

# **Energy, Environment, and Sustainability**

## **Series editors**

Avinash Kumar Agarwal, Department of Mechanical Engineering, Indian Institute of Technology Kanpur, Kanpur, Uttar Pradesh, India

Ashok Pandey, Distinguished Scientist, CSIR-Indian Institute of Toxicology Research, Lucknow, Uttar Pradesh, India

This books series publishes cutting edge monographs and professional books focused on all aspects of energy and environmental sustainability, especially as it relates to energy concerns. The Series is published in partnership with the International Society for Energy, Environment, and Sustainability. The books in these series are editor or authored by top researchers and professional across the globe. The series aims at publishing state-of-the-art research and development in areas including, but not limited to:

- Renewable Energy
- Alternative Fuels
- Engines and Locomotives
- Combustion and Propulsion
- Fossil Fuels
- Carbon Capture
- Control and Automation for Energy
- Environmental Pollution
- Waste Management
- Transportation Sustainability

More information about this series at <http://www.springer.com/series/15901>

Rashmi Avinash Agarwal  
Avinash Kumar Agarwal  
Tarun Gupta · Nikhil Sharma  
Editors

# Pollutants from Energy Sources

Characterization and Control

 Springer

*Editors*

Rashmi Avinash Agarwal  
Department of Civil Engineering  
Indian Institute of Technology Kanpur  
Kanpur, Uttar Pradesh, India

Tarun Gupta  
Department of Civil Engineering  
Indian Institute of Technology Kanpur  
Kanpur, Uttar Pradesh, India

Avinash Kumar Agarwal  
Department of Mechanical Engineering  
Indian Institute of Technology Kanpur  
Kanpur, Uttar Pradesh, India

Nikhil Sharma  
Department of Mechanical Engineering  
Indian Institute of Technology Kanpur  
Kanpur, Uttar Pradesh, India

ISSN 2522-8366 ISSN 2522-8374 (electronic)  
Energy, Environment, and Sustainability  
ISBN 978-981-13-3280-7 ISBN 978-981-13-3281-4 (eBook)  
<https://doi.org/10.1007/978-981-13-3281-4>

Library of Congress Control Number: 2018961692

© Springer Nature Singapore Pte Ltd. 2019

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd. The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

# Preface

Energy demand has been rising remarkably due to increasing population and urbanization. Global economy and society are significantly dependent on the energy availability because it touches every facet of human life and activities. Transportation and power generation are two major examples. Without the transportation by millions of personalized and mass transport vehicles and availability of  $24 \times 7$  power, human civilization would not have reached contemporary living standards.

The International Society for Energy, Environment and Sustainability (ISEES) was founded at Indian Institute of Technology Kanpur (IIT Kanpur), India in January 2014 with an aim to spread knowledge/awareness and catalyse research activities in the fields of Energy, Environment, Sustainability and Combustion. The Society's goal is to contribute to the development of clean, affordable and secure energy resources and a sustainable environment for the society and to spread knowledge in the above-mentioned areas and create awareness about the environmental challenges, which the world is facing today. The unique way adopted by the society was to break the conventional silos of specializations (Engineering, science, environment, agriculture, biotechnology, materials, fuels etc.) to tackle the problems related to energy, environment and sustainability in a holistic manner. This is quite evident by the participation of experts from all fields to resolve these issues. The ISEES is involved in various activities such as conducting workshops, seminars, conferences, etc. in the domains of its interests. The society also recognizes the outstanding works done by the young scientists and engineers for their contributions in these fields by conferring them awards under various categories.

Second International Conference on 'Sustainable Energy and Environmental Challenges' (SEEC-2018) was organized under the auspices of ISEES from December 31st 2017–January 3rd, 2018 at J N Tata Auditorium, Indian Institute of Science Bangalore. This conference provided a platform for discussions between eminent scientists and engineers from various countries including India, USA, South Korea, Norway, Finland, Malaysia, Austria, Saudi Arabia and Australia. In this conference, eminent speakers from all over the world presented their views related to different aspects of energy, combustion, emissions and alternative energy

resource for sustainable development and cleaner environment. The conference presented 5 high voltage plenary talks from globally renowned experts on topical themes namely “Is It Really the End of Combustion Engines and Petroleum?” by Prof. Gautam Kalghatgi, Saudi Aramco; “Energy Sustainability in India: Challenges and Opportunities”, by Prof. Baldev Raj, NIAS Bangalore; “Methanol Economy: An Option for Sustainable Energy and Environmental Challenges”, by Dr. Vijay Kumar Saraswat, Hon. Member (S&T) NITI Ayog, Government of India; “Supercritical Carbon Dioxide Brayton Cycle for Power Generation” by Prof. Pradip Dutta, IISc Bangalore and “Role of Nuclear Fusion for Environmental Sustainability of Energy in Future” by Prof. J. S. Rao, Altair Engineering.

