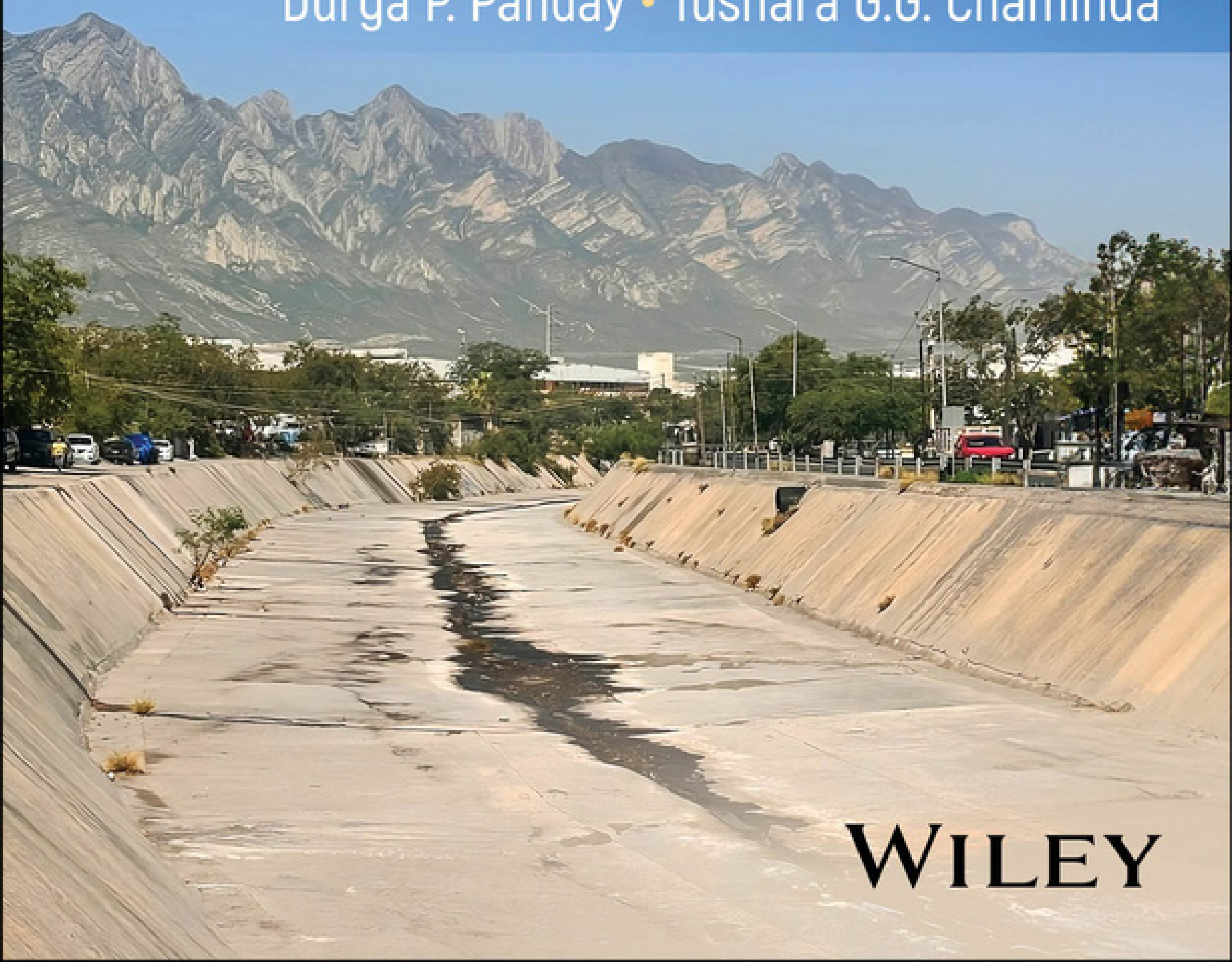
Water Scarcity Management

Enabling Technologies

Edited by

Kanchan D. Bahukhandi • Manish Kumar
Durga P. Panday • Tushara G.G. Chaminda



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Dr. Manish Kumar received his PhD in Environmental Engineering from the University of Tokyo. He is a Distinguished Professor at Tecnológico de Monterrey, Monterrey, Mexico; UPES, Dehradun; and Chuo University, Hachioji, Japan. A fellow of FRSC, JSPS, and WARI, he has supervised 10 PhD students, edited over 15 books, and published more than 250 SCI/SCIE papers with over 14,000 citations. Featured among the world's top 2% researchers, he has led major global projects on water sustainability and wastewater epidemiology while serving on editorial boards of top journals including *npj Clean Water*.

