



Emerging and Legacy Pollutants in Vietnam Related to the Climate–Water–Energy–Food Nexus

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Introduction

Unsustainable uses of natural resources, including wasteful consumption and production practices, are primarily responsible for three major global environmental crises: climate change, biodiversity loss and environmental pollution. For example, the mission of United Nations' Sustainable Development Goal (SDG) 12 is to “ensure sustainable production and consumption patterns” by 2030. However, the capacity to achieve SDG 12 and other SDGs relies on addressing the complex linkages between natural resource management, environmental impact assessment and regulation, technological changes and socio-economic development. The “climate–water–energy–food” nexus is a central concept for understanding the complex interactions between the abiotic (atmosphere, water, soils, sediments) and biotic (plants, animals) components of the environment together with human influences (industrial, economic, geopolitical, psychosocial, demographic factors) upon these.

In the context of achieving the SDGs, countries with fast-growing economies play a pivotal role, given their significant reserves of natural resources, growing populations, active labor forces, major manufacturing and recycling centers and, in many cases, unique geopolitical positioning to facilitate efficient shipping and receiving of raw and processed goods.

All of these factors contribute to significant production from these economies of a wide variety of commodities and high-technology products to the global market. Nevertheless, the subsequent threats to the environment and human health are substantial and require extensive efforts to ensure sustainable socio-economic development, including regulations to secure responsible production practices.

This special issue is dedicated to original research from various disciplines investigating emerging and legacy pollutants related to energy production, urbanization, agriculture, transport, industrial production and consumption, with a specific focus on environmental threats in the rapidly developing country of Vietnam. We considered articles that address topics relevant to SDG 2 (Zero Hunger), SDG 6 (Clean Water), SDG 7 (Energy), SDG 11 (Sustainable Cities), SDG 12 (Responsible Consumption), SDG 13 (Climate), SDG 14 (Life Below Water) and SDG 15 (Life on Land). The international conference on “Integrated multidisciplinary sciences towards sustainable development” held in October 2022 and organized by the International Institute for Environmental Studies, Trent University and Ho Chi Minh City University of Technology (HCMUT) facilitated the academic exchanges on these topics, and most of the articles in this special issue originated from presentations or stemmed from discussions at the conference.

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Environmental Challenges in Vietnam

Vietnam has emerged among the world's fastest-growing economies, with GDP growth rates reaching 8.0% in 2022 relative to the global average of 3.1% (The World Bank 2022). As an inevitable consequence, this rapid economic growth and industrialization have negatively impacted the natural environment through deforestation, pollution, loss of biodiversity and genetic variability, as well as threatening human health. Although population growth has slowed from the ca. 2% growth in the 1990s to 0.7% in 2022, the year 2023 will

likely mark a significant population milestone of 100 million, making Vietnam the 15th most populous country in the world over a surface area ranked 67th worldwide. Urbanization and intensive food production (e.g., agriculture, aquaculture) are the other anthropogenic pressures on natural ecosystems in that nation.

Finally, although Vietnam makes a relatively small contribution to global greenhouse gas (GHG) emissions at 0.8%, the fast rate of economic growth has translated into one of the highest rates of acceleration of GHG emissions in the world (The World Bank 2022), measured as 458 million tons of carbon dioxide equivalents (MtCO₂e) in 2020 versus only 157 MtCO₂e in 2001 (data from www.climatewatchdata.com). The significant emissions, primarily from the energy and agricultural sectors, place Vietnam at 43rd in the Climate Change Performance Index ranking in 2022. Climate change impacts, including high temperatures and drought, extreme weather events and sea level rise, have inflicted tremendous costs to socio-economic growth, estimated at \$10 billion lost in 2020 or 3.2% of GDP, reduce agricultural productivity and threaten to inundate 50% of the Mekong Delta, home to 17 million people (The World Bank 2022).

While chemical contamination in Vietnam is often related to anthropogenic sources, geogenic elements, including radionuclides, also contribute to impacts on the environment and on human health. There are often cases of synergistic effects when socio-economic activities alter the natural equilibria governing the cycles of geogenic contaminants, leading to more pronounced and long-lasting consequences. For example, the over-exploitation of deep groundwater aquifers for drinking water supplies to mega-city populations prompted the migration of arsenic-contaminated surface groundwater to deeper aquifers (Winkel et al. 2011). This situation can ultimately deprive millions of people of safe sources of water and pose significant challenges over the long term.

Furthermore, the complex modern geopolitical history of Vietnam with several wars, the requirement for intensive food production and the wasteful life cycles of materials used in high-technology sectors have led to the combined occurrence of various “legacy” contaminants (e.g., dioxins from Agent Orange, toxic metals, pesticides) and emerging contaminants (e.g., microplastics, pharmaceutical and personal care products, radionuclides in rare earth and uranium ores). Such situations require extensive and integrated approaches to mitigate the related impacts that involve environmental management tools and regulations, stakeholder engagement, and advances in the environmental sciences and other scientific disciplines.

Path for Vietnam to Address Environmental Threats and Climate Risks

The national socio-economic development plan in Vietnam for 2021–2025 emphasizes environmental protection and climate change adaptation, with specific targets for delivering access to clean water and collecting waste, including strict sanctions for constraining environmental pollution (National Assembly 2021). There are major directives to enhance the effective use and management of natural resources, strengthen climate change adaptation capacity, and promote innovation and development of science and technology. Vietnam has also vowed to halt deforestation, cut GHG emissions and end investment in fossil fuels, scale up renewable energy deployment, and promote human capital and cultural values. The World Bank (2022) in its Country Climate and Development Report for Vietnam also recommended further adaptation policies for the vulnerable Mekong Delta, to shield coastal urban areas and vital transportation links from extreme weather, reduce air pollution, accelerate the energy transition and scale up social protections. In this context, strengthening environmental sciences and technologies becomes central to facilitating solutions to address the threats from environmental pollution and the climate crisis that Vietnam is facing.

Summary of the Articles in the Special Issue

While researchers from Vietnam and other countries have previously published scientific articles on contamination challenges in Vietnam, this special issue is unique in providing a collection of nine articles that focus on topics of chemical contamination in this rapidly developing region of Southeast Asia. The articles in the special issue address topics of contamination of the atmosphere, surface water and sediments, and groundwater, as well as the aquatic food web. Also presented in this special issue are articles focusing on integrated and practical approaches to environmental protection, such as environmental carrying capacity and Nature-based Solutions (NbS) for heavy metal remediation. Overall, the articles investigate a wide variety of environmental contaminants (i.e., PM_{2.5}, BTEX compounds, pesticides, radionuclides, heavy metals, nutrients), their sources (i.e., industries, traffic, mining activities), and the complex connections with land use patterns, climate change and the extraction of natural resources.

Despite such a variety of topics covered, these articles illustrate the main environmental challenges of Vietnam, with clear linkages between the climate-water-energy-food

nexus and socio-economic factors. These research outcomes play a central role in setting the cornerstone for advancing our understanding of the transport and the fate of chemical contaminants in the environment, their ecotoxicological effects, impacts, and environmental risks. Ultimately, the generated knowledge will be essential to developing contamination mitigation strategies, orienting to more sustainable and responsible development, and building new climate-resilience strategies in Vietnam, as well as other countries with fast-growing economies.

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