The conference included 27 technical sessions on topics related to energy and environmental sustainability including five plenary talks, 40 keynote talks, and 18 invited talks from prominent scientists, in addition to 142 contributed talks, and 74 poster presentation by students and researchers. The technical sessions in the conference included Advances in IC Engines: SI Engines, Solar Energy: Storage, Fundamentals of Combustion, Environmental Protection and Sustainability, Environmental Biotechnology, Coal and Biomass Combustion/Gasification, Air Pollution and Control, Biomass to Fuels/Chemicals: Clean Fuels, Advances in I.C. Engines: CI Engines, Solar Energy: Performance, Biomass to Fuels/Chemicals: Production, Advances in I.C. Engines: Fuels, Energy Sustainability, Environmental Biotechnology, Atomization and Sprays, Combustion/Gas Turbines/Fluid Flow/Sprays, Biomass to Fuels/Chemicals, Advances in I.C. Engines: New Concepts, Energy Sustainability, Waste-to-Wealth, Conventional and Alternate Fuels, Solar Energy, Waste Water Remediation and Air Pollution. One of the highlights of the conference was the Rapid Fire Poster Sessions in (i) Energy Engineering, (ii) Environment and Sustainability, and (III) Biotechnology, where more than 75 students participated with great enthusiasm and won many prizes in a fiercely competitive environment. 200+ participants and speakers attended this four days conference, which also hosting Dr. Vijay Kumar Saraswat, Hon. Member (S&T) NITI Ayog, Government of India as the chief guest for the book release ceremony, where 16 ISEES books published by Springer, under a special dedicated series “Energy, Environment and Sustainability” were released. This was the first time that such significant and high quality outcome has been achieved by any society in India. The conference concluded with a panel discussion on “Challenges, Opportunities & Directions for Future Transportation Systems”, where the panelists were Prof. Gautam Kalghatgi, Saudi Aramco; Dr. Ravi Prashanth, Caterpillar Inc.; Dr. Shankar Venugopal, Mahindra and Mahindra; and Dr. Bharat Bhargava, DG, ONGC Energy Center, and Dr. Umamaheshwar, GE Transportation, Bangalore. The panel discussion was moderated by Prof. Ashok Pandey, Chairman, ISEES. This conference laid out the roadmap for technology development, opportunities and challenges in Energy, Environment and Sustainability domain. All these topics are very relevant for the country and the world in present context. We acknowledge the support received from various funding agencies and organizations for the successful conduct of the Second ISEES conference SEEC-2018, where these books germinated. We would therefore like to acknowledge SERB, Government of

India (Special thanks to Dr. Rajeev Sharma, Secretary); ONGC Energy Center (Special thanks to Dr. Bharat Bhargava), TAFE (Special thanks to Sh. Anadrao Patil), Caterpillar (Special thanks to Dr Ravi Prashanth), Progress Rail, TSI, India (Special thanks to Dr. Deepak Sharma); Tesscorn, India (Special thanks to Sh. Satyanarayana); GAIL, VOLVO, and our publishing partner Springer (Special thanks to Swati Meherishi).

The editors would like to express their sincere gratitude to large number of authors from all over the world for submitting their high quality work in a timely manner and revising it appropriately at a short notice. We would like express our special thanks to Dr. Tapan Kumar Pradhan, Dr. Atul Dhar, Dr. Akhilendra Pratap Singh, Dr. Ludovica Luise, Dr. Joonsik Hwang, Dr. Chetan Patel, Dr. Pravesh Chandra Shukla, Dr. Sundeep Singh, Dr. Rohit Singla, Dr. Rajesh Prasad, Dr. Vikram Kumar, Dr. Dev Prakash Satsangi, Dr. Anoop Kumar Shukla, Mr. Maneesh Kumar, Mr. Neeraj Sharma, Mr. Sunil Kumar, Mr. Yeshudas Jiotode, Mr. Pawan Kumar, who reviewed various chapters of this book and provided very valuable suggestions to the authors to improve their manuscript.

The book covers different aspects of Energy consumption, environmental pollution and progress of a country is dependent on such aspects. This book is relevant for engineers, agriculturists, environmentalists, ecologists, governmental individuals, policy makers involved in area of pollutants from energy sources, environmental safety, and health issues. The book language is easy to understand, comprehensive in diagnostic techniques and may continue to serve well to students working in the field of energy and sustainability. The effective utilization of high-grade energy through thermochemical conversion of different wastes is discussed in this book. The methods and techniques to extract energy from e-wastes and biomass and their optimization can surely support the energy sector and satisfy a part of energy demand.

