ENVIRONMENTAL ARSENIC IN A CHANGING WORLD
Arsenic in the Environment – Proceedings

Series Editors

Jochen Bundschuh
UNSECO Chair on Groundwater Arsenic within 2030 Agenda for Sustainable Development & Faculty of Health, Engineering and Sciences, The University of Southern Queensland, Toowoomba, Queensland, Australia

Prosun Bhattacharya
KTH-International Groundwater Arsenic Research Group, Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology, Stockholm, Sweden
School of Civil Engineering and Surveying and International Centre for Applied Climate Science, The University of Southern Queensland, Toowoomba, Queensland, Australia

ISSN: 2154-6568
Environmental Arsenic in a Changing World
As2018

Editors

Yong-Guan Zhu
Key Laboratory of Urban Environment and Health, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen, P.R. China
Research Centre for Eco-environmental Sciences, Chinese Academy of Sciences, Beijing, P.R. China

Huaming Guo
State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences (Beijing), Beijing, P.R. China
MOE Key Laboratory of Groundwater Circulation and Environment Evolution, School of Water Resources and Environment, China University of Geosciences (Beijing), Beijing, P.R. China

Prosun Bhattacharya
KTH-International Groundwater Arsenic Research Group, Department of Sustainable Development, Environmental Sciences and Engineering, KTH Royal Institute of Technology, Stockholm, Sweden
School of Civil Engineering and Surveying and International Centre for Applied Climate Science, The University of Southern Queensland, Toowoomba, Queensland, Australia

Jochen Bundschuh
UNSECO Chair on Groundwater Arsenic within 2030 Agenda for Sustainable Development & Faculty of Health, Engineering and Sciences, The University of Southern Queensland, Toowoomba, Australia

Arslan Ahmad
KWR Water Cycle Research Institute, Nieuwegein, The Netherlands
KTH-International Groundwater Arsenic Research Group, Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology, Stockholm, Sweden
Department of Environmental Technology, Wageningen University and Research (WUR), Wageningen, The Netherlands

Ravi Naidu
Global Centre for Environmental Remediation (GCER), Faculty of Science & Information Technology, The University of Newcastle, Callaghan, NSW, Australia
Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE), University of Newcastle, Newcastle, New South Wales, Australia
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 south-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 deposits 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\(^2\).

---

\(^1\) [https://www.britannica.com/place/Fujian](https://www.britannica.com/place/Fujian)

Table of contents

About the book series xxi
Dedication xxiii
Organizers xxv
Sponsors and Contributors xxvii
Scientific Committee xxix
Foreword (Director General, Institute of Urban Environment, Chinese Academy of Sciences) xxxiii
Foreword (Vice President, China University of Geosciences, Beijing) xxxv
Foreword (KTH Royal Institute of Technology) xxxvii
Foreword (Deputy Vice Chancellor, University of Southern Quensland) xxxix
Foreword (Director, KWR Watercycle Research Institute) xli
Foreword (Vice Chancellor and President, The University of Newcastle) xliii
Editors’ foreword xlv
List of contributors xlvii

Plenary presentations

Sedimentological and hydro-biogeochemical processes controlling arsenic behavior in the Holocene and upper Pleistocene aquifers of the central Yangtze River Basin 3
Y.X. Wang, Y.Q. Gan, Y. Deng, Y.H. Duan, T.L. Zheng & S. Fendorf

Groundwater Assessment Platform (GAP): A new GIS tool for risk forecasting and mitigation of geogenic groundwater contamination 5
M. Berg & J.E. Podgorski

Arsenic biogeochemistry from paddy soil to rice 7
F.-J. Zhao

Mechanism of As(III) S-adenosylmethionine methyltransferases and the consequences of human polymorphisms in hAS3MT 9
B.P. Rosen, C. Packianathan & J. Li

Genetic susceptibility and alterations in relation to arsenic exposure, metabolism and toxicity 12
H. Ahsan & B. Pierce

Arsenic oral bioavailability in soils, housedust, and food: implications for human health 15
L.Q. Ma, H.B. Li, D. Zhao & A.L. Juhasz

Arsenic removal by iron-based nanomaterials 18
M.I. Litter
Distribution of arsenic hazard in public water supplies in the United Kingdom – methods, implications for health risks and recommendations
D.A. Polya, L. Xu, J. Launder, D.C. Gooddy & M. Ascott

Section 1: Arsenic behaviour in changing environmental media

1.1 Sources, transport and fate of arsenic in changing groundwater systems
AdvectAs challenge: multidisciplinary research on groundwater arsenic dissolution, transport, and retardation under advective flow conditions

Arsenic in the Baltic Sea sediments – past, present, and future
M. Szubska & J. Beldowski

The role of aquifer flushing on groundwater arsenic across a 35-km transect in the upper Brahmaputra River in Assam, India
R. Choudhury, C. Mahanta, M.R. Khan, B. Nath, T. Ellis & A. van Geen

Geographical controls on arsenic variability in groundwater of Upper Indus Basin, Punjab, Pakistan
A. Farooqi, N. Mushtaq, J.A. Khattak, I. Hussain & A. van Geen

The influence of irrigation-induced water table fluctuation on iron redistribution and arsenic fate in unsaturated zone
Z.Y. Chi, X.J. Xie, K.F. Pi & Y.X. Wang

Towards imaging the spatial distribution of geochemical heterogeneities and arsenic sources
M. Rolle, M. Battistel, F. Onses, R. Mortensen, S. Fakhreddine, S. Fendorf, P.K. Kitanidis & J.H. Lee

Source of arsenic bearing detrital minerals in shallow aquifer of southeastern Bangladesh
A.H.M. Selim Reza & H. Masuda

Groundwater arsenic contamination in selected area of Bihar

Naturally occurring arsenic in geothermal systems in Turkey
A. Baba

Exploring arsenic and other geogenic groundwater contaminants in the vast and scarcely studied Amazon Basin
C.M.C. de Meyer, M. Berg, J. Rodriguez, E. Carpio, P. Garcia & I. Wahnfried

Arsenic volume estimates in Holocene clay plug sediments in Bihar, India
S. Kumar, M.E. Donselaar & F. Burgers

Steady-state groundwater arsenic concentrations in reducing aquifers
B.C. Bostick, A.A. Nghiem, A. van Geen, J. Sun, B.J. Mailloux, P.H. Viet & P.T.K. Trang

Arsenic and polymetallic contaminants in groundwater of the arid regions of South Africa
T.A. Abiye

Effect of recharging water from Meghna River on the arsenic contaminated groundwater
H. Masuda, N. Hirai & A.H.M. Selim Reza

Groundwater arsenic distribution reconnaissance survey in Myanmar
L.A. Richards, G.P. Pincetti Zúñiga & D.A. Polya

Potential arsenic contamination in drinking water sources of Tanzania and its link with local geology
J. Ijumulana, F. Mtalo & P. Bhattacharya
Spatial variability of trace elements with Moran’s I Analysis for shallow groundwater quality in the Lower Katari Basin, Bolivian Altiplano

I. Quino, O. Ramos, M. Ormachea, J. Quintanilla & P. Bhattacharya

Influence of hydrothermal fluids enriched in As and F on the chemistry of groundwaters of the Duero Basin, Spain

E. Giménez-Forcada, S. Timón-Sánchez & M. Vega-Alegre

1.2 Origin and reactivity of organic matter in high arsenic groundwater systems

Arsenic methylation and its relationship to abundance and diversity of arsM Genes in composting manure


Hydrogeological and geochemical comparison of high and low arsenic groundwaters in the Hetao Basin, Inner Mongolia

H.Y. Wang

Effects of sediment properties and organic matter on biomobilization of arsenic from aquifer sediments in microcosms

Z. Xie, M. Chen, J. Wang, X. Wei, F. Li, J. Wang & B. Gao

Organic acid effect on arsenate bioaccessibility in gastric and alveolar simulated biofluid systems

S.Q. Kong, R.A. Root & J. Chorover

Abundance, size distribution and dissolved organic matter binding of arsenic in reducing aquifer

Y.Q. Sun, H. Lin, S.B. Han, J. Sun, M. Ma, L.D. Guo & Y. Zheng

Sedimentological controls on the formation of high arsenic aquifers in the central Yangtze River Basin since the Last Glacial Maximum

Y. Deng, Y.X. Wang & T. Ma

Roles of dissolved organic matter on seasonal arsenic variation in shallow aquifers of the central Yangtze River Basin by EEM-PARAFAC analysis

X.F. Yuan, Y. Deng & Z.J. Lu

Roles of iron and/or arsenic reducing bacteria in controlling the mobilization of arsenic in high arsenic groundwater aquifer

H. Liu, P. Li, Y.H. Wang & Z. Jiang

The DOM characteristic in As-affected aquifer of Chaobai River in the North China Plain

Y.F. Jia & Y.H. Jiang

Sulfurated fertilizers enhance the microbial dissolution and release of arsenic from soils into groundwater by activating arsenate-respiring prokaryotes


