational Organizers from KTH Royal Institute of Technology (Sweden), the University of Southem Queensland (Australia), the KWR Watercycle Research Institute (KWR) (The Netherlands), and the International Society of Groundwater for Sustainable Development (ISGSD) for their elaborate work on this volume, which, I hope, will greatly improve our understanding of arsenic cycling in the system of biosphere, hydrosphere, geosphere, and anthroposphere.

Professor Dr. Li Wan
Vice President
China University of Geosciences (Beijing)
Beijing, China
May 2018

Environmental Arsenic in a Changing World –
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Foreword (KTH Royal Institute of Technology)

Arsenic is a natural or anthropogenic contaminant in many areas around the globe, where human subsistence is at risk. It is considered as a class 1 carcinogen, and its presence in groundwater has emerged as a major environmental calamity in several parts of the world. It has been estimated that nearly 137 million people drink water contaminated with arsenic globally. The widespread discovery of arsenic in Asia has paved the way to the discovery of the presence of this element in different environmental compartments as a "silent" toxin, especially in countries such as Bangladesh, Cambodia, China, India, Nepal, Pakistan, Taiwan, Thailand and Vietnam, the situation of arsenic toxicity is alarming and severe health problems are reported amongst the inhabitants relying on groundwater as drinking water. It is important to note that approximately 250 000 people in Sweden rely on drinking water from private wells with arsenic concentrations above the drinking water guideline value of 10 μg/L. However recent investigations have also shown that the problem of arsenic in groundwater exists in many countries in Latin America, Europe, Africa and Australia. The use of arsenic contaminated groundwater in irrigation landscapes especially in the rice cultivating regions and its bioaccumulation in rice and several other food crops has emerged as an additional pathway for arsenic exposure to humans and livestock through the food chain. New areas with elevated arsenic occurrences are reported in groundwater exceeding the maximal contamination levels set by the WHO and other national and international regulatory organizations are identified each year. It therefore requires innovative solutions to ensure access to clean drinking water. The Netherlands is now focusing on reducing their arsenic levels to below 1 μg/L, as there is a healthy arsenic content, and therefore assumes that the requirements will be tightened.

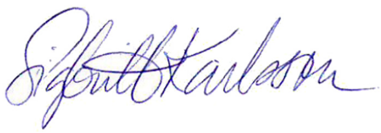
Since 2000, we have witnessed a remarkable rise in interest on research in the field of arsenic. Many research councils and international donor organizations have provided significant support to local and international research teams to develop strategies to address the problem with an aim to minimize the risk of arsenic exposure among the population. As a consequence, there has been a radical increase in the number of scientific publications that give a holistic overview on the occurrence, fate and cycling of arsenic in natural environment, its impact on human health, and implications on the society.

The WHO/FAO Joint Expert Committee (JEC) review document on Food Additives, resulted in withdrawal of the provisional tolerable weekly intake (PTWI) since 2010. The other important gaps identified by the JEC is particularly related to the need for accurate quantification of arsenic in dietary and other exposure routes as well as the speciation of arsenic and bioavailability that account for the total daily intake. Long-term exposure to arsenic is related to non-specific pathological irreversible effects and has significant social and economic impacts. The presence of arsenic in rice and rice products available in the markets has raised a critical concern – and this includes rice cakes, breakfast cereals as well as plain rice. Daily intake of inorganic arsenic in small quantities in rice and all rice products leads to high levels of arsenic exposure—and especially to the group of population with rice as the staple diet. Children are vulnerable to arsenic exposure, where the risk of arsenic exposure is exceptionally high due to the consumption of rice cakes especially in the pre-schools. Thus, arsenic in environment is clearly a concern that needs an inter- and multi-disciplinary and cross-disciplinary platform of research including hydrogeology and hydrogeochemistry, environmental sciences, food and nutrition, toxicology, health and medical sciences, remediation technologies and social sciences.

