



Editorial

Water Resources and Sustainable Development

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Abstract: This editorial introduces the Special Issue titled "Water Resources and Sustainable Development," underscoring the critical need for sustainable management of water resources in light of increasing demand, climate change impacts, and pollution. The issue delves into the intricate relationship between water availability, quality, utilization, and the socioeconomic determinants shaping these aspects, highlighting the necessity for novel, balanced strategies that cater to societal, economic, and environmental requirements. The research within this Special Issue is segmented into four key areas: understanding hydrochemical properties and water quality; evaluating anthropogenic effects on water resources; strategizing water resource management; and applying technological innovations in water resource management. Collectively, these studies broaden our comprehension of water resources and sustainable development, stressing the importance of continuous research in this sphere. As we look ahead, this editorial accentuates the importance of ongoing exploration and innovation in these pivotal areas, focusing on understanding climate change implications, mitigating human-induced impacts, refining water management strategies, and harnessing technological advancements. Its overarching aim is to propel worldwide initiatives towards achieving comprehensive water security and sustainability.

Keywords: water resources management; hydrochemical characteristics; water quality protection; hydrological processes; climate change; human activities; technological innovations



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1. Introduction

Water, often described as the planet's lifeblood, faces mounting stress from escalating demand, climate change, and pollution [1]. Once perceived as limitless, this invaluable resource is now understood to be finite and increasingly scarce. The distribution of water resources across the globe is uneven, with some areas enjoying water abundance and others wrestling with severe scarcity. Countries endowed with extensive river systems, such as Canada and Brazil, stand in stark contrast to arid and semi-arid regions such as the Middle East and North Africa, where chronic water shortages persist [2,3]. The pressure on water resources intensifies with rapid urbanization and population growth, as seen in countries such as India and China, leading to the overuse of groundwater and stress on surface water bodies [4,5]. The challenges are further compounded by climate change, which introduces greater unpredictability in water availability, evidenced by an increase in both droughts and floods [6]. With the world's population on the rise and ever-progressing climate change, sustainable water resource management has become an urgent necessity [7].

Water resources, central to sustainable socioeconomic development, support a wide range of economic activities and are vital for human survival. The availability and management of these resources often dictate a nation's prosperity and societal wellbeing [8]. Agriculture, which consumes about 70% of the world's freshwater, epitomizes the economic dependence on water. It forms the economic mainstay of many developing countries,

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where a significant proportion of the population relies on farming. In regions such as Sub-Saharan Africa and parts of Asia, where water scarcity is a pressing issue, the absence of reliable water sources can drastically impede agricultural productivity, leading to food insecurity, poverty, and economic stagnation [9]. Conversely, effective water management can enhance agricultural output, improve food security, and stimulate economic growth. Beyond agriculture, water is integral to various industrial processes, emphasizing the economic consequences of water resource management [10]. A lack of sufficient or reliable water can disrupt industrial operations, dampen economic output, and result in job losses, whereas sustainable water management can encourage industrial growth and economic resilience [11].

Water resources significantly contribute to societal wellbeing by supporting a range of essential services [12]. One of the most vital is sanitation, where water is used to maintain cleanliness and prevent disease spread. Access to clean water and sanitation facilities is a fundamental human right and a crucial indicator of societal progress [13,14]. Yet, as of 2021, an estimated 2.2 billion people globally still lack access to safely managed drinking water, and 4.2 billion are without safely managed sanitation services [15]. This stark reality underscores the societal implications of water resource management and the urgent need for solutions that expand access to clean water and sanitation services. Additionally, water quality directly impacts human health, with contaminated water being a primary cause of diseases such as cholera, dysentery, and typhoid [16–19]. Water resources also enhance recreational activities and mental health, offering spaces for relaxation, exercise, and connection with nature. They play a pivotal role in maintaining environmental sustainability, supporting biodiversity, regulating the Earth's climate, and acting as a buffer against climate change [20–22].

Considering the pivotal role of water resources in socioeconomic development, it is crucial to examine their relationship with sustainable development. This involves understanding the complex interplay between water availability, quality, usage, and the socioeconomic factors that influence these dynamics. It also requires exploring innovative strategies for water resource management that balance societal, economic, and environmental needs [23,24]. This Special Issue on "Water Resources and Sustainable Development" in *Water* aims to address these critical areas. It brings together a collection of research that provides fresh insights into the challenges and opportunities in water resource management for sustainable development. The studies presented in this issue cover diverse geographies and contexts, offering a comprehensive view of the current state of knowledge in the field. With the publication of this Special Issue, we aim to stimulate further research and dialogue on this vital topic, contributing to global efforts towards achieving water security and sustainability.

2. Findings Reported in the Special Issue

This Special Issue includes 16 papers, among which 14 are research articles and 2 are review papers. These 16 papers can be clustered into four main topical groups: hydrochemical characteristics and water quality; impact of human activities on water resources; water management strategies; and technological applications for water resource management.

Hydrochemical Characteristics and Water Quality: This cluster of papers includes two papers and delves into the hydrochemical properties of notable water bodies. Pastukhov et al. (contribution 1) investigated the hydrochemical characteristics of the Irkutsk Reservoir, an important drinking water source in the Baikal region, while Lin et al. (contribution 2) examined the hydrochemical characteristics of surface water in the Danjiang River basin and assessed the risk to human health posed by polluted water bodies. They present a comprehensive examination of the distribution of key ions and trace elements, thereby enriching our understanding of water quality and its potential health implications. The studies underscore the necessity of consistent monitoring and evaluation of water quality, particularly in areas where these reservoirs are primary sources of potable water.