1.3 Biogeochemical processes controlling arsenic mobility, redox transformation and climate change impacts

Structural insight into the catalytic mechanism of arsenate reductase from Synechocystis sp. PCC 6803

Y. Yan, J. Ye, X. Zhang, X.M. Xue & Y.G. Zhu

Impacts of environmental factors on arsenate biotransformation and release in Microcystis aeruginosa using Taguchi experimental design

Z.H. Wang, Z.X. Luo & C.Z. Yan

Elevated oxidizing compounds influencing the biogeochemistry of arsenic in subsurface environments

W.J. Sun
Multiple species of arsenic biotransformation occur in *Nostoc* sp. PCC 7120
X.M. Xue & Y.G. Zhu

Irrigation activities affecting arsenic mobilization in topsoil in Datong Basin, northern China
Z.Y. Xiao & X.J. Xie

Effects of microbial communities on arsenic mobilization and enrichment in groundwater from the Datong Basin, China
L. Yan, X.J. Xie, K.F. Pi, K. Qian, J.X. Li, Z.Y. Chi & Y.X. Wang

The effects of the bioanode on the microbial community and element profile in paddy soil
G. Williamson & Z. Chen

Role of carbonate on arsenic mobilization in groundwater
X.B. Gao, P.L. Gong & W.T. Luo

Effect of symbiotic bacteria on the accumulation and transformation of arsenite by *Chlorella salina*
Y.X. Wang, Q.N. Yu & Y. Ge

Arsenic transformation mediated by *Pantoea* sp. IMH in spent nZVI waste residue
L. Ye & C.Y. Jing

Land scale biogeography of arsenic biotransformation genes in estuarine wetland

Arsenic, manganese, and dissolved organic matter biogeochemistry in the Bengal Basin (India) and Southern Pampean plain (Argentina)
M. Vega, S. Datta, N.N. Sosa, H. Kulkarni & M. Berube

Arsenic mobilization in shallow aquifer of Bengal Delta Plain: role of microbial community and pathogenic bacteria
P. Ghosh & D. Chatterjee

Distribution and hydrogeochemical behavior of arsenic-enriched groundwater in the sedimentary aquifers: Comparison between Datong Basin, China and Kushtia District, Bangladesh
M.-E. Huq, C.L. Su, J.X. Li & R. Liu

Unravelling the role of microorganisms in arsenic mobilization using metagenomic techniques

Understanding arsenic evolution in a shallow, reducing aquifer in the lower Mekong basin, Cambodia using geochemical tracers

Significance of arsenic resistant prokaryotes in climate change perspective
A.B.M.R. Islam, S.A. Ahmad, M. Alauddin & K. Tazaki

Microbial study related with the arsenic hydrogeochemistry of the Xichú River in Guanajuato, Mexico
U.E. Rodríguez Castrejón, A.H. Serafin Muñoz, C. Cano Canchola & A. Álvarez Vargas

1.4 Arsenic and other trace elements in groundwater of China

Nano-TiO₂ both increases and decreases arsenic toxicity: Evidence from different aquatic animal experiments
Z.X. Luo, Z.H. Wang, F. Yang & C.Z. Yan

Interfacial interaction of arsenic(V) with Mg-containing calcite and calcite

viii
Temporal dynamics of microbial community structure and its effect on arsenic mobilization and transformation in Quaternary aquifers of the central Yangtze River Basin

Variation of Extracellular Polymeric Substances (EPS) of Chlamydomonas reinhardtii under arsenic stress

The connection of manganese and arsenic in unconfined groundwater and shallow confined groundwater of Jianghan plain, China
X. Yu & Y. Deng

Functions and unique diversity of genes and microorganisms involved in arsenic methylation in the arsenic-rich shallow and deep sediments of Jianghan Plain
X.B. Zhu, X.C. Zeng, Y. Yang, W.X. Shi & X.M. Chen

Characteristics and mechanisms of arsenic behavior during the microbial oxidation-reduction of iron
W. Xiu, H.M. Guo, X.N. Yu, W.J. Yuan & T.T. Ke

Microbial community in high arsenic groundwater aquifers from Hetao Plain of Inner Mongolia, China
Y.H. Wang, P. Li, Z. Jiang, H. Liu, D.Z. Wei & H.L. Wang

1.5 Spatial and temporal evolution of arsenic in mine waste and tailings
Application of stable isotopes on bioaccumulation and trophic transfer of arsenic in aquatic organisms around a closed realgar mine
F. Yang & C.Y. Wei

Arsenic characteristics in the terrestrial environment in the vicinity of the Shimen realgar mine, China
C.Y. Wei

Hydrochemical characteristics and the genesis of high arsenic groundwater in the ecotone between polymetallic sulfide mining area and irrigated agricultural area
Y.H. Dong, J.L. Li & T. Ma

Potential threat of arsenic contamination of water sources from gold mining activities in Lake Victoria areas, Tanzania
R.R.A.M. Mato & G.R. Kassenga

1.6 Arsenic mobility and fate in contaminated soils and sediments
Effect of humic acid on microbial arsenic reduction in anoxic paddy soil
X.M. Li, J.T. Qiao & F.B. Li

Arsenic relative bioavailability in contaminated soils: comparison of animal models, dosing schemes, and biological endpoints
H.B. Li, J. Li, L.Q. Ma & A.L. Juhasz

Facilitated release of arsenic from polluted sediment in Plateau Lakeshore Wetland by phosphorus input
R. Zhao, L. Hou & Y.G. Liu

Quantification of arsenic adsorption and oxidation on manganese oxides
B. Rathí, O. Cirpka, J. Sun, J. Jamieson, A. Siade, H. Prommer & M. Zhu

A novel MAs(III)-selective ArsR transcriptional repressor
J. Chen, V.S. Nadar & B.P. Rosen

A preliminary investigation on adsorption behavior of As(III) and As(V) in Jianghan Plain
S. Wang, R. Ma, Y.F. Liu & J.Y. Wang
Surface complexation modeling of arsenic mobilization from goethite: Interpretation of in-situ experiments in a sedimentary basin of Inner Mongolia, China  
L. Stolze, D. Zhang, H.M. Guo & M. Rolle  

Effects of carbonate and Fe(II) on As(III) adsorption and oxidation on hydrous manganese oxide  
Z.X. Zhao, S.F. Wang & Y.F. Jia  

Effects of the seeding phenomenon in the scorodite precipitation process  
J.S. Villalobos, J.C. Bravo & F.P. Mella  

Effect of microbial sulfate reduction on arsenic mobilization in aquifer sediments from the Jianghan Plain, Central Yangtze River Basin  
J. Gao, Y. Deng, T.I. Zheng & H.C. Jiang  

Assessing arsenic ecotoxicity in tropical soils for regulatory purposes: Which endpoints are more appropriate?  

Arsenic and trace metal mobility in alum shale areas in Sweden  
G. Jacks & P. Bhattacharya  

1.7 Arsenic in dust and road deposits  

Trends in antimony pollution near exposed traffic nodes: comparison with arsenic  
B. Dousova, M. Lhotka, V. Machovic, F. Buzek, B. Cejkova & I. Jackova  

Arsenic contaminated dust and the mud accident in Fundão (Brazil)  
C.S. Fernandes, A.C. Santos, G.R. Santos & M.C. Teixeira  

1.8 Advances and challenges in arsenic analysis in solid and aqueous matrix  

Effects of arsenite oxidation on metabolic pathways and the roles of the regulator AioR in Agrobacterium tumefaciens GW4  
G.J. Wang, K.X. Shi, Q. Wang & X. Fan  

Sulfur-arsenic interactions and formation of thioarsenic complexes in the environment  
I. Herath, J. Bundschuh & P. Bhattacharya  

Application of spectral gamma and magnetic susceptibility in an As-bearing loessic aquifer, Argentina  
L. Sierra, S. Dietrich, P.A. Weinzeitel, P.A. Bea, L. Cacciabue, M.L. Gómez Samus & N.N. Sosa  

Speciation of arsenic in sediment and groundwater  
W.T. Luo, X.B. Gao, Y. Li, X. Zhang & P.L. Gong  

Total arsenic and inorganic arsenic speciation and their correlation with fluoride, iron and manganese levels in groundwater intended for human consumption in Uruguay  
I. Machado, V. Bühl & N. Mañay  

Optimization of the high pressure leaching of Complex Copper Concentrates of Codelco using a process simulator  
N.P. Werth  

Comparative genomic analysis reveals organization, function and evolution of ars genes in Pantoea spp.  
L.Y. Wang & C.Y. Jing  

Thioarsenic compounds exist in the drinking groundwater  
J.H. Liang & Z. Chen  

Arsenic speciation of groundwater and agricultural soils in central Gangetic basin, India  
M. Kumar & AL. Ramanathan
Section 2: Arsenic in a changing agricultural ecosystem and food chain effects

2.1 Processes and pathways of arsenic in agricultural ecosystems

Derivation of soil thresholds for arsenic applying species sensitivity distribution
C.F. Ding & X.X. Wang