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Dr. Durga P. Panday, an Associate Professor at UPES and investigator postdoc at Tecnologico de Moneterrey, specializes in Water Resources Engineering and Management, focusing on water quality, hydroclimatic extremes, and transboundary water sharing using game theory. With a decade of teaching experience, he is dedicated to sustainable water management through high-impact research and pragmatic strategies in premier journals.

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Foreword

Water scarcity is emerging as one of the most critical challenges facing humanity in the 21st century. As the global population increases, industrial activities expand, energy generation rises, the standard of living improves, and climate change continues to reshape ecosystems, the demand for fresh, clean water is growing at an unprecedented rate. Addressing this challenge requires not only technological innovation but also a deep understanding of traditional and indigenous knowledge, which has led to sustainable management of water resources for centuries.

This book, *Water Scarcity Management: Enabling Technologies*, offers a comprehensive examination of water scarcity through both modern and historical lenses. Divided into four sections, it provides a thorough exploration of current water contaminants, conservation practices, and security trends across different regions of the world.

The book's first section sets the stage by outlining current water contaminants and conservation practices. It serves as a reminder that the roots of water scarcity are complex, often involving a web of factors, such as pollution, mismanagement, and overexploitation. The second section turns our attention to the status of water security and availability across continents, offering detailed analyses of regions that are facing some of the most severe water crises, from Asia and Africa to the Americas, Australia, and Europe.

One of the most innovative aspects of this book is its third section, which highlights the significance of indigenous technologies and traditional water management practices. From Asia to the islands, these practices offer a wealth of knowledge, often overlooked, that could be vital in developing sustainable solutions for modern water challenges.

The final section focuses on actionable solutions – both traditional and modern – that could mitigate the growing water crisis. It not only discusses the technological advances in water treatment but also dives into the critical question of sustainability. Chapters on traditional water-related practices, modern technological solutions, and the challenges in achieving long-term water security shed light on how integrated approaches are essential for securing our global water future.

In compiling this volume, the editors have made a significant contribution to both academic discourse and practical applications. The diverse perspectives and interdisciplinary approaches presented here are crucial, as we navigate the complex relationship between water, technology, and society in the Anthropocene.

This book comes at a critical time, and I am confident it will provide valuable insights to researchers, practitioners, and policymakers who are working tirelessly to solve one of the defining issues of our time.

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Preface

With the world facing an acute water crisis in terms of both quantity and quality, our focus shifts towards traditional knowledge and indigenous technologies to ensure water security. This book extensively traversed continents, observing the interconnections between stakeholders, diverse water laws, and evolving water security concerns. As we delve into the past, we find the ever-changing landscape of water pollutants, from early industrialization to modern-day contaminants. This historical context prepares the background to address the complexities of present-day pollution.

The book has revealed the traditional wisdom and indigenous technologies that have long played a role in managing water resources through its chapters. We have brought out innovative practices of tribal, rural, and urban communities and modern water treatment methods that align with ecological balance.

The last phase of the book leads to sustainable solutions. We analyzed the long-term viability and environmental impacts of nature-based and modern technologies. This book aims at providing tangible, sustainable solutions to the world's water challenges. This book represents our collective effort to deepen our knowledge of the current issues surrounding water security and sustainability, offering a roadmap for safeguarding this precious resource on a global scale. We believe the solutions to the present problems can be solved through historical traditional practices and indigenous knowledge but with modern technological implementation.

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1

Emerging Contaminants and Water Conservation

Challenges, Strategies, and Solutions for Sustainable Water Management

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1.1 Introduction

As the number of people living on Earth continues to increase and there is a corresponding decrease in the amount of available water, water conservation has emerged as an increasingly pressing issue (Alotaibi et al. 2023). Emerging pollutants, on the other hand, pose a substantial danger to both the quality of the water supply and human health (Tripathi et al. 2023). The purpose of this chapter is to give a complete analysis of contemporary developing pollutants as well as water conservation practises, covering the sources, impacts, and management measures associated with these contaminants.

Emerging pollutants may have their origins in a wide number of sources, such as agricultural practises, industrial operations, wastewater treatment plants (WWTPs), or consumer products. Emerging contaminants (ECs) may come from industrial, municipal (household), agricultural, hospital, or laboratory effluent (Figure 1.1). Surface water, groundwater, drinking water, and WWTP effluent include environmental pollutants (Tripathi et al. 2023). Municipal wastewater is known to emit novel contaminants into the environment. These contaminants come from non-point and point sources, industrial activities, storm water runoff, home wastewater, and water treatment facilities (Pradhan et al. 2023). Due to high EC values in sludge, management is becoming more concerned (Das et al. 2022, Kumar et al. 2023a, b).