The biennial International Congress Series on Arsenic in the Environment is providing a common platform for sharing knowledge and experience on multidisciplinary issues on arsenic occurrences in groundwater and other environmental compartments on a worldwide scale to identify, assess, develop and promote approaches for management of arsenic in the environment and health effects. Since the first International Congress on "Arsenic in the Environment" at the UNAM, Mexico City in 2006, there has been an overwhelming response from the scientific community engaged with multidisciplinary facets of arsenic research to participate and present their research findings on this platform. The conference has been taken a form of biennial congress series with rotating venues at different continents. The following three events namely the 2nd International Congress (As 2008), with the theme "Arsenic from Nature to Humans" (Valencia, Spain) and the 3rd International Congress (As 2010) with the theme "Arsenic in Geosphere and Human Diseases" (Tainan, Taiwan), the 4th International Congress on Arsenic in the Environment (As 2012) with a theme "Understanding the Geological and Medical Interface" (Cairns, Australia), the 5th International Congress on Arsenic in the Environment (As 2014) with a theme "One Century of the Discovery of Arsenicosis in Latin America (1914–2014)" (Buenos Aires, Argentina) and the 6th International Congress on Arsenic in the Environment (As 2016) is envisioned with a theme "Arsenic Research and Global Sustainability" (Stockholm, Sweden) have been successfully organized and participated by the leading scientific community across the globe. The upcoming 7th International Congress on Arsenic in the Environment (As 2018) is envisioned with a theme "Environmental Arsenic in a Changing World" to be organized in Beijing, Peoples Republic of China between 1st and 6th July, 2018, with an aim to provide another international, multi- and interdisciplinary discussion platform for the presentation of cutting edge scientific research involving arsenic in natural systems, food chain, health impacts, clean water technology and other related social issues linked with environmental arsenic by bringing together scientific, medical, engineering and regulatory professionals.

I feel proud to write this foreword to this Volume of Arsenic in the Environment-Proceedings Series, containing the extended abstracts of the presentations to be made during the forthcoming 7th International Congress & Exihibition on Arsenic in the Environment – As 2018. The present volume "Environmental Arsenic in a Changing World" being published as a new volume of the book series "Arsenic in the Environment-Proceedings under the auspices of the International Society of Groundwater for Sustainable Development (ISGSD), will be an important updated contribution, comprising a large number of over 240 extended abstracts submitted by various researchers, health workers, technologists, students, legislators, and decision makers around the world that would be discussed during the conference. Apart from exchanging ideas, and discovering common interests, the scientific community involved in this specialized field needs to carry out researches, which not only address academic interests but also contribute to the societal needs through prevention or reduction of exposure to arsenic and its toxic effects in millions of exposed people throughout the world.

I deeply appreciate the efforts of the International Organizers from KTH-International Groundwater Arsenic Research Group, Department of Sustainable Development, Environmental Science and Engineering, School of Architecture and Built Environment KTH Royal Institute of Technology and the University of Southern Queensland, Toowoomba, Australia, the KWR Watercycle Research Institute (KWR) and the International Society of Groundwater for Sustainable Development (ISGSD) together with the Local Organizers from Institute of Urban Environment, Xiamen and the China University of Geosciences (Beijing) and the entire editorial team for their untiring work with this volume. I hope that the book will reflect the update on the current state-of-the-art knowledge on the interdisciplinary facets of arsenic in the environment required for the management of arsenic in the environment for protecting human health.



Professor Dr. Sigbritt Karlsson
KTH Royal Institute of Technology
Stockholm, Sweden
April 2018

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Foreword (Deputy Vice Chancellor, University of Southern Queensland)

The University of Southern Queensland (USQ) has great pleasure in co-organising the 7th International Congress & Exhibition on Arsenic in the Environment (As2018) themed 'Environmental Arsenic in a Changing World' in July 2018 in Beijing, China.

Arsenic originating from geogenic sources is a global issue as over 200 million people, so far known from over 80 countries, is at risk due to ingestion of arsenic-contaminated food and drinking water. In food, arsenic is particularly accumulated as a result of irrigation with arsenic-rich water – the staple food rice is thereby especially affected. Despite the fact that the problem occurs equally in developing and industrialized countries, the problem is most severe in the first country group where the poor are those who are at the highest risk and suffer most. Hence, arsenic pollution is an increasing global problem that will require a global approach and world wide solutions. Thereby, transdisciplinary research into the occurrence, mobility and bioavailability of arsenic in different environments including aquifers, soils, sediments as well as the food chain, will all become increasingly important.