Spatial variation of arsenic in irrigation well water from three flood plains (Ravi, Chenab and Jhelum) of Punjab, Pakistan
A. Javed, Z.U. Baig, A. Farooqi & A. van Geen

Occurrence of arsenic in agricultural soils from the Chaco-Pampean plain (Argentina)
C.V. Alvarez Gonçalvez, F.E. Arellano, A. Fernández-Cirelli & A.L. Pérez Carrera

Arsenic and antimony concentrations in Chinese typical farmland soils
A. Parvez, C.L. Ma, Q.Y. Zhong, C.Y. Lin, Y.B. Ma & M.C. He

Characterization of an agricultural site historically polluted by the destruction of arsenic-containing chemical weapons

Absorption and distribution of phosphorus from Typha under arsenic
W. Ren, G.Y. Yang, W. Yan, L. Hou & Y.G. Liu

Adsorption of arsenic by birnessite-loaded biochar in water and soil
H.Y. Wang, P. Chen & G.-X. Sun

The application of organics promotes arsenic methylation in paddy soils
G.L. Duan, Y.P. Yang, X.Y. Yi & Y.G. Zhu

Traceability of arsenic in agricultural water in Irrigation District 005, México
M.C. Valles-Aragón & M.L. Ballinas-Casarrubias

Arsenic data availability in agricultural soils and waters in Europe
T. Hatakka & T. Tarvainen

Arsenic in cattle: Evaluation of possible exposure biomarkers
C.V. Alvarez Gonçalvez, F.E. Arellano, A. Fernández-Cirelli & A.L. Pérez Carrera

2.2 Arsenic dynamics in rhizosphere

Bioelectrochemical arsenite oxidation in rice rhizosphere in plant-microbial fuel cells
X.Q. Wang, Y.H. Lv, C.P. Liu, F.B. Li & Y.H. Du

Thioarsenate formation in paddy soils
J. Wang, M. Romani, M. Martin & B. Planer-Friedrich

The role of radial oxygen loss on the flux of arsenic and other elements in rice rhizosphere
D. Yin, J. Luo, W. Fang & P.N. Williams

2.3 Microbial ecology of arsenic biotransformation in soils

Microbial transformation of arsenic in Bengal floodplain
H. Afroz, A.A. Meharg & C. Meharg

Concurrent methylation and demethylation of arsenic in fungal cells
Response of soil microbial communities to elevated antimony and arsenic contamination indicates the relationship between the innate microbiota and contaminant fractions
W. Sun, B.Q. Li, Z.X. Xu, E.Z. Xiao & T.F. Xiao

Transformation of roxarsone by Enterobacter sp. CZ-1 isolated from an arsenic-contaminated paddy soil
K. Huang, F. Gao & F.-J. Zhao

Functional microbial communities in high arsenic groundwater
P. Li, Z. Jiang & Y.X. Wang

2.4 Molecular mechanisms of plant arsenic uptake

Heterologous expression of PvACR3;1 decreased arsenic accumulation in plant shoots

Exploration of biochemical properties of soil and groundwater in arsenic affected blocks of Murshidabad district and isolation of potential arsenic resistant bacteria
S. Ahmed, A. Basu, D. Mandal, I. Saha & M. Biswas

An effective rhizoinoculation restraints arsenic translocation in peanut and maize plants exposed to a realistic groundwater metalloid dose
J.M. Peralta, C.N. Travaglia, R.A. Gil, A. Furlan, S. Castro & E.C. Bianucci

2.5 Speciation and toxicity of arsenic in food chain

Arsenic speciation in soil-water system and their uptake by rice (Oryza sativa)
P. Kumarathilaka, J. Bundschuh, S. Seneweera & A.A. Meharg

Application of nanofilms for arsenic speciation using surface-enhanced Raman spectroscopy (SERS)
V. Liamtsau & Y. Cai

Interannual variability of dissolved and rice grain concentrations of arsenic and cadmium in paddy fields subjected to different water managements
T. Honma, K. Nakamura, T. Makino & H. Katou

The effects of different arsenic species in relation to straighthead disease in rice
H.P. Martin, W. Maher, M. Ellwood, E. Duncan, P. Snell & F. Krikowa

Effects of foliar application of silicon on uptake and translocation of arsenite and DMA in rice (Oryza sativa)
W.-J. Liu, Y. Sun & Q.-L. Zhao

Persistence and plant uptake of methylarsenic in continuously- and intermittently-flooded rice paddies
S.C. Maguffin, M.C. Reid, A. McClung & J. Rohila

Geographical variation of arsenic in rice from Bangladesh: Cancer risk
S. Islam, M.M. Rahman & R. Naidu

Translocation of arsenic in food chain: A case study from villages in Gangetic basin, India
D. Ghosh & J. Routh

2.6 Threshold values of food arsenic

Bioaccessibility and arsenic speciation in carrots, beets and quinoa from a contaminated area of Chile
I. Pizarro, M. Gómez-Gómez, D. Román & M.A. Palacios
Section 3: Health impacts of environmental arsenic

3.1 Exposure and epidemiology of arsenic impacts on human health

Arsenic, DNA damage, and cancers of bladder and kidney – a long-term follow-up of residents in arseniasis endemic area of north-eastern Taiwan
S.-L. Wang, S.-F. Tsai, L.-I. Hsu, C.-J. Chen, K.-H. Hsu & H.-Y. Chiou

Arsinothricin: a novel arsenic-containing antibiotic

Arsenic induces Th1/Th2 imbalance in immune and non-immune organs
Y.Y. Guo, L. Zhao, S. Yang, G.F. Sun, B. Li, X.X. Duan & J.L. Li

Thiolation in arsenic metabolism: a chemical perspective
C. Fan, G. Liu & Y. Cai

AS3MT polymorphisms, arsenic metabolites and pregnancy
A. Stajnko, Z. Šlejkovec, D. Mazej, M. Horvat & I. Falnoga

Prevalence of cancer incidences in Bihar, India due to poisoning in groundwater
A. Kumar, R. Kumar, M. Ali & A.K. Ghosh

Arsenic exposure from drinking water and the occurrence of micro- and macrovascular complications of type 2 diabetes

Chronic arsenic exposure, endothelial dysfunction and risk of cardiovascular diseases
K. Hossain, S. Himeno, M.S. Islam, A. Rahman & M.M. Hasibuzzaman

Arsenic exposure, lung function, vitamin D and immune modulation in the Health Effects of Arsenic Longitudinal Study (HEALS) cohort

Arsenic in drinking water and childhood mortality: A 13-year follow-up findings
M. Rahman, N. Sohel & M. Yunus

3.2 Genetic predisposition of chronic arsenic poisoning

OsRCS3 functions as a cytosolic O-acetylserine(thiol)lyase and regulates arsenic accumulation in rice
C. Wang, Z. Tang & F.-J. Zhao

Epigenomic alterations in the individuals exposed to arsenic through drinking water in West Bengal, India
A.K. Giri, D. Chatterjee & N. Banerjee

Identification of arsenic susceptibility by using the micronucleus assay and Single Nucleotide Polymorphisms (SNP)
A.K. Bandypadhyay, D. Chatterjee & A.K. Giri

Alternative splicing of arsenic (III oxidation state) methyltransferase
D. Sumi & S. Himeno
3.3 Reliable biomarkers for arsenic exposure

Drinking water arsenic exposure, thyroid hormone biomarkers and neurobehavioral outcomes in adolescents

K.M. Khan, F. Parvez, L. Kamendulis, B. Hocevar, T. Zoeller & J.H. Graziano

Arsenic exposure in the Canadian general population: levels of arsenic species measured in urine, and associated demographic, lifestyle or dietary factors

A. St-Amand, S. Karthikeyan, M. Guay, R. Charron, A. Vezina & K. Werry

3.4 Risk assessment of chronic ingestion

Beyond the wells: role of diet on arsenic induced toxicity in exposed populations of Bihar, India


Effects of folate on arsenic methylation pattern and methionine cycle in sub chronic arsenic-exposed mice

D. Wang, Y. Li, B. Li, L. Lin & G.F. Sun

Health risk assessment of arsenic dispersion from mining in Mount Isa

J. Zheng, B.N. Noller, T. Huynh, R. Targa, J.C. Ng, V. Diacomanolis & H.H. Harris

Assessing drinking water quality at high dependent point of sources and potential health risk of massive population: A view from Tala Upazila of Satkhira District in Bangladesh

R. Saha, N.C. Dey & M. Rahman

Health impact of chronic arsenic exposure in the population of Gyaspur-Majhi village, Patna, Bihar India


Health risks related to seafood consumption and arsenic speciation in fish and shellfish from North Sea (Southern Bight) and Açu Port area (Brazil)


A dietary intervention in Bangladesh to counteract arsenic toxicity

J.E.G. Smits, R.M. Krohn, A. Vandenbergh & R. Raqib

Arsenic contamination in drinking water from groundwater sources and health risk assessment in the Republic of Dagestan, Russia

T.O. Abdulmutalimova, B.A. Revich & O.M. Ramazanov

3.5 Multi-metal synergies in chronic exposure cases

Interaction of polyaromatic hydrocarbons and metals on bioaccessibility and toxicity of arsenic

