

Environmental Pollution Exposure and Its Human Health Risks

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Environmental pollution remains one of the greatest challenges to sustainable development and public health worldwide. Despite significant advances in environmental legislation and pollution control strategies, human populations continue to be exposed to a wide range of chemical and physical stressors through air, water, soil, food, and indoor environments [1]. These exposures have been associated with numerous adverse health outcomes, including respiratory and cardiovascular diseases, neurological disorders, developmental alterations, endocrine disruption, and several types of cancer [2]. Consequently, environmental research has progressively evolved from simply identifying contaminants toward understanding their environmental behavior, exposure pathways, biological effects, and implications for risk assessment. This evolution has promoted increasingly multidisciplinary research, bringing together environmental chemistry, geosciences, toxicology, epidemiology, exposure science, analytical chemistry, computational modeling, and public health. Rather than considering environmental compartments independently, modern studies seek to understand how contaminants move through complex environmental systems, how humans are exposed, and how those exposures ultimately translate into adverse health effects. Such integrated approaches are essential for supporting evidence-based environmental management and improving public health protection [3].

The Special Issue *Environmental Pollution Exposure and Its Human Health Risks* reflects this multidisciplinary perspective by bringing together 11 studies that address different contaminants, environmental media, analytical methodologies, and geographical regions. Although each contribution focuses on a specific environmental problem, together, they provide a broad overview of current approaches used to characterize environmental exposure, evaluate potential health effects, and improve methodologies for environmental risk assessment.

One of the central themes emerging from this Special Issue is the importance of accurately characterizing environmental exposure. Reliable exposure estimates provide the foundation for both epidemiological and toxicological investigations, allowing researchers to establish more robust links between environmental contamination and human health. Industrial atmospheric emissions continue to represent an important source of exposure in many urban and peri-urban environments. One contribution evaluates residential exposure to particulate emissions from a cement production facility through atmospheric dispersion modeling and explores their association with cardiorespiratory mortality [4]. By incorporating atmospheric transport processes into exposure estimation, the study illustrates how spatially resolved models can strengthen environmental epidemiology beyond traditional proximity-based approaches. Air pollution is further examined through a methodological contribution that develops an advanced statistical framework for predicting the spatial variability of PM_{2.5} concentrations [5]. The proposed approach illustrates how probabilistic



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and spatial modeling techniques can improve exposure prediction while reducing uncertainty associated with conventional interpolation methods. Although the two studies pursue different objectives, both demonstrate that methodological advances in exposure assessment are becoming increasingly important for interpreting environmental health data and supporting decision-making. Drinking water constitutes another major pathway through which populations may experience long-term environmental exposure. One study investigates the possible relationship between chronic exposure to hexavalent chromium in groundwater and gastrointestinal cancer mortality [6]. Rather than limiting the analysis to contaminant occurrence, the work explores how prolonged environmental contamination may influence disease patterns in exposed communities. Persistent pollutants are represented by a study reconstructing historical human exposure to perfluorooctanoic acid (PFOA) using pharmacokinetic modeling [7]. This contribution demonstrates the value of exposure reconstruction for improving epidemiological investigations when historical environmental monitoring data are incomplete or unavailable. Together, these studies illustrate the importance of integrating environmental measurements with exposure modeling to better understand long-term health effects.

Potentially toxic elements continue to receive considerable attention because of their persistence, multiple anthropogenic sources, and widespread occurrence in both urban and industrial environments. Two complementary contributions investigate these contaminants using different environmental matrices. One evaluates trace-element contamination in soils, indoor dust, and settled particles collected from schools located in an industrialized coastal region, emphasizing the importance of assessing children's exposure in sensitive environments [8]. The second investigates the seasonal variability of potentially toxic elements in urban road dust by integrating geochemical indices, source identification, scanning electron microscopy coupled with energy-dispersive spectroscopy (SEM-EDS), lung bioaccessibility experiments, and quantitative health risk assessment [9]. Although conducted in different settings, both studies demonstrate that evaluating contaminant concentrations alone is insufficient for understanding potential health implications. Instead, combining chemical characterization with particle properties, source apportionment, exposure pathways, and bioaccessibility provides a more comprehensive assessment of potential human exposure. Food represents another important pathway through which environmental contaminants may affect human health. One contribution investigates the accumulation of potentially toxic elements in commercially important fish species from the Romanian Black Sea and evaluates the implications for seafood safety [10]. Besides providing information on food quality, the study highlights the importance of the continuous monitoring of aquatic ecosystems to protect consumers while improving our understanding of contaminant transfer through the food chain. Such investigations reinforce the close relationship between environmental quality, ecosystem integrity, and public health.

The Special Issue also explores the biological mechanisms underlying environmental exposure. An experimental investigation examines the combined effects of household dust and radon using cultured human lung cells, providing new insights into cellular responses associated with oxidative stress, inflammation, cytotoxicity, and DNA damage [11]. While epidemiological studies identify associations between environmental exposure and disease occurrence, experimental approaches help clarify the biological mechanisms through which pollutants may contribute to adverse health effects.

Complementing this laboratory perspective, another contribution focuses on indoor radon from a public health standpoint by reviewing current knowledge regarding public awareness, risk communication, and mitigation strategies [12]. This work reminds us that reducing environmental health risks depends not only on scientific evidence but also on effective communication, public engagement, and the implementation of preventive mea-

tures. Together, these two studies illustrate how environmental health research increasingly combines mechanistic investigations with social and educational perspectives to support more effective risk management. Methodological innovation constitutes another important contribution of this Special Issue. As environmental datasets become increasingly complex, quantitative tools capable of incorporating uncertainty into risk assessment are becoming indispensable. One study introduces an open-source computational platform based on Monte Carlo simulation for probabilistic human health risk assessment across multiple exposure pathways [13]. Such developments provide researchers and environmental agencies with transparent and flexible tools for evaluating uncertainty while improving the reproducibility and robustness of environmental risk assessments.

The concept of environmental exposure extends beyond chemical contaminants. One contribution investigates traffic-related environmental noise and its possible effects on cognitive performance among schoolchildren [14]. Although noise pollution is often considered separately from chemical contamination, it represents another environmental stressor capable of affecting human health and well-being, particularly among vulnerable populations. Including this topic broadens the scope of the Special Issue and emphasizes that environmental health encompasses multiple types of environmental hazards.

Taken together, the studies included in this Special Issue demonstrate the remarkable diversity of contemporary environmental health research. Despite addressing different contaminants, environmental compartments, analytical techniques, and geographical regions, they converge on several common themes. First, the accurate characterization of environmental exposure remains fundamental for understanding the relationship between pollution and health outcomes. Second, integrating environmental monitoring with analytical chemistry, toxicology, epidemiology, computational modeling, and exposure science provides a more comprehensive understanding of environmental problems than any single discipline alone. Finally, methodological innovation continues to improve our ability to characterize environmental contamination, quantify uncertainty, and support evidence-based environmental management and public health policies. Another important message emerging from these contributions is the increasing need for interdisciplinary collaboration. Environmental pollution is inherently complex, involving interactions among natural processes, anthropogenic activities, contaminant transport, exposure pathways, biological responses, and socioeconomic factors. Addressing these challenges therefore requires cooperation among environmental scientists, geochemists, toxicologists, epidemiologists, physicians, engineers, and policymakers. The diversity of studies presented in this Special Issue clearly demonstrates the benefits of integrating expertise from different scientific disciplines to improve our understanding of environmental pollution and its consequences for human health.

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