The use of agricultural practises such as pesticides and fertilisers, among other things, can contribute to the presence of newly discovered pollutants in both surface water and groundwater. WWTPs, which are designed to eliminate conventional pollutants but are less successful at removing ECs, are a substantial source of ECs (Dubey et al. 2023). This is because of the way that they are designed. Manufacturing and mining are two examples of industrial activity that might contribute to the discharge of chemicals into rivers. Last but not least, consumer goods, such as flame retardants and plasticizers, have the potential to make their way into water sources (Macklin et al. 2023).

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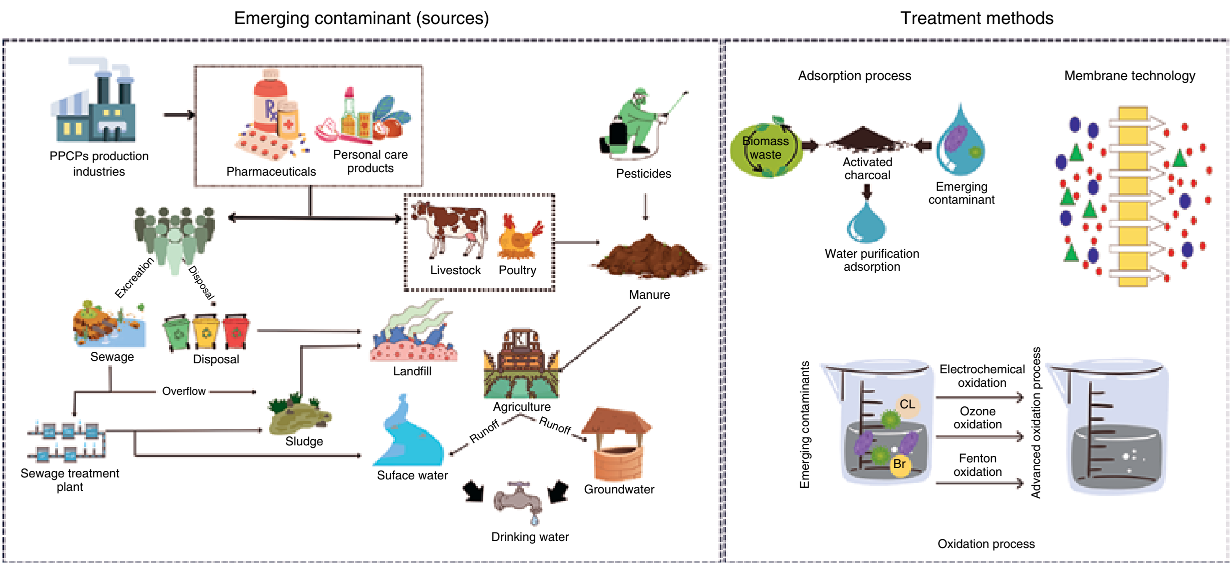

Figure 1.1 Classification of emerging contaminants that impact on soil, water, plants, and treatment processes.

It has been discovered that ECs have a wide range of effects on both human health and the environment (Neog et al. 2024). These effects can be broken down into several categories. Pharmaceuticals and personal care items, for instance, have been connected to endocrine disruption, which can have an effect on both the function and development of the reproductive system (Kumar et al. 2023d). There is evidence that flame retardants cause neurotoxicity, and certain per- and polyfluoroalkyl substances (PFAS) have been related to cancer and dysfunction in the immune system. Microplastics, which are small plastic particulates that can be discovered in water sources, have the potential to have both a physical and a chemical impact on the creatures that live in water (Farooq et al. 2023).

Emerging pollutants, in addition to having these effects, can also have ecological repercussions, such as changing the composition of microbial communities and disrupting the regular functioning of ecosystems (Li et al. 2023). These consequences can have cascade repercussions throughout food webs, which can have an effect on the health of organisms living in both aquatic and terrestrial environments. The Figure 1.1 represents a classification of emerging contaminants and their varied impacts on soil, water, and plants, highlighting the complex challenges they pose to environmental health. Additionally, it illustrates how these contaminants influence treatment processes, often requiring advanced or modified remediation strategies due to their persistence and resistance to conventional methods.