J.C. Ng, Q. Xia, S. Muthusamy, V. Lal & C. Peng

Contamination of arsenic and heavy metals in coal exploitation area


Contamination of water, soil and plant with arsenic and heavy metals

A. Yadav, K.S. Patel, L. Lata, H. Milosh, P. Li, J. Allen & W. Corns

3.6 Assessment of global burden of arsenic in drinking water and health care systems for exposed population

Pharmacodynamic study of the selenium-mediated arsenic excretion in arsenicosis patients in Bangladesh


xv
Exposure levels to various arsenic species and their associated factors in Korean adults 395
J.D. Park, I.G. Kang, S.G. Lee, B.S. Choi, H. Kim & H.J. Kwon

A medical geology perspective of arsenic as a poison and medicinal agents 397
J.A. Centeno

Section 4: Technologies for arsenic immobilization and clean water blueprints

4.1 Adsorption and co-precipitation for arsenic removal

Interaction of arsenic with co-precipitated Fe(II,III) (hydr)oxides 401
C.M. van Genuchten, T. Behrends, P. Kraal, S.L.S. Stipp & K. Dideriksen

Adsorptive removal of arsenic by calcined Mg-Fe-(CO₃) LDH: An artificial neural network model 403
M.K. Yadav, A.K. Gupta, P.S. Ghosal, A. Mukherjee & I.S Chauhan

Influence of Fe(II), Fe(III) and Al on arsenic speciation in treatment of contaminated water by Fe and Al (hydr)oxides co-precipitation 405
I.C. Filardi Vasques, R. Welmer Veloso & J.W. Vargas de Mello

Sorption of toxic oxyanions to modified kaolines 407
M. Lhotka & B. Dousova

Efficient removal of arsenic species by green rust sulfate (GR₅O₄) 409
J.P.H. Perez, H.M. Freeman, J.A. Schuessler & L.G. Benning

Arsenite removal from water by an iron-bearing Layered Double Hydroxide (LDH) 412
Q.H. Guo & Y.W. Cao

Effect of Ca²⁺ and PO₄³⁻ on As(III) and As(V) adsorption at goethite-water interface: Experiments and modeling 414
Y.X. Deng, L.P. Weng & Y.T. Li

An insight into As(III) adsorption behavior on β-cyclodextrin functionalized hydrous ferric oxide: Synthesis & characterization 416
I. Saha, K. Gupta, S. Ahmed, D. Chatterjee & U.C. Ghosh

Iron-based subsurface arsenic removal by aeration (SAR) – results of a pilot-scale plant in Vietnam 418
V.T. Luong, E.E. Cañas Kurz, U. Hellriegel, L.L. Tran, J. Hoinkis & J. Bundschuh

A new material could effectively treatment of arsenic-contaminated water 420
Y.F. Li, X. Li, D. Wang, B. Li, Q.M. Zheng, L.J. Dong & G.F. Sun

Decrease of arsenic in water from the Pampean plain (Argentina) by calcium salts addition 422
L. Cacciabue, S. Dietrich, P.A. Weinzettel, S. Bea, L. Sierra & C. Ayora

Adsorption and photocatalytic study of calcium titanate (CaTiO₃) for the arsenic removal from water 424
R.M. Tamayo Calderón, R. Espinoza Gonzales & F. Gracia Carooca

TiO₂ facet-dependent arsenic adsorption and photooxidation: Spectroscopic and DFT study 426
L. Yan & C.Y. Jing

Sorption studies and characterization of developed biochar composites for As(III) adsorption from water 428
P. Singh & D. Mohan

Evaluating the arsenic removal potential of Japanese oak wood biochar in aqueous solutions and groundwater 430
N.K. Niazi, I. Bibi, M. Shahid & Y.S. Ok

Modeling arsenic removal by co-precipitation under variable redox conditions 432
M.W. Korevaar, D. Vries & A. Ahmad

xv
Visual MINTEQ simulation for prediction of the adsorption of arsenic on ferrihydrite
R. Irunde, P. Bhattacharya, J. Ijumulana, F.J. Ligate, A. Ahmad, F. Mtalo & J. Mtamba

Clay-biochar composite for arsenic removal from aqueous media
M. Vithanage, L. Sandaruwan, G. Samarasinghe & Y. Jayawardhana

Iron coated peat as a sorbent for the simultaneous removal of arsenic and metals from contaminated water
A. Kasiuliene, I. Carabante, J. Kumpiene & P. Bhattacharya

4.2 Ion exchange and membrane technologies

Development of membrane by using iron-containing synthetic materials for arsenic removal from water
L.R. Velázquez, R.V. Moreno, R.R. Mendoza, C. Velázquez & S.E. Garrido Hoyos

As(V) rejection by NF membranes for drinking water from high temperature sources
B.J. Gonzalez, S.G.J. Heijman, A.H. Haidari, L.C. Rietveld & D. van Halem

As(III) oxidation during full-scale aeration and rapid filtration
J.C.J. Gude, L.C. Rietveld & D. van Halem

4.3 Nanotechnological applications in arsenic treatment

Combined effect of weak magnetic fields and anions on arsenite sequestration by zerovalent iron
Y. Sun & X. Guan

Remediation of arsenic contaminated groundwater with magnetite (Fe₃O₄) and chitosan coated Fe₃O₄ nanoparticles
S. Ahuja, C. Mahanta, S. Sathe, L.C. Menan & M. Vipasha

Removal of arsenic from wastewater treated by means of nanoparticles and magnetic separation
M.F. Isela, R.C. Mercedes E. & G.M. Rocío

A synergistic Cu-Al-Fe nano adsorbent for significant arsenic remediation and As(0) supported mitigation in aqueous systems
Y.K. Penke, G. Anantharaman, J. Ramkumar & K.K. Kar

Exploring the scope of nanoparticles for arsenic removal in groundwater
A. Kumar, H. Joshi & A. Kumar

Immobilization of magnetite nanoparticles for the removal of arsenic and antimony from contaminated water
G. Sun & M. Khiadani

Arsenic retention on technosols prepared with nanoparticles for treatment of mine drainage water
D. Bolaños, V. Sánchez, J. Paz, M. Balseiro & L. Cumbal

4.4 Arsenic solidification and immobilization for contaminated soils

Reciprocal influence of arsenic and iron on the long-term immobilization of arsenic in contaminated soils
I. Carabante, J. Antelo, J. Lezama-Pacheco, S. Fiol, S. Fendorf & J. Kumpiene

Evaluation of chemical stabilizers for the retention in a mining tailing contaminated soil

Treatment of low-level As contaminated excavated soils using ZVI amendment followed by magnetic retrieval
J.N. Li, S. Riya, A. Terada & M. Hosomi

Arsenic remediation through magnetite based in situ immobilization
J. Sun, B.C. Bostick, S.N. Chillrud, B.J. Mailloux & H. Prommer
4.5 Phytoremediation of arsenic-contaminated soils

Phytate enhanced dissolution of As-goethite and uptake by As-hyperaccumulator *Pteris vittata*

X. Liu, J.W. Fu, Y. Cao, Y. Chen & L.Q. Ma

Development of a phyto-stabilization strategy based on the optimization of endogenous vegetal species development on a former arsenic-bearing mine waste

H. Thouin, M.P. Norini, P. Gautret, M. Motelica, F. Battaglia-Brunet, L. Le Forestier, L. De Lary De Latour & M. Beaulieu

Phytoremediation of arsenic using a chemical stabilizer and *Eleocharis macrostachya* in a contaminated mining soil

J.M. Ochoa-Rivero, M.A. Olmos-Márquez, C.G. Sáenz-UrIBE & M.T. Alarcón-Herrera

4.6 Innovative technologies

Removal of arsenic by fungal strains of *Fusarium*

E.E. Pellizzari, G.R. Bedogni, E.H. Monzon & M.C. Gimenez

Permanent remediation of toxic arsenic trioxide in Canada’s North

P.E. Brown

Identification arsenic (V) by cyclic voltammetry and recovery of arsenic by electrodeposition

H.I. Navarro Solis, G. Rosano Ortega & S.E. Garrido Hoyos

Constructed wetlands as an alternative for arsenic removal

C.E. Corroto, A. Iriel, E. Calderón, A. Fernández-Cirelli & A.L. Pérez Carrera

Simultaneous electricity production and arsenic mitigation in paddy soils by using microbial fuel cells


Arsenic removal from groundwater by capacitive deionization (CDI): findings of laboratory studies with model water

E.E. Cañas Kurz, V.T. Luong, U. Hellriegel, J. Hoinkis & J. Bundschuh

As(III) removal in natural groundwaters: influence of HPO$_4^{2-}$, H$_4$SiO$_4$, Ca$^{2+}$, Mg$^{2+}$ and humic acid in complex, realistic water matrices

D.J. de Ridder & D. van Halem

Fecal contamination of drinking water in arsenic-affected area of rural Bihar: tube-well and storage container survey

M. Annaduzzaman, L.C. Rietveld & D. van Halem

Biomineralization of charophytes and their application in arsenic removal from aquatic environment

S. Amirnia, T. Asaeda & C. Takeuchi

Efficient generation of aqueous Fe in electrocoagulation systems for low-cost arsenic removal

S. Müller, T. Behrends & C.M. van Genuchten

Arsenic removal without thio-As formation in a sulfidogenic system driven by sulfur reducing bacteria under acidic condition

Y. Hong, J. Guo, J. Wang & F. Jiang

Arsenic retention and distribution in a treatment wetland prototype


Reactive transport modeling to understand attenuation of arsenic concentrations in anoxic groundwater during Fe(II) oxidation by nitrate


Simultaneous oxidation of As(III) and reduction of Cr(VI) by *Alcaligenus* sp.