Kanpur, India

Rashmi Avinash Agarwal  
Avinash Kumar Agarwal  
Tarun Gupta  
Nikhil Sharma

# Contents

## Part I General

- 1 Introduction to Pollutants from Energy Sources: Characterization and Control** ..... 3  
Rashmi Avinash Agarwal, Avinash Kumar Agarwal,  
Tarun Gupta and Nikhil Sharma
- 2 Combustion-Based Transportation in a Carbon-Constrained World—A Review** ..... 7  
Tamour Javed, Ahfaz Ahmed, Vallinayagam Raman,  
Awad B. S. Alqaity and Bengt Johansson

## Part II Pollutants from Coal

- 3 A Review on Pollutants from Coal Based Power Sector** ..... 37  
Shashi Kant Verma, S. L. Sinha and D. K. Chandraker
- 4 Atmospheric Emissions from Thermal (Coal-Fired) Power Plants and Associated Environmental Impacts** ..... 53  
Gyanesh Kumar Singh, Pradhi Rajeev, Debajyoti Paul  
and Tarun Gupta
- 5 Polycyclic Aromatic Hydrocarbons (PAHs) Pollution Generated from Coal-Fired Thermal Power Plants: Formation Mechanism, Characterization, and Profiling** ..... 73  
Abhrajyoti Tarafdar and Alok Sinha
- 6 Strategies for Collection, Treatment, and Recycling of Fly Ash from Thermal Power Plants** ..... 91  
Swatantra Pratap Singh, Amritanshu Shriwastav and Abhishek Gupta
- 7 Commercial Coal Mining in India Opened for Private Sector: A Boon or Inutile** ..... 105  
Manish Yadav, Nitin Kumar Singh and Sneha Gautam



<b>8</b>	<b>Development of Small-Scale Thermoelectric Power Generators Using Different Micro-combustor Configurations for Standalone Power Applications</b> . . . . .	<b>117</b>
	B. Aravind and Sudarshan Kumar	
 <b>Part III Pollutants from Nuclear Energy</b>		
<b>9</b>	<b>Sources of Nuclear Pollutants and Their Controls</b> . . . . .	<b>139</b>
	Shashi Kant Verma	
<b>10</b>	<b>Advanced Source Inversion Module of the JRODOS System</b> . . . . .	<b>149</b>
	Ivan Kovalets, Spyros Andronopoulos, Radek Hofman, Petra Seibert, Ievgen Ievdin and Oleksandr Pylypenko	
 <b>Part IV MSW and Disposal</b>		
<b>11</b>	<b>Effective Utilization of High-Grade Energy Through Thermochemical Conversion of Different Wastes</b> . . . . .	<b>189</b>
	A. Santhoshkumar, R. Muthu Dinesh Kumar, D. Babu, Vinoth Thangarasu and R. Anand	
<b>12</b>	<b>Matrix Method for Evaluation of Existing Solid Waste Management Processes in Jalandhar City, Punjab, India</b> . . . . .	<b>253</b>
	Anchal Sharma, Rajiv Ganguly and Ashok Kumar Gupta	
<b>13</b>	<b>Turning Coal Fly Ash into Zeolite for Effective Waste Management</b> . . . . .	<b>269</b>
	A. R. K. Gollakota, Chi-Min Shu and Sneha Gautam	
<b>14</b>	<b>Production and Characterisation of Teak Tree Saw Dust and Rice Husk Biochar</b> . . . . .	<b>291</b>
	Monoj Bardalai, D. K. Mahanta and Biplab Das	
<b>15</b>	<b>Parametric Evaluation of Leachate Generated from a Non-engineered Landfill Site and Its Contamination Potential of Surrounding Soil and Water Bodies</b> . . . . .	<b>307</b>
	Rajiv Ganguly, Deepika Sharma, Anchal Sharma, Ashok Kumar Gupta and B. R. Gurjar	
 <b>Part V Coatings</b>		
<b>16</b>	<b>Sustainable Coating Design and Role of Liquid-Mediated Contact</b> . . . . .	<b>325</b>
	R. K. Upadhyay and L. A. Kumaraswamidhas	

# Editors and Contributors

## About the Editors



**Dr. Rashmi Avinash Agarwal** is a senior researcher at IIT Kanpur. She completed her doctoral degree in Inorganic Chemistry from IIT Kanpur in 2014. She completed her M.Sc. in Organic Chemistry from Rajasthan University, Jaipur in 2002 and B.Sc. in Chemistry, from Kanoria College, Rajasthan University, Jaipur in 2000. She has expertise in coordination chemistry, coordination polymers, organic synthesis, inorganic synthesis, crystal structure determination, supramolecular chemistry, porous materials, topology, fluorescence, SC (single crystal)-to-SC transformation, synthesis of nano-particles. Dr. Rashmi A. Agarwal has published over 20 research papers in leading international journals.



