



# Arsenic in Rice

*A Global Menace*

Garima Awasthi | Sudhakar Srivastava | Mahipal Singh Sankhla  
*Editors*

 **CRC Press**  
Taylor & Francis Group  
APPLE ACADEMIC PRESS

Non Commercial Use

First edition published 2024

**Apple Academic Press Inc.**

1265 Goldenrod Circle, NE,  
Palm Bay, FL 32905 USA

760 Laurentian Drive, Unit 19,  
Burlington, ON L7N 0A4, CANADA

**CRC Press**

2385 NW Executive Center Drive,  
Suite 320, Boca Raton FL 33431

4 Park Square, Milton Park,  
Abingdon, Oxon, OX14 4RN UK

© 2024 by Apple Academic Press, Inc.

*Apple Academic Press exclusively co-publishes with CRC Press, an imprint of Taylor & Francis Group, LLC*

Reasonable efforts have been made to publish reliable data and information, but the authors, editors, and publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors are solely responsible for all the chapter content, figures, tables, data etc. provided by them. The authors, editors, and publishers have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged, please write and let us know so we may rectify in any future reprint.

Except as permitted under U.S. Copyright Law, no part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

For permission to photocopy or use material electronically from this work, access [www.copyright.com](http://www.copyright.com) or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. For works that are not available on CCC please contact [mpkbookspermissions@tandf.co.uk](mailto:mpkbookspermissions@tandf.co.uk)

Trademark notice: Product or corporate names may be trademarks or registered trademarks and are used only for identification and explanation without intent to infringe.

---

**Library and Archives Canada Cataloguing in Publication**

Title: Arsenic in rice : a global menace / edited by Garima Awasthi, PhD, Sudhakar Shrivastava, PhD,  
Mahipal Singh Sankhla, PhD.

Names: Awasthi, Garima, editor. | Shrivastava, Sudhakar, editor. | Sankhla, Mahipal Singh, editor.

Description: First edition. | Includes bibliographical references and index.

Identifiers: Canadiana (print) 20230513700 | Canadiana (ebook) 20230513794 | ISBN 9781774914663 (hardcover) |  
ISBN 9781774914670 (softcover) | ISBN 9781003408390 (ebook)

Subjects: LCSH: Rice—Effect of arsenic on. | LCSH: Soils—Arsenic content. | LCSH: Groundwater—Arsenic content.  
Classification: LCC SB191.R5 A77 2024 | DDC 633.1/899—dc23

**Library of Congress Cataloging-in-Publication Data**

---

CIP data on file with US Library of Congress

---

---

ISBN: 978-1-77491-466-3 (hbk)

ISBN: 978-1-77491-467-0 (pbk)

ISBN: 978-1-00340-839-0 (ebk)

Non Commercial Use

# Contents

---

<i>Contributors</i> .....	<i>xi</i>
<i>Abbreviations</i> .....	<i>xv</i>
<i>Preface</i> .....	<i>xix</i>
<i>Introduction</i> .....	<i>xxi</i>
<b>1. Arsenic in Rice in a Nutshell: Tell-Tale Toxic Interplay of Chemical Offense and Biochemical Defense.....</b>	<b>1</b>
Jayanta Kumar Biswas, Rubina Khanam, and Sudhakar Srivastava	
<b>2. Status of Arsenic Contamination in Paddy Fields: Soil Water Chemistry.....</b>	<b>27</b>
Vinay Aseri, Varad Nagar, Anuj Sharma, Apoorva Singh, Mahipal Singh Sankhla, and Kumud Kant Awasthi	
<b>3. Rhizospheric Physiology of Rice Plants Towards Arsenic.....</b>	<b>47</b>
Anshika Kaushik, Anjali Awasthi, Garima Awasthi, and Sunil K. Gupta	
<b>4. Long-Distance Translocation Mechanism of Arsenic from Soil to Rice Grain .....</b>	<b>75</b>
Manju Shri, Sonali Dubey, Sanjay Dwivedi, Pradyumna Kumar Singh, and Rudra Deo Tripathi	
<b>5. Arsenic-Induced Phytotoxicity in Rice Plants.....</b>	<b>95</b>
Prashant Singh, Nandini Gupta, Payal M. Deoghare, and Rakhi Agarwal	
<b>6. Translocation and Accumulation of Arsenic in Rice Grains: Role of Transporters in Tolerance and Its Incorporation in the Food Chain .....</b>	<b>119</b>
Jyotirmay Kalita, Amit Kumar Pradhan, Sabnoor Yeasrin Jyoti, Bikash Kalita, Saurav Jyoti Roy, Indrajit Kalita, Mahesh Das, Hunmily Teronpi, Preetom Regon, and Bhaben Tanti	
<b>7. Agronomic Measures to Lessen Arsenic in Rice .....</b>	<b>143</b>
Anshika Kaushik, Amarnath Mishra, Varad Nagar, Pritam P. Pandit, Rushikesh L. Chopade, Rohit Kumar Verma, Apoorva Singh, and Shikha Verma	

**8. Biotechnology and Nanotechnology for Reducing the Arsenic Toxicity in Rice..... 179**  
 Tejasvi Bhatia, Anuradha Sandhu, Meghna, Jyoti Pandey, and Hanoor Sharma

**9. Microbial-Mediated Measures to Regulate Arsenic in Rice..... 207**  
 Gaurav Kumar Singh, Ankita, Jitender Singh, and Navjot Kaur

**10. The Determination and Speciation of Arsenic in Rice..... 227**  
 Dipak Kumar Mahida, Ankita Patel, and Rakesh Rawal

***Index*..... 249**

Apple Academic Press

Author Copy



## CHAPTER 10

---

# The Determination and Speciation of Arsenic in Rice

DIPAK KUMAR MAHIDA,<sup>1</sup> ANKITA PATEL,<sup>1</sup> and RAKESH RAWAL<sup>2</sup>

<sup>1</sup>*Department of Biochemistry and Forensic Science, Gujarat University, India*

<sup>2</sup>*Department of Life Science, Gujarat University, India*

---

### ABSTRACT

Arsenic is a highly toxic and carcinogenic metalloid that is found in soil and contaminated water. It accumulates in rice when contaminated water is exposed to paddy fields and creates a major threat to human health. The anaerobic growing condition of flooded rice paddies and the physiological specificities of rice are major factors responsible for increased arsenic levels in rice. Periodically, different techniques are developed for the determination, separation, and quantification of arsenic in various parts of the rice plant. In this chapter, we discussed different determination techniques for arsenic and their speciation as well as extraction and separation methods for different parts of rice. The formation/transformation and chemical complexity of arsenic species (Arsenite, Arsenate, DMA, MMA, AsC, AsB, DMTAV, TMAO, Me<sup>4</sup>As<sup>+</sup>, DPAA, PAA, MPAA, DMPAO, MDPAO) is also discussed here. Inductively coupled plasma mass spectrometry (ICP-MS) and ion chromatography are the most common methods used for simultaneous speciation of arsenic. ICP-MS hyphenated to high-performance liquid chromatography (HPLC) or laser ablation (LA) is broadly used. Hydride generation atomic absorption spectrophotometry (HG-AAS) and DNA-gated graphene field effect transistors are specific non-chromatographic methods developed

---

Arsenic in Rice: A Global Menace. Garima Awasthi, Sudhakar Shrivastava, and Mahipal Singh Sankhla, (Eds.)

© 2024 Apple Academic Press, Inc. Co-published with CRC Press (Taylor & Francis)