N. Rane, V. Nandre, S. Kshirsagar, S. Gaikwad & K. Kodam

Nitrate respirers mediate anaerobic As(III) oxidation in filters

C.Y. Jing & J.L. Cui
Section 5: Sustainable mitigation and management

5.1 Societal involvement for mitigations of long-term exposure

Sustainable arsenic mitigation and management through community participation
A.K. Ghosh, A. Kumar, R. Kumar & M. Ali

Community effects on safe water selection – the case of West Bengal
M. Sakamoto, S. Mukhopadhyay, K. Bakshi & S. Roy

Likelihood of adoption of arsenic-mitigation technologies under perceived risks to health, income, and social discrimination to arsenic contamination
S.K. Singh & R.W. Taylor

Social approach to arsenic mitigation in Gangetic belt, India
S. Singh & Chandrbhushan

5.2 Policy instruments to regulate arsenic exposure

Integrating policy, system strengthening, research and harmonized services delivery for scaling up drinking water safety in Bangladesh

5.3 Risk assessments and remediation of contaminated land and water environments – Case studies

Effect of arsenic risk assessment in Pakistan on mitigation action
J.E. Podgorski, S.A.M.A.S. Eqani & M. Berg

Alleviation of altered ultrastructure in arsenic stressed rice cultivars under proposed irrigation practice in Bengal Delta Basin
A. Majumdar, A. Barla, S. Bose, M.K. Upadhyay & S. Srivastava

Arsenic linked to a former mining activity in the Hunan province: distribution at the local scale and bacterial As(III) oxidation

Assessing the phytoremediation potential of a flowering plant Zinnia angustifolia for arsenic contaminated soil
Poonam & S. Srivastava

Evaluation of leaf proteomics responses during selenium mediated tolerance of arsenic toxicity in rice (Oryza sativa L.)
R. Chauhan, S. Awasthi, S. Mallick, V. Pande, S. Srivastava & R.D. Tripathi

Evaluation of proteomics responses of rice (Oryza sativa) during arsenic toxicity amelioration by a potential microbial consortium
S. Awasthi, R. Chauhan, S. Srivastava & R.D. Tripathi

Evaluation of nitrogen supply on arsenic stress responses of rice (Oryza sativa L.) seedlings
S. Srivastava

Remediation of a heavy metals contaminated site in urban area: a case study from southern China
H. Huang, Y.F. Wang, S.J. Wang, Y.C. Liu, B. Zhang & Y. Yang

Influence of pH in the conditioning and dehydration processes of arsenic-containing sludge
S.E. Garrido Hoyos, K. García, J. Briseño & B. Lopez

Assessment of environmental and health risks of arsenic in agricultural soils
Acid induced arsenic removal from soil amended with clay-biochar composite
M. Vithanage, L. Weerasundara & A.K. Ghosh

5.4 Mitigation and management of arsenic in a sustainable way

Implementation of arsenic mitigation: insights from Araihazar and Matlab – two extensively studied areas in Bangladesh
K.M. Ahmed, A. van Geen & P. Bhattacharya

Mitigation actions performed to the remediation of groundwater contamination by arsenic in drinking water sources in Chihuahua, Mexico

Microorganism: natural sweepers of arsenic in industrial wastewater

Smart phone Fe test kit as quick screening tool for identification of high risk areas for arsenic exposure
D. Halem & A. Mink

Thiourea supplementation reduces arsenic accumulation in two selected rice (Oryza sativa L.) cultivars in a field study in Bengal Delta Basin, India
M.K. Upadhyay, S. Srivastava, A. Majumdar, A. Barla & S. Bose

Effects of boron nutrition on arsenic uptake and efflux by rice seedlings
R.L. Zheng & G.X. Sun

Sustainable management of groundwater resources in China: the impact of anthropogenic and natural occurring arsenic pollution
X.Y. Jia & D.Y. Hou

Simultaneous removal of arsenic and fluoride from water using iron and steel slags
J. García-Chirino, B.M. Mercado-Borrayo, R. Schouwenaars, J.L. González-Chávez & R.M. Ramírez-Zamora

Mitigation of As accumulation in paddy rice (Oryza sativa L.) by amendments containing iron and manganese

Arsenic removal from water of the Peruvian rivers using low cost carbon base adsorbents produced from agro industry waste
G. Cruz, M.M. Gomez & J.L. Solis

Arsenic oxidation by hypertolerant Bacillus sp. L-148 in artificial groundwater microcosm
A.V. Bagade, D. Paul, A. Giri, D. Dhotre, S. Pawar & K. Kodam

Relation between As(III) oxidation potential and siderophore production: a study of tannery As(III) oxidizers
V. Nandre & K. Kodam

Arsenic removal to <1 µg L\(^{-1}\) by coprecipitation with in-situ generated Fe(III) precipitates with and without advanced pre-oxidation
A. Ahmad, J. van Mook, B. Schaaf & A. van der Wal

Reduction of low arsenic concentrations in drinking water to below 1 µg L\(^{-1}\) by adsorption onto granular iron (hydr)oxides
A. Jeworrek, A. Ahmad, B. Hofs, J. van Mook & A. van der Wal

Mitigating of arsenic accumulation in rice (Oryza sativa L.) from typical arsenic contaminated paddy soil of southern China using α-MnO\(_2\) nano-flowers: pot experiment and field application
B. Li, S. Zhou & M. Lei
Phycoremediation of arsenic by *Chlorella* sp. CB4
*M.O. Alam, S. Chakraborty & T. Bhattacharya*

Arsenic removal from natural contaminated groundwaters in Calabria Region (Italy) by nanofiltration
*A. Figoli, I. Fuoco, C. Apollaro, R. Mancuso, G. Desiderio, R. De Rosa, B. Gabriele & A. Criscuoli*

Towards harmonizing approaches for scaling up access to arsenic safe water in Bangladesh: The Arsenic Safe Village Concept
*N. Akter, B. Onabolu, M. Bolton & H. Sargsyan*

Harmonizing sector approaches for scaling up access to arsenic safe water in Bangladesh: The DPHE-UNICEF Arsenic Mitigation Protocol
*B. Onabolu, S.K. Ghosh, N. Akter, S. Rahman & M. Bolton*

Iran’s first waterworks with granular ferric hydroxide-based dearsenification – a look back over the first two years of operation
*C. Bahr, F. Tarah & M. Mahdyarfar*

5.5 Drinking water regulations of water safety plan

Arsenic pollution in shallow drinking wells in Yuncheng Basin, China: occurrence and mechanisms
*C.C. Li*

Analysis of tubewell arsenic concentration test results using an updated arsenic information management system in Nepal
*R. Ogata & M. Sakamoto*

Integrating arsenic in water safety planning in The Netherlands
*P. van der Wens & A. Ahmad*

5.6 Arsenic in drinking water and implementation plan for safe drinking water supply from sustainable development perspectives

Sustainable small-scale, membrane based arsenic remediation for developing countries
*J. Hoinkis, E.E. Cañas Kurz, U. Hellriegel, T.V. Luong & J. Bundschuh*

Identifying the arsenic-safe aquifers of the Ganges Delta: some insights into sustainable aquifer management
*M. Chakraborty, A. Mukherjee, K.M. Ahmed, P. Bhattacharya & A.E. Fryar*

ASMITAS – a novel application for digitalizing the SASMIT Sediment Color Tool to identify arsenic safe aquifers for drinking water supplies
*S. Sharma, P. Bhattacharya, D. Kumar, P. Perugupalli, M. von Brömssen, M.T. Islam & M. Jakariya*

Deep hand tube-well water for achieving sustainable development goal in arsenic affected villages: Bangladesh experience
*B.A. Hoque, S. Khanam, M.A. Zahid, M.M. Hoque, N. Akter, M.N. Mahmud, S. Huque & S. Ahmed*

Small-scale piped water supply: end-user inclusive water research in arsenic affected areas in India and Bangladesh (DELTAP)

Author index

xx
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)
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 career 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 Instelling Antwerpen, Wilrijk, Belgium during the period between 1984 and 1986. After an illustrious career as a scientist abroad, he returned back 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 achievements. He has left behind his legacy through a number of his students who also made significant 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”

xxiv
Organizers

ORGANIZERS OF BIANNUAL CONGRESS AND EXHIBITION SERIES:
ARSENIC IN THE ENVIRONMENT

Jochen Bundschuh
University of Southern Queensland (USQ), Toowomba, QLD, Australia
International Society of Groundwater for Sustainable Development (ISGSD) Stockholm, Sweden