It gives me pleasure to congratulate the organisers for their success in bringing this Congress to China and acknowledge the collaborative and cooperative efforts of the KTH Royal Institute of Technology. I hope that these proceedings will serve as a lasting record in co-organising this international Congress.

Professor Mark Harvey
Deputy Vice Chancellor (Research & Innovation)
The University of Southern Queensland
Toowoomba, Australia
April 2018

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Foreword (Director, KWR Watercycle Research Institute)

It is with great pleasure and expectations that I write this Foreword to the Proceedings of the 6th International Congress and Exhibition on Arsenic in the Environment (As2018), themed 'Environmental Arsenic in a Changing World' held in Beijing, Peoples Republic of China, July 1–6, 2018.

The International Congress on Arsenic in the Environment has been previously held five times: Mexico 2006, Spain 2008, R. O. China 2010 Australia, 2012, Argentina 2014 and Sweden 2016. The Congress series has evolved into a highly reputable platform for sharing and assessing global knowledge on various aspects of arsenic research. Arsenic in drinking water is a global problem affecting populations on all five continents. Despite historical recognition of arsenic toxicity, more than 200 million people around the world are still exposed to above acceptable arsenic levels. This situation is alarming. Arsenic contamination of drinking water can be caused both by natural and anthropogenic processes. For example, in Poland and Brazil, arsenic contamination of groundwater due to anthropogenic mining activities have been reported. On the other hand, in some parts of Turkey elevated arsenic in groundwater is attributed to natural geothermal factors, and in Bangladesh geogenic processes are the major cause of large scale arsenic contamination. Whatever the origin may be, once detected in drinking water sources, suitable arsenic remediation measures should be taken to ensure supply of safe drinking water – as this is the fundamental right of every human being.

In the Netherlands, drinking water companies have recently updated their policy on arsenic and they will present their rationale at As2016. KWR Watercycle Research Institute is collaborating with the water companies in various fundamental and applied research projects to support the realization of this policy. Recognizing the global significance of arsenic for safe water supply, KWR has gladly invested in realizing As 2018 via participation in the organizing committee and the scientific board of As2018, by our research scientist, Mr. Arslan Ahmad, from our Knowledge Group Water Systems and Technology.

I congratulate all the authors, reviewers and editors for providing excellent content and structure to this book. I hope that these proceedings will serve as a deep-rooted record of the state-of-the-arsenic-related-science in the year 2018 and serve as a reference base for future research and support water suppliers and policy makers all over the world in addressing the arsenic problem efficiently and effectively.

Prof. Dr. Wim van Vierssen
Director
KWR Watercycle Research Institute
Nieuwegein, The Netherlands
April, 2018

Environmental Arsenic in a Changing World –
Zhu, Guo, Bhattacharya, Ahmad, Bundschuh & Naidu (Eds)
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Foreword (Vice-Chancellor and President, The University of Newcastle)

THE UNIVERSITY OF
NEWCASTLE
AUSTRALIA

It is with deep satisfaction that I write this foreword to the 7th International Congress & Exhibition on Arsenic in the Environment (As 2018). 'Environmental Arsenic in a Changing World' will be held in July 2018 in Beijing, China. The University of Newcastle (UON) is very proud to be part of this international congress series as co-organizer.

The first arsenic workshop (Arsenic in the Asia-Pacific Region) was organized by Professor Ravi Naidu in Adelaide, South Australia in 2001 where the extent, severity and potential risks arising from exposure to arsenic, as well as the fate of arsenic in water, soil and food was discussed. The continuation of this as a global congress - "*Arsenic in the Environment*" - was then held in Mexico in 2006. Since then, the international congress series has been held every two years at various locations around the globe. Thus, this arsenic congress has received enormous attention and is a platform where scientists, government officials, policy makers and regulators share their knowledge on the recent developments in arsenic research.