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Impact of Anthropogenic Activities on Water Resources: This topical cluster includes three papers, focusing on the consequences of human activities such as antibiotic pollution, alterations in land use, and mining on water resources. The research in this area is critical in quantifying the scale of anthropogenic alterations to water resources and formulating strategies to alleviate negative impacts. For instance, the study by Jia et al. (contribution 3) provides a robust scientific basis for optimal water resource distribution and sustainable development in the Cele–Yutian Oasis in China. Chen et al. (contribution 4) studied the adsorption behavior of the mesoporous molecular sieve MCM-41 in relation to common antibiotics. Lyv et al. (contribution 5) quantified the impact of coal mining on the underground water resources in the New Shanghai No. 1 Coal Mine.

Water Management Strategies: This topical cluster discusses diverse strategies for water resource management. These papers highlight the need for sustainable water management practices and explore the challenges and opportunities associated with their implementation. For instance, Wen et al. (contribution 6) highlight the importance of collaborative governance in managing water resources, water conservancy facilities, and socioeconomic systems within a river basin. In addition, the comprehensive review of Jordan's water resources provides an in-depth understanding of the country's water management issues and potential remedies (contribution 7), while another paper (contribution 8) advocates for an integrated watershed management approach for sustainable development.

Technological Innovations in Water Resource Management: The remaining papers delve into the application of various technological solutions for managing water resources. These papers showcase the potential of digital tools and advancements in computational and monitoring techniques in enhancing water resource efficiency and sustainability. For example, the study by Bonilla et al. (contribution 9) offers a feasible methodology for small cities to digitize their water distribution systems, even with limited budgets. Similarly, the research by Lee et al. (contribution 10) developed an optimal water allocation model for reservoir system operation. Zhao et al. (contribution 11) proposed a method by which to calculate the base value range of the ecological compensation standard in transboundary river basins, providing a basis for negotiation on the determination of the ecological compensation standard. Al-Rashidi et al. (contribution 12) used a fuzzy logic technique to develop groundwater suitability maps for irrigation purposes in Kuwait. Xu et al. (contribution 13) incorporated the concept of virtual water into the water rights allocation model. Monitoring is important in hydrogeological studies and can provide vital information for groundwater resources management. For example, Lu et al. (contribution 14) found that groundwater depth significantly affects vegetation coverage in the Ulan Buh Desert. Du et al. (contribution 15) analyzed the trend of water resources in the groundwater overexploitation area of the North China Plain, and Makanda et al. (contribution 16) assessed the water quality status of the Blesbokspruit River Catchment using the total maximum daily loads (TMDLs) and chemical mass balance (CMB) techniques.

In conclusion, the collection of papers in this Special Issue collectively broadens our knowledge of water resources and sustainable development. They emphasize the critical role of ongoing research in understanding hydrochemical characteristics, assessing the impact of human activities, strategizing water management, and utilizing technology in water resource management. Each of these domains plays a pivotal role in safeguarding the sustainability of our water resources amidst escalating environmental and human pressures.

3. Looking Ahead: Future Directions

As we cast our gaze towards the future, the intersection of water resources and sustainable development looms large, underscoring the imperative for continued research and innovation in this domain. The wealth of research presented in this Special Issue illuminates several pivotal areas that warrant further exploration.

Continuing Surveillance of Hydrochemical Dynamics and Water Quality: The research on water quality and hydrochemical properties underscores the necessity for persistent and extensive monitoring of global water bodies. This calls for the creation of advanced,

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user-friendly monitoring tools and methodologies [25]. It also necessitates a stronger emphasis on international collaboration and data exchange [26,27]. Future investigations should strive to deepen our understanding of climate change's effects on water quality and availability and explore potential mitigation strategies.

Addressing Anthropogenic Influences on Water Resources: The escalating impact of human activities on water resources necessitates attention. Future research should aim to further quantify these effects, with a spotlight on emerging challenges such as novel forms of pollution and the repercussions of rapid urbanization and industrialization [28]. Concurrently, efforts should be channeled towards promoting sustainable practices across water-intensive sectors such as agriculture and industry.

Advancing Water Management Strategies: The studies focusing on water management strategies underscore the need for a more integrated and comprehensive approach to water resource management. Future endeavors should aim to refine these strategies, ensuring they are adaptable to local conditions and resilient in the face of climate change [29]. The role of policy-making and governance in enforcing sustainable practices is another crucial area that merits further investigation.

Leveraging Technological Innovations: The potential of technology in enhancing water resource efficiency and sustainability is a recurring theme in this Special Issue. Future research should continue to push the boundaries of these technologies, exploring ways to make them accessible and affordable to communities worldwide. The role of digital tools in revolutionizing water resource management is a particularly promising avenue that deserves additional exploration.

In summation, the future of research in water resources and sustainable development hinges on a multifaceted understanding of environmental, socioeconomic, and technological variables. As we forge ahead, we hope that the research encapsulated in this Special Issue will serve as a catalyst for further exploration in this critical field, driving global efforts towards achieving water security and sustainability for all.

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