Prosun Bhattacharya
KTH-International Groundwater Arsenic Research Group
Department of Sustainable Development, Environmental Sciences and Engineering, KTH Royal Institute of Technology, Stockholm, Sweden
University of Southern Queensland (USQ), Toowomba, QLD, Australia
International Society of Groundwater for Sustainable Development (ISGSD) Stockholm, Sweden

Arslan Ahmad
KWR Water Cycle Research Institute, Nieuwegein, The Netherlands

Ravi Naidu
Global Centre for Environmental Remediation, The University of Newcastle, Callaghan, NSW, Australia
CRC CARE, University of Newcastle, Callaghan, NSW, Australia

Local Organizing Committee

Yong-Guan Zhu
Key Laboratory of Urban Environment and Health, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen, P.R. China
Research Centre for Eco-environmental Sciences, Chinese Academy of Sciences, Beijing, P.R. China

Huaming Guo
State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences (Beijing), Beijing, P.R. China
MOE Key Laboratory of Groundwater Circulation and Environment Evolution, School of Water Resources and Environment, China University of Geosciences (Beijing), Beijing, P.R. China
Sponsors and Contributors
Scientific committee

T. Abiye: School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
A. Ahmad: KWR Water Cycle Research Institute, Nieuwegein, The Netherlands; KTH-International Groundwater Arsenic Research Group, Department of Sustainable Development, Environmental Sciences and Engineering, KTH Royal Institute of Technology, Stockholm, Sweden & Department of Environmental Technology, Wageningen University and Research (WUR), Wageningen, The Netherlands
K.M. Ahmed: Department of Geology, University of Dhaka, Dhaka, Bangladesh
M.T. Alarcón Herrera: Centro de Investigación en Materiales Avanzados (CIMAV), Chihuahua, Chih., Mexico
M. Alauddin: Department of Chemistry, Wagner College, Staten Island, NY, USA
S. Anac: Ege University, Izmir, Turkey
M. A. Armienta: National Autonomous University of Mexico, Mexico D.F., Mexico
M. Auge: Buenos Aires University, Argentina
A. Baba: Geothermal Energy Research and Application Center, Izmir Institute of Technology, Izmir, Turkey
M. Berg: Eawag, Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland
P. Bhattacharya: KTH-International Groundwater Arsenic Research Group, Department of Sustainable Development, Environmental Sciences and Engineering, KTH Royal Institute of Technology, Stockholm, Sweden; University of Southern Queensland (USQ), Toowoomba, QLD, Australia & International Society of Groundwater for Sustainable Development (ISGSD) Stockholm, Sweden
M. Biagini: Salta, Argentina
P. Birkle: Saudi Aramco, Exploration and Petroleum Engineering Center – Advanced Research Center (EXPEC ARC), Geology Technology Team (GTT), Dhahran, Saudi Arabia
M. del Carmen Blanco: National University of the South, Bahía Blanca, Argentina
M. Blarasin: Río Cuarto National University, Río Cuarto, Argentina
A. Boischio: Pan American Health Organization, USA
K. Broberg: Karolinska Institutet, Solna, Sweden
J. Bundschuh: University of Southern Queensland (USQ), Toowoomba, Queensland, Australia; & International Society of Groundwater for Sustainable Development (ISGSD), Stockholm, Sweden
M. Bäckström: Man-Technology-Environment Research Centre, Örebro University, Örebro, Sweden
Y. Cai: Florida International University, Miami, USA
A.A. Carbonell Barrachina: Miguel Hernández University, Orihuela, Alicante, Spain
M.L. Castro de Esparza: CEPIS, Lima, Peru
J.A. Centeno: Joint Pathology Center, Malcolm Grow Medical Clinic, Joint Base Andrews Air Naval Facility, Washington DC, USA
D. Chandrasekharam: Department of Earth Sciences, Indian Institute of Technology-Bombay, Mumbai, India
D. Chatterjee: Department of Chemistry, University of Kalyani, Kalyani, India
C.-J. Chen: Academia Sinica, Taipei City, R.O. China
L. Charlet: Earth and Planetary Science Department (LIGT-OSUG), University of Grenoble-I, Grenoble, France
V. Ciminelli: Department of Metallurgical and Materials Engineering, Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil
L. Cornejo: University of Tarapacá, Arica, Chile
L.H. Cumbal: Escuela Politécnica del Ejército, Sangolquí, Ecuador
A. F. Danil de Namor: University of Surrey, UK
S. Datta: Kansas State University, Manhattan, Kansas, USA
D. De Pietri: Ministry of Health, Buenos Aires, Argentina
L.M. Del Razo: Cinvestav-IPN, México D.F., Mexico
E. de Titto: Health Ministry, Buenos Aires, Argentina
V. Devesa: IATA-CSIC, Valencia, Spain
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
Institute of Urban Environment
Chinese Academy of Sciences
Xiamen, PR. China
May 2018
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 chronic 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 arsenosis (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 Organizers from China University of Geosciences (Beijing) and the Institute of Urban Environment, and the International Organizers from KTH Royal Institute of Technology (Sweden), the University of Southern 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
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 Arsenicism 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 & Exhibition 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 unending 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
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
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
Foreword (Vice-Chancellor and President, The University of Newcastle)

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 Institute 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.

Yong-Guan Zhu  
Huaming Guo  
Prosun Bhattacharya  
Jochen Bundschuh  
Arslan Ahmad  
Ravi Naidu  
*(Editors)*
List of contributors