Arsenic is a toxic element and is categorized as a Class I carcinogen, which is ubiquitous in the environment. Arsenic is present in our environment as a naturally occurring substance and because of anthropogenic activities. It is generally found in waters (both surface and sub-surface), soil, food and the air and can occur in both organic and inorganic forms. Arsenic occurrence in water in the Australian landscape is generally low but major pollution can occur due to mining activities, the use of arsenic based pesticides and herbicides, as well as from CCA treated wood. Arsenic concentrations in cattle dip and sheep dip soils and railway corridor soils in Australia are also at levels two to five times above the health screening levels. These are the major causes of arsenic contaminated sites in Australia.

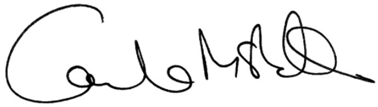
The first arsenic contamination was reported in Germany in 1885 and arsenic related health effects (widely known as Bell Ville Disease) were first reported in 1917 from the province of Cordoba, Argentina. Later, gangrene was reported in the population of arsenic impacted villages in south-western Taiwan, generally known as Blackfoot disease. During the 1960s, high levels of arsenic were detected in the groundwater of the Lagunera region of Mexico where various arsenic related diseases were also reported at this time. The global epidemiological research based on the data from these studies played a crucial role in establishing arsenic related health effects.

UON is a leading research organisation, which contributes to both Australian and international social, economic, cultural and environmental well-being through its innovative research activities that supports research in identified areas of strength, to address national and international challenges. UON continues to build its global reputation for delivering world-class research and innovation, a reputation that has been built on high quality performance in a wide range of specialist research fields.

We are ranked in the top 1% of the world's universities, according to the QS World University Rankings 2017/18. Our Engineering – Mineral and Mining discipline - was ranked in the top 30 in the world for the second consecutive year in the 2018 QS World University Rankings by Subject list. The University also had six subjects ranked in the world's top 100 and 15 subjects ranked in the world's top 200. The University was 8th in Australia for research deemed to be ‘well above world standard’ in the 2015 Excellence in Research Australia (ERA) exercise.

UON researchers have been working in Bangladesh and India over many years and have made substantial contributions to various aspects of arsenic research including arsenic chemistry, toxicity and bioavailability, human health effects, and food quality and safety. By combining laboratory-based studies with field surveys, they have contributed significantly to the generation of new knowledge in this important research field. UON researchers have also made major contributions by developing new and novel analytical techniques for arsenic speciation in various environmental matrices, which has helped to understand the toxicity, bioavailability, and accurate estimation of human health risks. UON’s current activities include: researching geographical variations and age related dietary exposure in rice along with cancer and non-cancer effects; inorganic arsenic levels in rice and rice based diets and the potential risk to babies and toddlers; lowering arsenic levels in rice by managing irrigation options with enhanced productivity; and arsenic bioavailability in various rice varieties using a swine model to understand the human health risk.

We sincerely hope that the congress proceedings will become an excellent and much-used resource for researchers and others who are working on arsenic and related research fields. We would like to thank the contributors and conference delegates for their active participation. We would also like to express our whole-hearted appreciation to all co-organizers and others who will be involved in the congress series and who will no doubt make this congress a great success.



Professor Caroline McMillen
Vice-Chancellor and President
The University of Newcastle (UON)
Newcastle, Australia
May 2018

Editors' foreword

Occurrence of elevated arsenic concentrations in ground water used for drinking purpose, and associated health risks, were reported at first international conference on environmental arsenic, which was held in Fort Lauderdale, USA, almost exactly 40 year ago; October, 1976. Over the past 2 to 3 decades arsenic in drinking water, and more recently, in plant based foods, especially rice, has been recognized as a major public health concern in many parts of the world. Latest surveys estimated that currently more than 200 million people around the world are exposed to unacceptably high arsenic levels. The geological, geomorphological and geochemical reasons for high arsenic concentrations in groundwater vary from place to place and require different mitigation policies and practices. Although, the high income countries may invest in research and development of suitable remediation techniques, arsenic in private water sources is not always tested. On the other hand, low to lower-middle income countries, such as many areas in South-East Asia, Africa and South America, where millions of people still use arsenic-contaminated drinking water, are still coping with stagnated mitigation efforts and slow progress towards safe drinking water. It is disturbing to enter almost any village of the Bengal basin today and find that groundwater drawn from untested shallow wells continues to be used routinely for drinking and cooking, given that the arsenic problem was already recognized in the mid-1980s in West Bengal and the mid-1990s in Bangladesh. Equally problematic is the fact that hundreds of millions of wells world-wide are not yet tested for arsenic. Moreover, many low and lower-middle income countries have yet not been able to revise their standards for arsenic in drinking water to 10 μg/L, the guideline value of the World Health Organization. We sincerely believe that sharing knowledge and experience on arsenic related science and practices on a world-wide scale and across varied disciplines can serve as an effective strategy to support global arsenic management and mitigation efforts.