**Avinash Kumar Agarwal** is a Professor in the Department of Mechanical Engineering in Indian Institute of Technology Kanpur. His areas of interest are IC engines, combustion, alternative fuels, conventional fuels, optical diagnostics, laser ignition, HCCI, emission and particulate control, and large bore engines. He has published 24 books and 230+ international journal and conference papers. Professor Agarwal is a Fellow of SAE (2012), ASME (2013), ISEES (2015) and INAE (2015). He received several awards such as Prestigious Shanti Swarup Bhatnagar Award—2016 in Engineering Sciences, Rajib Goyal

prize—2015, NASI-Reliance Industries Platinum Jubilee Award—2012; INAE Silver Jubilee Young Engineer Award—2012; SAE International’s Ralph R. Teetor Educational Award—2008; INSA Young Scientist Award—2007; UICT Young Scientist Award—2007; INAE Young Engineer Award—2005.



**Dr. Tarun Gupta** Professor and PK Kelkar Research Fellow at the Department of Civil Engineering, IIT Kanpur, India. He holds a Doctor of Science (2004) in Environmental Health, Harvard University (USA) and Master of Technology (2000), Environmental Science and Engineering, Indian Institute of Technology Bombay (9-month research stay at the TU Dresden, Germany). He has published more than 95 articles in ISI indexed journals, 4 book chapters, and filed 4 Indian patents. A submicron aerosol sampler designed, developed and evaluated at the IIT Kanpur has since been commercialized by Envirotech (Delhi). He has developed several low-flow-rate and high-flow-rate impaction-based samplers and a non-selective membrane-based diffusion denuder. He is a member of INYAS (2016), PK Kelkar Research Fellowship (2015), NASI Scopus Young Scientist (2015), INSA Young Scientist (2011), INAE Young Engineer (2009), and IEI Young Engineer (2008).



**Nikhil Sharma** is a scientist in the Engine Research Laboratory in IIT Kanpur, India. He received his M.Tech. in Mechanical Engineering from NIT Hamirpur, India in 2012. and his Ph.D. from IIT Kanpur, in 2017. He was an assistant professor at Amity University’s Department of Mechanical and Automation Engineering, Noida. His areas of research include alternative fuels for IC engines (biodiesel, alcohols), emission control and particulate characterisation.

## Contributors

**Avinash Kumar Agarwal** Engine Research Laboratory, Department of Mechanical Engineering, Indian Institute of Technology Kanpur, Kanpur, India

**Rashmi Avinash Agarwal** Department of Civil Engineering, Indian Institute of Technology Kanpur, Kanpur, India

**Ahfaz Ahmed** Clean Combustion Research Center, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia

**Awad B. S. Alquaity** Institute for Combustion Technology, RWTH Aachen University, Aachen, Germany

**R. Anand** Department of Mechanical Engineering, National Institute of Technology, Tiruchirappalli, Tamil Nadu, India

**Spyros Andronopoulos** NCSR Demokritos, Institute of Nuclear and Radiological Sciences and Technology, Energy and Safety, Attiki, Greece

**B. Aravind** Combustion Research Laboratory, Department of Aerospace Engineering, Indian Institute of Technology Bombay, Mumbai, India

**D. Babu** Department of Mechanical Engineering, National Institute of Technology, Tiruchirappalli, Tamil Nadu, India

**Monoj Bardalai** Department of Mechanical Engineering, Tezpur University, Sonitpur, Assam, India

**D. K. Chandraker** Reactor Design and Development Group, Bhabha Atomic Research Centre, Mumbai, Maharashtra, India

**Biplab Das** Department of Mechanical Engineering, Tezpur University, Sonitpur, Assam, India

**Rajiv Ganguly** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat, Solan, Himachal Pradesh, India

**Sneha Gautam** Department of Environmental Science and Engineering, Marwadi University, Rajkot, Gujarat, India

**A. R. K. Gollakota** Department of Safety, Health and Environmental Engineering, National Yunlin University of Science and Technology, Douliu, Yunlin, Taiwan, ROC