Abdulmutalimova, T.O.: Institute of Geology, Dagestan Center of Science, Russian Academy of Sciences, Makhachkala, Dagestan, Russia
Abhinav, S.: Mahavir Cancer Institute & Research Centre, Patna, Bihar, India
Abiye, T.A.: School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
Afroz, H.: Institute for Global Food Security, Queens University Belfast, Belfast, UK
Ahmad, A.: KWR Water Cycle Research Institute, Nieuwegein, The Netherlands; KTH-International Groundwater Arsenic Research Group, Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology, Stockholm, Sweden; Department of Environmental Technology, Wageningen University and Research (WUR), Wageningen, The Netherlands
Ahmad, S.A.: Department of Occupational and Environmental Health, Bangladesh University of Health Sciences, Dhaka, Bangladesh
Ahmed, F.: UNICEF Bangladesh, Dhaka, Bangladesh
Ahmed, K.M.: Department of Geology, University of Dhaka, Dhaka, Bangladesh
Ahmed, S.: Department of Chemistry, Sripat Singh College, Murshidabad, India
Ahmed, S.: Environment and Population Research Centre (EPRC), Dhaka, Bangladesh
Ahmed, S.: Institute of Child and Mother Health, Sk Hospital, Dhaka, Bangladesh
Ahsan, H.: Departments of Health Studies, Medicine and Human Genetics and Cancer Research Center, The University of Chicago, Chicago, IL, USA; Institute for Population and Precision Health, Chicago Center for Health and Environment, The University of Chicago, Chicago, IL, USA
Ahuja, S.: Department of Civil Engineering, Indian Institute of Technology, Guwahati, India
Akter, N.: UNICEF Bangladesh, Dhaka, Bangladesh
Alam, K.: UNICEF Bangladesh, Dhaka, Bangladesh
Alam, M.O.: Department of Civil and Environmental Engineering, Birla Institute of Technology, Mesra, India
Alarcón-Herrera, M.T.: Centro de Investigación Materiales Avanzados (Sede Chihuahua-CIMAV), Chihuahua, Chih., Mexico
Álvarez Vargas, A.: Departamento de Biología, División de Ciencias Naturales y Exactas, Universidad de Guanajuato, Campus Guanajuato, México
Amin, R.: UNICEF Bangladesh, Dhaka, Bangladesh
Amirnia, S.: Department of Environmental Science, Saitama University, Saitama, Japan
Anantharaman, G.: Department of Chemistry, Indian Institute of Technology, Kanpur, India
Annaduzzaman, M.: Sanitary Engineering Section, Faculty of Civil Engineering and Geoscience, Delft University of Technology, Delft, The Netherlands
Antelo, J.: Technological Research Institute, University of Santiago de Compostela, Santiago de Compostela, Spain
Apollaro, C.: Department of Biology, Ecology and Earth Sciences (DIBEST), University of Calabria, Rende (CS), Italy
Kumar, A.: Department of Chemistry, Indian Institute of Technology, Roorkee, India
Kumar, A.: Department of Hydrology, Indian Institute of Technology, Roorkee, India
Kumar, A.: Mahavir Cancer Institute and Research Centre, Patna, Bihar, India
Kumar, D.: Excedol AB, Bromma, Sweden
Kumar, M.: Department of Environmental Science, School of Earth, Environment & Space Studies, Central University of Haryana, Jant Pali, Mahendergarh, India; School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India
Kumar, R.: Mahavir Cancer Institute & Research Centre, Patna, Bihar, India
Kumar, S.: Department of Applied Geoscience and Engineering, Delft University of Technology, Delft, The Netherlands
Kumarathilaka, P.: School of Civil Engineering and Surveying, Faculty of Health, Engineering and Sciences, University of Southern Queensland, Toowoomba, QLD, Australia
Kumari, P.: Mahavir Cancer Institute and Research Center, Patna, India
Kumari, S.: B.R.A. Bihar University, Muzaffarpur, Bihar, India; Mahavir Cancer Institute and Research Center, Patna, India
Kumari, P.: Waste Science and Technology Research Group, Department of Civil, Environmental and Natural Resources Engineering, Lulea University of Technology, Lulea, Sweden
Kuramata, M.: Institute for Agro-Environmental Sciences, NARO, Tsukuba, Ibaraki, Japan
Kwon, H.J.: Dankook University, Cheonong, South Korea
Lal, V.: Queensland Alliance for Environmental Health Sciences (QAEHS), The University of Queensland, Brisbane, QLD, Australia
Lan, V.M.: CETASD, Vietnam National University, Hanoi, Vietnam
LaPorte, P.F.: Division of Hematology-Oncology, University of California Los Angeles, Los Angeles, California, USA
Lapworth, D.J.: British Geological Survey, Wallingford, UK
Larebeke, N.V.: Analytical, Environmental and Geochemical Department (AMGC), Vrije Universiteit Brussel, Brussels, Belgium
Lata, L.: Department of Soil Science/Geology, Maria Curie-Skłodowska University, Lublin, Poland
Lauer, F.T.: College of Pharmacy, University of New Mexico, Albuquerque, NM, USA
Launder, J.: School of Earth and Environmental Sciences and Williamson Research Centre for Molecular Environmental Science, University of Manchester, Manchester, UK
Le Forestier, L.: BRGM, ISTO, Orléans, France
Le Guédard, M.: LEB Aquitaine Transfert, Villeneuve d'Ornon, France
Lee, J.H.: Department of Civil and Environmental Engineering, Stanford University, Stanford, CA, USA; Department of Environmental Engineering, University of Hawaii, Honolulu, HA, USA
Lee, S.G.: College of Medicine, Chung-Ang University, Seoul, South Korea
Leermakers, M.: Analytical, Environmental and Geochemical Department (AMGC), Vrije Universiteit Brussel, Brussels, Belgium
Lei, M.: College of Resource & Environment, Hunan Agricultural University, Changsha, P.R. China
Lezama-Pacheco, J.: Department of Earth System Science, Stanford University, Stanford, CA, USA
Lhotka, M.: University of Chemistry and Technology Prague, Prague, Czech Republic
Li, B.: Environment and Non-Communicable Disease Research Center, Key Laboratory of Arsenic-related Biological Effects and Prevention and Treatment in Liaoning Province, School of Public Health, China Medical University, Shenyang, P.R. China
Li, B.: College of Resource & Environment, Hunan Agricultural University, Changsha, P.R. China
Li, B.Q.: Guangdong Key Laboratory of Agricultural Environment Pollution Integrated Control, Guangdong Institute of Eco-Environmental Science & Technology, Guangzhou, P.R. China
Li, C.C.: School of Environmental Studies, China University of Geosciences, Wuhan, P.R. China
Li, C.H.: College of Resources and Environmental Sciences, Jiangsu Provincial Key Laboratory of Marine Biology, Nanjing Agricultural University, Nanjing, P.R. China
Li, F.: School of Environmental Studies, China University of Geosciences, Wuhan, Hubei, P.R. China
Li, F.B.: Guangdong Key Laboratory of Integrated Agro-environmental Pollution Control and Management, Guangdong Institute of Eco-Environmental Science & Technology, Guangzhou, P.R. China
Li, H.B.: State Key Laboratory of Pollution Control and Resource Reuse, School of the Environment, Nanjing University, Nanjing, P.R. China
Liu, Y.C.: Research and Development Department, China State Science Dingshi Environmental Engineering Co., Ltd, Beijing, P.R. China
Liu, Y.F.: School of Environmental Studies, China University of Geosciences, Wuhan, P.R. China
Liu, Y.G.: Research Institute of Rural Sewage Treatment, Southwest Forestry University, Kunming, P.R. China; College of Ecology and Soil & Water Conservation, Southwest Forestry University, Kunming, P.R. China
Lloyd, J.R.: School of Earth and Environmental Sciences, The University of Manchester, UK
Lopez, B.: Universidad Politécnica del Estado de Morelos, Jiutepec, Mor., Mexico
Loukola-Ruskeniemi, K.: Geological Survey of Finland, Espoo, Finland
Lu, Z.J.: Geological Survey, China University of Geosciences, Wuhan, P.R. China
Luo, J.: State Key Laboratory of Pollution Control and Resource Reuse, School of the Environment, Nanjing University, Jiangsu, P.R. China
Luo, L.: Hunan Agricultural University, Changsha, Hunan, P.R. China
Luo, W.T.: School of Environmental Studies, China University of Geosciences, Wuhan, P.R. China
Luo, Z.X.: Key Laboratory of Urban Environment and Health, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen, P.R. China; College of Chemistry and Environment, Fujian Province Key Laboratory of Modern Analytical Science and Separation Technology, Minnan Normal University, Zhangzhou, P.R. China
Luong, T.V.: Vietnamese-German University, Ho Chi Minh City, Vietnam; UNESCO Chair on Groundwater Arsenic within the 2030 Agenda for Sustainable Development & Faculty of Health, Engineering and Sciences, University of Southern Queensland, Toowoomba, Australia
Luong, V.T.: Faculty of Health, Engineering and Sciences, University of Southern Queensland, Toowoomba, QLD, Australia
Lv, Y.H.: Guangdong Key Laboratory of Integrated Agro-environmental Pollution Control and Management, Guangdong Institute of Eco-Environmental Science & Technology, Guangzhou, P.R. China
Ma, C.L.: State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, Beijing, P.R. China
Ma, L.Q.: Research Center for Soil Contamination and Environment Remediation, Southwest Forestry University, Kunming, P.R. China; Soil and Water Sciences Department, University of Florida, Gainesville, FL, USA
Ma, M.: College of Engineering, Peking University, Beijing, China; School of Environmental Science and Technology, Southern University of Science and Technology, Shenzhen, China
Ma, R.: School of Environmental Studies, China University of Geosciences, Wuhan, P.R. China; Laboratory of Basin Hydrology and Wetland Eco-restoration, China University of Geosciences, Wuhan, P.R. China
Ma, T.: School of Water Resources and Environmental Engineering, East China University of Technology, Nanchang, P.R. China
Ma, Y.B.: Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing, P.R. China
Machado, I.: Analytical Chemistry, Faculty of Chemistry, DEC, Universidad de la República (UdelaR), Montevideo, Uruguay
Machovic, V.: University of Chemistry and Technology Prague, Prague, Czech Republic
Magnone, D.: School of Earth, Atmospheric and Environmental Sciences and Williamson Research Centre for Molecular Environmental Science, University of Manchester, Manchester, UK; School of Geography, University of Lincoln, Lincoln, UK
Maguffin, S.C.: Civil & Environmental Engineering, Cornell University, Ithaca, NY, USA; Dale Bumpers National Rice Research Center, Stuttgart, AR, USA
Mahanta, C.: Department of Civil Engineering, Indian Institute of Technology, Guwahati, Assam, India
Mahdyarfar, M.: Delta Niroo Gamaron Co., Tehran, Iran
Maher, W.: Institute for Applied Ecology, University of Canberra, Canberra, ACT, Australia
Mahmud, M.N.: UNICEF Bangladesh, Dhaka, Bangladesh
Mailloux, B.J.: Barnard College and Lamont-Doherty Earth Observatory, Columbia University, New York, USA; Department of Environmental Sciences, Barnard College, New York, NY, USA
Majumdar, A.: Earth and Environmental Science Research Laboratory, Department of Earth Sciences, Indian Institute of Science Education and Research Kolkata (IISER-K), Mohanpur, West Bengal, India
Makino, T.: Institute for Agro-Environmental Sciences, NARO, Tsukuba, Japan
Mallick, S.: CSIR – National Botanical Research Institute, Lucknow, Uttar Pradesh, India
Mancuso, R.: LISOC Group, Department of Chemistry and Chemical Technologies, University of Calabria, Rende (CS), Italy
Mandal, D.: Sripat Singh College, Jiaganj, Murshidabad, India
Mandal, U.: Department of Chemistry, University of Kalyani, Kalyani, Nadia, West Bengal, India
Manojlović, D.D.: Institute of Chemistry, Technology and Metallurgy, Center of Chemistry, Belgrade, Serbia
Maihây, N.: Toxicology, Faculty of Chemistry, DEC, Universidad de la República (Udelar), Montevideo, Uruguay
Martin, H.P.: Research School of Earth Sciences, Australian National University, Canberra, ACT, Australia
Martin, M.: Dipartimento di Scienze Agrarie, Forestali e Alimentari, University of Torino, Turin, Italy
Martin-Domnguez, I.R.: Centro de Investigación en Materiales Avanzados SC (CIMAV), Chihuahua, Chih., Mexico
Marti, G.C.: Department of Soil Science, Federal University of Lavras, Minas Gerais, Brazil
Masuda, H.: Department of Biology and Geosciences, Osaka City University, Sumiyoshi-ku, Osaka, Japan
Mato, R.R.A.M.: Department of Environmental Science and Management, Ardhi University, Dar es Salaam, Tanzania
Matthews, H.: School of Health Sciences, University of Salford, Salford, UK
Mazej, D.: Department of Environmental Sciences, Jožef Stefan Institute, Ljubljana, Slovenia
McClung, A.: Civil & Environmental Engineering, Cornell University, Ithaca, NY, USA; Dale Bumpers National Rice Research Center, Stuttgart, AR, USA
Meharg, A.A.: Institute for Global Food Security, Queens University Belfast, Belfast, UK
Meharg, C.: Institute for Global Food Security, Queens University Belfast, Belfast, UK
Mei, X.Y.: College of Resources and Environment, Yunnan Agricultural University, Kunming, P.R. China
Mella, F.P.: EcoMetales Limited, Providencia, Región Metropolitana, Santiago de Chile, Chile
Menan, L.C.: Department of Civil Engineering, Indian Institute of Technology, Guwahati, India
Mendoza, R.R.: Facultad de Química, Universidad Autónoma de Querétaro, Santiago de Querétaro, Qro, Mexico
Meng, C.: Hunan Agricultural University, Changsha, Hunan, P.R. China
Mercado-Borrayo, B.M.: Instituto de Ingeniería, Universidad Nacional Autónoma de México (UNAM), Mexico City, Mexico
Mercedes, E.R.C.: Posgrado de Ingeniería, UNAM, Instituto Mexicano de Tecnología del Agua, Jiutepec, Mor., Mexico
Milosh, H.: Department of Soil Science/Geology, María Curie-Skłodowska University, Lublin, Poland
Mink, A.: Watermanagement Department, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands
Mirlean, N.: Laboratório de Oceanografia Geológica, Instituto de Oceanografía, Universidade Federal do Rio Grande (FURG), Rio Grande, RS, Brazil
Moham, D.: School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India
Mondal, D.: School of Environment & Life Sciences, University of Salford, Salford, UK
Monzon, E.H.: Laboratorio de Microbiológia General, Universidad Nacional del Chaco Austral, P.R. Sáenz Peña, Chaco, Argentina
Morais, M.: Kinross Brasil Mineração, Brazil
Moreno, R.V.: Facultad de Química, Universidad Autónoma de Querétaro, Santiago de Querétaro, Qro, Mexico
Mortensen, R.: SDC University, Beijing, China
Motelica, M.: BRGM, ISTO, Orléans, France
Mtalo, F.: DAFWAT Research Group, Department of Water Resources Engineering, College of Engineering and Technology, University of Dar es Salaam, Dar es Salaam, Tanzania
Mtamba, J.: DAFWAT Research Group, Department of Water Resources Engineering, College of Engineering and Technology, University of Dar es Salaam, Dar es Salaam, Tanzania
Mueller, I.: Saxon State Office for Environment, Agriculture and Geology, Freiberg, Germany
Mukherjee, A.: Department of Geology and Geophysics, Indian IIT Kharagpur, Kharagpur, West Bengal, India; School of Environmental Science and Engineering, IIT Kharagpur, Kharagpur, West Bengal, India; Applied Policy Advisory to Hydrogeosciences Group, IIT Kharagpur, Kharagpur, West Bengal, India
Mukhopadhyay, S.: Kalyani Institute for Study, Planning and Action for Rural Change (KINSPARC), Kalyani West Bengal, India
Müller, S.: Department of Earth Sciences-Geochemistry, Faculty of Geosciences, Utrecht University, Utrecht, The Netherlands
Mushtaq, N.: Environmental Geochemistry Laboratory, Faculty of Biological Sciences, Department of Environmental Sciences, Quaid-i-Azam University, Islamabad, Pakistan
Muthusamy, S.: Queensland Alliance for Environmental Health Sciences (QAEHS), The University of Queensland, Brisbane, QLD, Australia