The biannual International Congress Series on Arsenic in the Environment aims at providing a common platform for sharing knowledge and experience on multidisciplinary issues on arsenic occurrences in groundwater and other environmental compartments on a worldwide scale for identifying and promoting optimal approaches for the assessment and management of arsenic in the environment. The International Congress on Arsenic in the Environment has previously been held six times; Mexico 2006, Spain 2008, R. O. China 2010, Australia, 2012, Argentina 2014 and Sweden 2016. The seventh International Congress on Arsenic in the Environment (As2018) is being organized in Beijing, the Capital of the Peoples Republic of China, between 1 and 6 July, 2018 and with a theme "Environmental Arsenic in a Changing World". The UN Agenda 2030 for Sustainable Development adopted in September 2015, list 17 Sustainable Development Goals (SDGs) of raise the global profile of arsenic in order to achieve universal and equitable access to safe and affordable drinking water for all. This emphasizes holistic management of drinking water services and monitoring of drinking water quality and deployment of clean water technology in the across the world for protecting human health. We envision As2018 as a global interdisciplinary platform to exchange and disseminate research results to improve our understanding of the occurrence, mobility, bioavailability, toxicity and dose-response relationship with various health effects of environmental arsenic in the current epoch of a changing world.

We have received a large number of (over 250) extended abstracts which were submitted mainly from researchers, but also health workers, technologists, students, legislators, government officials. The topics to be covered during the Congress As 2018 have been grouped under the five general thematic areas:

Theme 1: Arsenic Behaviour in Changing Environmental Media
Theme 2: Arsenic in a Changing Agricultural Ecosystem
Theme 3: Health Impacts of Environmental Arsenic
Theme 4: Technologies for Arsenic Immobilization and Clean Water Blueprints
Theme 5: Sustainable Mitigation and Management.

We thank the international scientific committee members, for their efforts on reviewing the extended abstracts. Further, we thank the sponsors of the Congress from around the world: KTH Royal Institute of Technology (Sweden), University of Southern Queensland (Australia), KWR Watercycle Research Institute (The Netherlands), The University of Newcastle (Australia) and the CRC-CARE, at the University of South Australia and OPCW for their generous support – Thank you all sponsors for your support that contributed to the success of the congress As2018.

The International Organizers would like thank Instutute of Urban Environment, Chinese Academy of Sciences and the China University of Geosciences, Beijing, China Centre for International Science and Technology Exchange (CISTE), KWR Watercycle Research Institute, The Netherlands, the Global Centre for Environmental Remediation, The University of Newcastle and CRC CARE, University of Newcastle, NSW, Australia and the University of Southern Queensland, Australia for their support to organize the 7th International Congress and Exhibition on Arsenic in the Environment (As2018). We thank the KTH Royal Institute of Technology, especially the KTH School of Architecture and Built Environment for supporting the KTH-International Groundwater Arsenic Research Group at the Department of Sustainable Development, Environmental Sciences and Engineering, Stockholm as an International Organizer of this Congress. We would like to thank Dr. M. Mahmudur Rahman, Professor M. Alauddin, P. Kumarathilaka, Dr. G. Sun, Dr. J. Ye and M. Tahmidul Islam for their help with the preparation and formatting of the content of this volume. Lastly, the editors thank Janjaap Blom and Lukas Goosen of the CRC Press/Taylor and Francis (A.A. Balkema) Publishers, The Netherlands for their patience and skill for the final production of this volume.

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