1.1.1 Sources of Heavy Metal

Approximately 40% of the world's lakes and rivers have been contaminated by heavy metals (Zhou et al. 2020), stemming from both natural and human activities. Natural sources involve interactions with metal-containing rocks and volcanic eruptions (Ali et al. 2019). Volcanic emissions, including geothermal activity and degassing, contribute sporadically (Naggar et al. 2018). Anthropogenic sources encompass industrial processes, agriculture, and domestic practices (Gautam et al. 2014); as shown in Figure 1.2.

Mining, pivotal for many economies, releases heavy metals into water bodies, impacting groundwater, soil erosion, and health. Urbanisation and industrialisation exacerbate pollution levels, as evidenced by arsenic in India's drinking water and various heavy metals in Nigeria's mining communities. Latin America faces chronic exposure issues, with millions affected by arsenic-contaminated water exceeding WHO limits. China grapples with high metal concentrations in coastal rivers (Xu et al. 2017), while mercury contamination plagues Venezuela's artisan gold mining areas. Turkey also battles heavy metal contamination. Mitigating heavy metal pollution is crucial globally, with economic challenges hindering remediation efforts in developing nations.

1.1.2 Irrigation Water Quality

1.1.2.1 Sodium Percent

Sodium, when interacting with soil, diminishes its permeability. Higher levels of sodium prompt a cation exchange process, leading to a reduction in water and air movement within

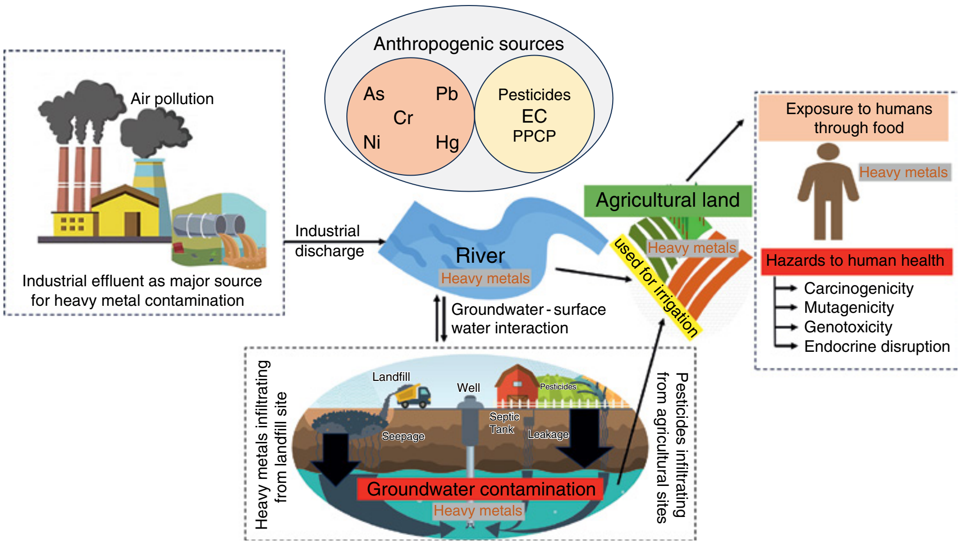

Figure 1.2 Sources of heavy metal concentration in food plants and trophic transfer to human

the soil, particularly under moist conditions (Hopkins et al. 2007). The term "sodium percent" is defined as follows:

$$Na^{+}(\%) = \left[\left(Na^{+}\right) \times 100 / \left(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}\right)\right]$$

Wilcox diagram is used to classify irrigation water based on sodium percent.

1.1.2.2 Chloride

Chloride levels in irrigation water contribute to its overall salinity and can pose toxicity risks to plants when concentrations are excessively high. Elevated chloride levels can lead to foliar burns when deposited on leaves. Some plant species are more vulnerable to chloride damage than others. To mitigate the harm caused by high chloride levels in irrigation water, options include selecting less sensitive crop varieties, utilising irrigation methods such as furrow, flood, or drip irrigation to minimise foliar contact, and rinsing plants at the conclusion of each irrigation cycle if a source of high-quality water is accessible. Excessive chlorine in plants can lead to leaf tissue accumulation, resulting in a burnt appearance, despite chlorine being a micronutrient essential for plant growth (Hopkins et al. 2007).

1.1.2.3 Salinity

Irrigation water with an electrical conductivity below 0.2 μS/cm, as discussed earlier, can lead to issues with soil permeability. When water salinity is very low, it can leach out calcium and cause soil particles to become more prone to breaking apart, resulting in difficulties with water infiltration. To prevent these infiltration problems, it is suggested to add a calcium salt such as gypsum or calcium chloride to the irrigation water, increasing the salinity to 0.2–0.3 μS/cm (Hopkins et al. 2007).