Nadar, V.S.: Department of Cellular Biology and Pharmacology, Herbert Wertheim College of Medicine, Florida International University, Miami, Florida, USA

Naidu, R.: Global Centre for Environmental Remediation (GCER), Faculty of Science, The University of Newcastle, Callaghan, NSW, Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE), The University of Newcastle, Callaghan, NSW Australia

Nakamura, K.: Institute for Agro-Environmental Sciences, NARO, Tsukuba, Japan

Nandre, V.: Department of Chemistry, Savitribai Phule Pune University, Pune, India

Natal-da-Luz, T.: Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Coimbra, Portugal

Nath, B.: Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY, USA

Navarro Solis, H.I.: Escuela de Ingeniera Ambiental, Universidad Popular Autónoma del Estado de Puebla A.C., Puebla, Pue., Mexico

Navin, S.: Mahavir Cancer Institute & Research Centre, Patna, Bihar, India

Neumann, T.: Institute of Applied Geosciences, KIT, Karlsruhe, Germany

Ng, J.C.: Queensland Alliance for Environmental Health Sciences (QAEHS), The University of Queensland, Brisbane, QLD, Australia; Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE), Newcastle, NSW, Australia

Nghiem, A.A.: Barnard College and Lamont-Doherty Earth Observatory, Columbia University, New York, USA

Niazi, N.K.: Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad, Faisalabad, Pakistan

Niraj, P.K.: Mahavir Cancer Institute & Research Centre, Patna, Bihar, India

Noller, B.N.: Centre for Mined Land Rehabilitation, Sustainable Minerals Institute, The University of Queensland, Brisbane, QLD, Australia

Norini, M.P.: BRGM, ISTO, Orléans, France


Ochoa-Riveros, J.M.: Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP)-CIRNOC-Experimental Station La Campana, Aldama, Chih., Mexico

Ogata, R.: Japan International Cooperation Agency (JICA), Japan; The University of Tokyo, Tokyo, Japan

Ok, Y.S.: Korea Biochar Research Center, Korea University, Republic of Korea

Oliveira, C.: Department of Soil Science, Federal University of Lavras, Minas Gerais, Brazil

Olmos-Márquez, M.A.: Universidad Autónoma de Chihuahua, Chihuahua, Chih., Mexico; Junta Municipal de Agua y Saneamiento, Chihuahua, Chih., Mexico

Olopade, C.: Departments of Health Studies, Medicine and Human Genetics and Cancer Research Center, The University of Chicago, Chicago, IL, USA

Onabolu, B.: UNICEF Bangladesh, Dhaka, Bangladesh

Onses, F.: Department of Environmental Engineering, Technical University of Denmark, Kongens Lyngby, Denmark

Ormachea, M.: Laboratorio de Hidroquimica, Instituto de Investigaciones Quimicas, Universidad Mayor de San Andrés, La Paz, Bolivia

Packianathan, C.: Herbert Wertheim College of Medicine, Florida International University, Miami, FL, USA

Paing, J.: O-pure, Beaumont-la-Ronce, France

Palacios, M.A.: Department of Analytical Chemistry, Faculty of Chemistry, Universidad Complutense de Madrid, Madrid, Spain

Pande, V.: Department of Biotechnology, Kumaun University, Nainital, Uttarakhand, India

Park, J.D.: College of Medicine, Chung-Ang University, Seoul, South Korea

Parvez, A.: State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, Beijing, P.R. China

Parvez, F.: Department of Environmental Health, Columbia University New York, NY, USA

Patel, K.S.: School of Studies in Chemistry/Environmental Science, Pt. Ravishankar Shukla University, Raipur, India

Patzner, M.: Geomicrobiology and Hydrology, University of Tübingen, Tübingen, Germany

Paul, D.: Division of Biochemical Sciences, CSIR-National Chemical Laboratory, Pune, India
Zhong, Q.Y.: State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, Beijing, P.R. China
Zhou, P.: School of Agriculture and Biology, Key Laboratory of Urban Agriculture, Ministry of Agriculture, Bor S. Luh Food Safety Research Center, Shanghai Jiao Tong University, Shanghai, China
Zhou, S.: College of Resource & Environment, Hunan Agricultural University, Changsha, P.R. China
Zhu, G.B.: Key Laboratory of Drinking Water Science and Technology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, P.R. China
Zhu, M.: Department of Ecosystem Science and Management, University of Wyoming, Laramie, WY, USA
Zhu, X.B.: State Key Laboratory of Biogeology and Environmental Geology and Department of Biological Science and Technology, School of Environmental Studies, China University of Geosciences, Wuhan, P.R. China
Zhu, Y.G.: State Key Lab of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, P.R. China; Key Laboratory of Urban Environment and Health, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen, P.R. China
Zoeller, T.: Department of Biology, University of Massachusetts Amherst, Amherst, MA, USA
Zu, Y.Q.: College of Resources and Environment, Yunnan Agricultural University, Kunming, P.R. China