**Abhishek Gupta** Department of Desalination and Water Treatment, Zuckerberg Institute for Water Research, Ben-Gurion University of the Negev, Beersheba, Israel; Department of Desalination and Water Treatment, The Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Beersheba, Israel

**Ashok Kumar Gupta** Department of Civil Engineering, Jaypee University of Information Technology, Wagnaghat, Solan, Himachal Pradesh, India

**Tarun Gupta** Department of Civil Engineering, Indian Institute of Technology Kanpur, Kanpur, India

**B. R. Gurjar** Department of Civil Engineering, IIT Roorkee, Roorkee, Uttarakhand, India

**Radek Hofman** University of Vienna, Vienna, Austria

**Ievgen Ievdin** Ukrainian Center of Environmental and Water Projects, Kiev, Ukraine; BfS—Federal Office for Radiation Protection, Oberschleissheim, Germany

**Tamour Javed** Fuel Technology Division, Research and Development Center, Saudi Aramco, Dhahran, Saudi Arabia

**Bengt Johansson** Clean Combustion Research Center, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia

**Ivan Kovalets** Institute of Mathematical Machines and Systems Problems NAS of Ukraine, Kiev, Ukraine; Ukrainian Center of Environmental and Water Projects, Kiev, Ukraine

**Sudarshan Kumar** Combustion Research Laboratory, Department of Aerospace Engineering, Indian Institute of Technology Bombay, Mumbai, India

**L. A. Kumaraswamidhas** Indian Institute of Technology (ISM), Dhanbad, India

**D. K. Mahanta** Department of Mechanical Engineering, Tezpur University, Sonitpur, Assam, India

**R. Muthu Dinesh Kumar** Department of Mechanical Engineering, National Institute of Technology, Tiruchirappalli, Tamil Nadu, India

**Debajyoti Paul** Department of Earth Sciences, Indian Institute of Technology Kanpur, Kanpur, India

**Swatantra Pratap Singh** Department of Desalination and Water Treatment, Zuckerberg Institute for Water Research, Ben-Gurion University of the Negev, Beersheba, Israel

**Oleksandr Pylypenko** Institute of Mathematical Machines and Systems Problems NAS of Ukraine, Kiev, Ukraine; Ukrainian Center of Environmental and Water Projects, Kiev, Ukraine

**Pradhi Rajeev** Department of Civil Engineering, Indian Institute of Technology Kanpur, Kanpur, India

**Vallinayagam Raman** Clean Combustion Research Center, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia

**A. Santhoshkumar** Department of Mechanical Engineering, National Institute of Technology, Tiruchirappalli, Tamil Nadu, India

**Petra Seibert** University of Vienna, Vienna, Austria

**Anchal Sharma** Department of Civil Engineering, Jaypee University of Information Technology, Wagnaghat, Solan, Himachal Pradesh, India

**Deepika Sharma** Department of Civil Engineering, Jaypee University of Information Technology, Wagnaghat, Solan, Himachal Pradesh, India

**Nikhil Sharma** Engine Research Laboratory, Department of Mechanical Engineering, Indian Institute of Technology Kanpur, Kanpur, India

**Amritanshu Shrivastav** Centre for Environmental Science and Engineering, IIT Bombay, Mumbai, India

**Chi-Min Shu** Department of Safety, Health and Environmental Engineering, National Yunlin University of Science and Technology, Douliu, Yunlin, Taiwan, ROC

**Gyanesh Kumar Singh** Department of Civil Engineering, Indian Institute of Technology Kanpur, Kanpur, India

**Nitin Kumar Singh** Department of Environmental Science and Engineering, Marwadi University, Rajkot, Gujarat, India

**Alok Sinha** Department of Environmental Science and Engineering, Indian Institute of Technology (ISM), Dhanbad, India

**S. L. Sinha** Mechanical Engineering Department, Malla Reddy Engineering College (Autonomous), Secunderabad, Telangana, India

**Abhrajyoti Tarafdar** Division of Environmental Science and Ecological Engineering, Korea University, Seoul, Republic of Korea

**Vinoth Thangarasu** Department of Mechanical Engineering, National Institute of Technology, Tiruchirappalli, Tamil Nadu, India

**R. K. Upadhyay** Indian Institute of Technology Kanpur, Kanpur, India; Indian Institute of Technology (ISM), Dhanbad, India

**Shashi Kant Verma** Mechanical Engineering Department, Malla Reddy Engineering College (Autonomous), Secunderabad, Telangana, India

**Manish Yadav** Environment Department, Central Mine Planning and Design Institute Limited, Bhubaneswar, India